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The effects of three concept mapping strategies on seventh-grade students' science achievement at an urban middle school

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THE EFFECTS OF THREE CONCEPT MAPPING STRATEGIES ON SEVENTH-GRADE STUDENTS' SCIENCE ACHIEVEMENT AT AN URBAN MIDDLE SCHOOL

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Dissertation Abstract

The Effects of Three Concept Mapping Strategies on Seventh-Grade Students' Science Achievement at an Urban Middle School

There is great concern over students' poor science achievement in the United States. Due to the lack of science achievement, students are not pursing science related careers resulting in an increase in outsourcing to other countries. Learning strategies such as concept mapping may ameliorate this situation by providing students with tools that encourage meaningful learning. The purpose of this quasi-experimental study was to measure the effects of three concept mapping learning strategies (concept identifying, proposition identifying, student generated) on urban middle school students' understanding of the circulatory system. Three intact classes of seventh-grade students were assigned to one of the three concept mapping strategies. The students were given a pretest on the circulatory system then learned and used their respective concept mapping strategies while learning about the circulatory system. At the conclusion of the study, students' science achievement was measured by performance on an achievement test and rubric scores of their respective concept identifying, proposition identifying, and student generated concept maps. The results of the study suggest that all three of the concept mapping strategies are effective in increasing students' science achievement. Additionally, the moderate significant correlations between the posttest and concept map scores of the current study established that concept maps are a useful measure of student knowledge. Lastly, the results of the current study also suggest that the concept

identifying mapping strategy may be a useful scaffold in instructing students how to develop student generated concept maps.

This dissertation, written under the direction of the candidate's dissertation committee and approved by the members of the committee, has been presented to and accepted by the Faculty of the School of Education in partial fulfillment of the requirements for the degree of Doctor of Education. The content and research methodologies presented in this work represent the work of the candidate alone.

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Lastly, I would like to acknowledge my past and present students for inspiring me to work towards making a positive change in the educational system.

Dedication

I dedicate this dissertation to my amazing family. Mom and Dad you have always shown me so much love and support that I truly could not have done this without you. Thank you very much for always having faith in me and allowing me to follow my dreams. Joti and Manny you have always found ways to help me realize the brighter, funnier side of situations when I was stressed out. There were multiple times when I had nothing to laugh about but you two always seemed to find a way to make it happen. Jagdip and Sareena the relationships I have with the both of you are truly priceless. I feel so fortunate to have such a loving older brother and equally loving sister-in-law. Aneil I am very happy that over the last four years we have become closer. I have been fortunate to watch you grow into a wonderful man and want you to know that I will always be here for you. Ria, Alisha, Ronik, Milan, Jaanik, and Amir, I cannot express in words how much love I have for all of you. Thinking about you, talking to you on the phone, or seeing you, instantly puts a smile on my face.

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CHAPTER I

STATEMENT OF THE PROBLEM

Representatives of the United States Department of Education have expressed concern with science literacy among students in the United States. (United States Department of Education, 2004). They have identified that America's schools are not producing the science excellence required for global economic leadership and homeland security in the 21st century (United States Department of Education, 2004). The National Center for Education Statistics (NCES) is responsible for carrying out the National Assessment of Educational Progress (NAEP), also known as the Nation's Report Card, which is the only nationally representative and continuing assessment of what America's students know and can do in school. In 2005, the NCES conducted a study that included a representative sample of 300,000 students that assessed students' science achievement in grades 4, 8, and 12. The results of the study indicated that, compared to middle and high school students, younger students (4th graders) are making the most progress in science (NAEP, 2009). Specifically, in 2005, 29% of the fourth graders performed at or above *Proficient* and 68% performed at or above *Basic*. In comparison to the 2000 results, the percentage of fourth graders performing at *Proficient* or above and at *Basic* or above levels increased by 2% and 5%, respectively. The results further indicated that at grade 8 there has been no overall improvement in science achievement since 2000 (NAEP, 2009). The percentage of eighth graders performing at *Proficient* or above decreased by 1%, with 30% of the eighth graders performing at *Proficient* or above in 2000 and only 29% performing at *Proficient* or above in 2005. The percentage of eighth grade students performing at *Basic* or above remained the same (59%) from 2000 to 2005. Lastly, the percentage of twelfth graders performing at *Proficient* or above remained stagnant at 18% between the years of 2000 and 2005. There was a 2% increase from 52% to 54% of students performing at *Basic* or above from 2000 and 2005 (NAEP, 2009). Representatives of the United States Department of Education (2004) asserted that the longer students stay in the current system the worse they do.

Particular concern exists about urban middle school students' science achievement (Parsons, 2008). United States urban schools, which are schools serving high-poverty and high-minority populations, face significant obstacles due to the characteristics of their neighborhoods, student backgrounds, teacher preparation, and school level resources (Ruby, 2006). In 2005, the NCES conducted the first Trial Urban District Assessment (TUDA) in science to examine the performance of fourth and eighth grade students in 10 large urban districts. These urban districts serve student populations that are more diverse than the nation's public schools overall. In general, large urban districts educate 25% of all school-age students, 35% of all poor students, 30% of all English-language learners, and nearly 50% of all minority students (Hewson, Kahle, Scantlebury, & Davies, 2001). The percentage of eighth-graders performing at or above *Basic* in science ranged from 22% to 52% in the districts, compared to 57% for the nation (NAEP, 2009). The percentage of eighth-graders performing at or above *Proficient* in science ranged from 6% to 27% in the districts, compared to 27% for the nation (NAEP, 2009). The results from the TUDA data demonstrate that urban middle school students' science achievement is lower than the rest of the nation's public schools.

Students enrolled in urban school districts who are underperforming in their science classes are likely to face challenges related to their academic careers. Students achieving below the *Basic* performance level in middle school are often unprepared for rigorous high school science courses that are aimed to prepare them in furthering their education in science related fields (Ruby, 2006). As teachers work towards raising students' science achievement, under-prepared students enrolled in urban school districts continue to fall behind.

Not only are students falling behind academically in comparison to their peers in the United States, these students are also not keeping up with their counterparts in other countries (National Academy of Sciences, 2007). In 2003, the Organization for Economic Co-operation and Development (OECD) Program for International Student Assessment measured the performance of 15 year olds in 49 industrialized countries. One of the disturbing results from the assessment was that United States students scored 19^{th} in science literacy (National Academy of Sciences, 2007).

Unfortunately, over the last few decades, middle schools have been labeled, "The Forgotten Middle," "Stuck in the Middle," and "Muddled in the Middle" (Kay, 2009). Ironically, middle school education is critical in that it is often the last chance for engaging and motivating students to achieve. The No Child Left Behind (NCLB) Act proposed by President Bush in 2001 was initiated in response to the decline of educational achievement among United States students compared to their international peers (Johnson & Hanegan, 2006). One of the principles that NCLB was built upon was stronger accountability for results (Johnson & Hanegan, 2006). Accordingly, states have to implement yearly assessments in mathematics, reading, and science; however, only the tests administered in math and reading count toward Adequate Yearly Progress (AYP) goals. The AYP goals are used to determine if schools are meeting the standards set forth by the NCLB Act (Johnson & Hanegan, 2006). Consequently, teachers are focusing on improving reading, writing, and mathematics scores on high-stakes tests and science is being left behind across grade levels (Goldston, 2006).

In addition to science instruction being neglected in favor of the tested subjects of math and reading/language arts, there are a few other reasons why students may be experiencing difficulty learning science. First, science is a subject that encompasses a plethora of rules and principles (Ueckert & Newsome, 2008). If students lack an understanding of these rules and principles they will struggle to understand the scientific information. Moreover, these rules and principles are often presented to students as isolated ideas or concepts. Second, students frequently enter the science classroom with previously established scientific misconceptions (Thompson & Logue, 2007). These students experience difficulty replacing the erroneous scientific information with true scientific facts. Lastly, to understand multifaceted science topics, students must have a well-established foundation of prior science learning (Buntting, Coll, & Campbell, 2006). Since science is a subject that builds on itself, if students fail to acquire basic science content, they will likely struggle with the more complex scientific concepts that follow.

Contributing to the low science achievement among middle school students are the pedagogical approaches used by some teachers. Some science instructors still hold traditional teacher-directed teaching philosophies that place the learner in a passive learning role. In these teacher-directed classrooms, students do not actively participate in the acquisition of scientific knowledge by engaging in meaningful learning (Hill, 2005). Ausubel (1968) described meaningful learning as the establishment of non-arbitrary relations among concepts in the learner's mind. Meaningful learning is achieved if learners are provided the opportunity to relate new information to ideas they already know, and to do so learners need to be placed in active rather than passive learning roles (Ausubel, 1968). Unfortunately, students oftentimes are expected to learn through rote memorization. This type of learning disempowers learners because they do not actively make connections to their prior knowledge (BouJaoude & Attieh, 2008). In addition, information learned by rote memorization is frequently forgotten (Cardellini, 2004). Hence, it is important for students to engage in scientific learning that facilitates meaningful learning.

There are various learning strategies that are used in science classrooms to attempt to help students overcome some of the difficulties of learning science. Learning strategies are activities that students employ to improve their learning of new information (Liu, 2009). Harrison, Andrews, and Saklofske (2003) suggested that students who use learning strategies during academic tasks work more effectively than students who do not use learning strategies. Some of the learning strategies used in science classrooms that engage students by involving them in the learning process include: underlining, note-taking, discussing with co-learners, and outlining (Hilbert & Renkl, 2008). Underlining is a strategy that involves students reading through content and underlining ideas that appear important to their understanding. Students can participate in the note-taking strategy in various ways. For example, the teacher may introduce content through teacher-directed lessons while students take notes. On the other hand, students may be independently assigned the task of taking notes on material presented in a textbook. Discussing with co-learners in pairs or small groups is another learning strategy in which students share their understanding of the content learned. The outlining learning strategy involves students identifying key topics and subtopics and arranging them in outline form.

Although the learning strategies mentioned above are currently being used by teachers to assist students with the acquisition of science content, they may not be encouraging the connection of prior knowledge with new knowledge to enhance meaningful learning (Hilbert & Renkl, 2008). Concept mapping is a learning strategy that promotes meaningful learning by requiring students to show the interrelatedness of a group of concepts and integrating new knowledge with pre-existing knowledge (Plotnick, 2001). Students recall prior knowledge and determine if and how the new information learned is relevant to their previous understanding of a given topic. The concept mapping learning strategy is effective because it enables students to make visual connections between information, thus helping them better understand the subject (Aidman & Egan, 1998). The effectiveness of concept mapping has been compared to the aforementioned learning techniques, and the results demonstrate that learners who use concept mapping as a learning strategy perform better on science assessments than learners who use underlining, note-taking, discussing with co-learners, or outlining (Hilbert & Renkl, 2008).

Furthermore, the concept mapping learning strategy is beneficial in understanding students' misconceptions. Student generated concept maps reveal students' level of understanding. Teachers and students can analyze concept maps and identify deficiencies, allowing teachers to address the deficiencies before students attempt to build scientific knowledge based on inaccurate information.

Despite the apparent benefits of using concept mapping as a learning strategy, there is still a need for additional research. Some studies have revealed that not all variations of the concept mapping learning strategy are equally effective (Wang & Dwyer, 2004, 2006). There are four types of concept maps: (1) teacher generated, (2) student generated, (3) concept identifying, and (4) proposition identifying. Teacher generated concept maps are created entirely by the teacher and given to the students as a study tool (Lim et al., 2009). In contrast, student generated concept maps are created entirely by the students (Harpaz, Balik, & Ehrenfeld, 2004; Novak & Gowin, 1984). Concept identifying concept maps are partially completed concept maps that students complete by finding the correct concepts to place in the nodes (Wang & Dwyer, 2006). Similarly, proposition identifying concept maps are also partially completed maps, however rather than finding the correct concepts to place in the nodes, students complete them by providing linking word(s) between concepts in order to create propositions or node-link networks (Wang & Dwyer, 2006).

There is inconsistency with the results demonstrating which variations (e.g. teacher generated, student generated, concept identifying, or proposition identifying) of the concept mapping strategies are the most effective (Lim, Lee, & Grabowski, 2009). Further research that investigates the various concept mapping strategies needs to be conducted so that students can utilize learning strategies that are the most useful. If students do not use effective learning strategies in science class to engage in meaningful learning they will be unprepared to pursue science-related professions.

In addition, the majority of studies examining concept mapping as a learning strategy involve high school, undergraduate, or graduate student samples. Only a few studies include students from middle school grades (Guastello, Beasley, & Sinatra, 2000; Snead & Snead, 2004) and only one of those studies (Guastello et al., 2000) included seventh-grade inner-city school students. Since it has been suggested that students who perform poorly in middle school science classes do not pursue careers in science-related fields, it is important to increase middle school students' science achievement (Snead & Snead, 2004). Snead and Snead (2004) also suggested that additional studies involving middle school students need to be conducted in order to discover ways of increasing the number of students pursuing science related careers.

Overall, United States middle school students' science achievement is an issue of great concern (Snead & Snead, 2004). These students are not demonstrating the same level of science achievement as their international counterparts. There are many factors contributing to students' poor science achievement. One of the factors affecting students' science achievement is the implementation of teacher-directed lessons that inhibit meaningful learning. Since many teachers are delivering instruction through teacher-directed lessons, students are not being taught or encouraged to use learning strategies that promote meaningful learning. Concept mapping is a learning strategy that has been suggested to be effective in promoting meaningful learning; therefore, students should be taught how to use concept maps. However, there are conflicting results related to the effectiveness of the various concept mapping strategies so additional research that investigates which concept mapping strategy would be the most useful in helping raise students' science achievement is required.

Purpose of the Study

The purpose of this quasi-experimental study was to measure the effects of three concept mapping learning strategies (concept identifying, proposition identifying, student generated) on urban middle school students' understanding of the circulatory system. Three intact classes of seventh-grade students were assigned to one of the three concept mapping strategies. The students were given a pretest on the circulatory system then learned and used their respective concept mapping strategies while learning about the circulatory system. At the conclusion of the study, students' science achievement was measured by performance on an achievement test and rubric scores of their respective concept identifying, proposition identifying, and student generated concept maps.

Significance of the Study

The findings of the current study are significant for several reasons. First, the study contributed to preexisting concept mapping literature by demonstrating that the three concept mapping strategies (concept identifying, proposition identifying, student generated) assist in raising students' science achievement. The majority of the concept mapping literature evaluates the effectiveness of a single concept mapping strategy. Moreover, the study contributed to the limited research related to the use of concept mapping as a learning strategy among urban middle school students. Previous concept mapping research has predominantly been conducted in high school or undergraduate/graduate school settings in suburban districts.

Second, this study is significant because the three types of concept maps were evaluated for accuracy. The majority of the concept mapping literature does not involve evaluating the concept maps for accuracy. The results of the current study indicated that based on rubric scores, the students in the concept identifying concept mapping group had the most accurate concept maps, followed by the students in the proposition identifying and student generated concept mapping groups. It is essential to evaluate the concept maps to determine which type of concept mapping learning strategy assists students in constructing knowledge and accurately demonstrates their understanding of the concepts learned.

Lastly, this study was significant because the results indicate that particular concept mapping strategies may be more appropriate for learning specific types of information. In this study, the circulatory system posttest mean scores revealed that the students in the concept identifying concept mapping group performed the highest on the vocabulary and process items and the students in the student generated concept mapping group performed the highest on the identification items. Moreover, the students in the proposition identifying concept mapping group performed the lowest on the vocabulary and identification items. These results suggest that the proposition identifying concept map may not be a useful learning strategy for learning vocabulary and identification terms.

Theoretical Rationale

Meaningful Reception Learning Theory

The idea of concept mapping is based on Ausubel’s (1962, 1963a, 1968) meaningful reception learning theory. Ausubel proposed that meaning occurs when learners actively interpret their experiences using particular internal, cognitive operations.

The meaningful reception learning theory describes these cognitive operations and how they interact with experience to give rise to learning.

Ausubel (1961) made the distinction that there are two different types of learning that occur in classrooms: reception and discovery. He suggested that most school learning is of the reception type. Reception learning is when the learner is presented with all of the content to be learned in its final form (Ausubel, 1961). The learner's responsibility is to internalize the information and store it for future use. Conversely, in discovery learning, the learner is required to internalize the information presented by rearranging it and integrating it with the existing cognitive structure. Once the information is integrated with the existing cognitive structure, it is to be reorganized if needed to create a desired end product or discover a missing means-end relationship (Ausubel, 1961). The concept mapping learning strategies encourage discovery learning because learners are required to integrate new information learned by relating it to pre-existing knowledge.

A second distinction that Ausubel (1961) and Ausubel, Novak, and Hanesian (1978) made was between rote and meaningful learning. As mentioned previously, rote learning is the same as verbatim memorization. According to Ausubel, when individuals engage in rote learning, the new material memorized is not integrated with related information that is already known. The memorized information stands independently and isolated from the learners' pre-existing cognitive structure. In contrast, Ausubel identified that meaningful learning is when individuals relate meaningful information to what the learner already knows. Through this process, the information learned is integrated into the learner's pre-existing cognitive structure. Ausubel (1961) emphasized that either rote or meaningful learning can occur in reception and discovery learning situations. Concept mapping is a strategy that precipitates meaningful learning because it requires learners to relate meaningful information to what the learner already knows.

Three conditions are critical for meaningful learning to occur (Ausubel, 1960). First, the individual must learn the information with the intention of integrating the new information with his or her pre-existing cognitive structure. If the individual attempts to simply memorize the information, meaningful learning will not result. Second, the learning material presented to the individual should be potentially meaningful. In other words, the learning material should be organized, readable, and relevant so that the individuals are not failing to learn the material meaningfully because of the manner in which it is presented. Lastly, the most important condition for meaningful learning is what learners already know and how that knowledge relates to what they are asked to learn. Since meaningful learning requires students to integrate new knowledge with pre-existing knowledge, the learning and retention of the meaningful new material is dependent on the learner's prior knowledge.

"The model of cognitive organization proposed for the learning and retention of meaningful material assumes the existence of a cognitive structure that is hierarchically organized…" (Ausubel, 1963b, p. 217). Ausubel defined cognitive structure as the learner's overall memory structure or integrated body of knowledge. The cognitive structure is composed of collections of ideas that are arranged hierarchically and by theme. Within each hierarchy, the most inclusive ideas are the strongest and more stable; therefore, those ideas are more easily remembered than specific ideas low in the hierarchy. For an example of cognitive structure, when learning about cells, the most inclusive ideas may be that cells are required for survival, there are different types of cells, and cells reproduce by making copies of themselves during mitosis. The specific ideas included under the inclusive idea “mitosis” might be the different steps involved in the process of mitosis. According to Ausubel, the general ideas high in the hierarchy (such as, cells reproduce by making copies of themselves during mitosis) would be more stable and therefore more easily remembered than specific ideas low in the hierarchy (such as, the various steps involved in the process of mitosis). Essentially, a learner’s cognitive structure resembles the format of a concept map, with general ideas higher in the hierarchy and more specific ideas lower in the hierarchy.

Ausubel (1961) described the cognitive structure as an overall framework into which new knowledge is incorporated. Furthermore, he described that the integration of the new knowledge into a pre-existing cognitive structure occurs through anchoring ideas. Anchoring ideas are the specific, relevant ideas in the learner’s cognitive structure that provide the entry points for new information to be incorporated (Ausubel, 1961). In essence, the anchoring ideas are prerequisites to meaningful learning.

There are three ways the new information can be added to an individual’s cognitive structure (Ausubel 1962). The new information can be subordinate to (lower in the structure), superordinate to (higher in the structure), or coordinate with (at the same level in the structure) an existing idea. Ausubel (1962, 1963a, 1968) coined the term “subsumption” to describe the attachment of new ideas and details to anchoring ideas in a subordinate fashion. He suggested that new, incoming ideas are subsumed under more general and inclusive anchoring ideas already in memory. New ideas can be subsumed under anchoring ideas in two ways: derivative subsumption and correlative subsumption.

Derivative subsumption describes the learning of new examples that are illustrative of an established concept or previously learned idea. An example of derivative subsumption is when learners subsume “strawberries” under the established concept “fruit.” The learner’s cognitive structure may already contain examples of other fruit, such as apples and oranges; however, the learner would recognize strawberries as relevant and would subsume the new example under the concept fruit. In derivative subsumption, the pre-existing concept or idea does not change. Correlative subsumption refers to the elaboration or modification of a pre-existing concept or idea by the subsumption of new ideas learned. For example, a learner may have the pre-existing idea in his or her cognitive structure that all fruits grow on trees. If the learner later discovered that a grape is a fruit and it does not grow on trees, then the overarching idea that “all fruits grow on trees” gets modified in the learner’s cognitive structure. In essence, the new idea interacts with the existing idea to modify the learner’s understanding in some way. Accordingly, the pre-existing concept or idea gets altered with the addition of the newly subsumed idea.

Ausubel et al. (1978) recognized that not all learning occurs through the processes of derivative and correlative subsumption because not all learning occurs in a subordinate manner. Occasionally, individuals draw on subordinate ideas or examples to discover the more general superordinate concepts or ideas. Additionally, there are instances when individuals learn about concepts or ideas that are at the same level in the hierarchy as the anchoring ideas. For this type of learning, Ausubel et al. (1978) proposed the processes of superordinate and combinatorial learning.

Superordinate learning refers to the generation of new, inclusive concepts or ideas under which pre-existing ideas or examples can be subsumed. For example, if an individual already had the concepts allele, genotype, and phenotype in their cognitive structure, creating the concept “genetics” and subsuming the related concepts under genetics would be superordinate learning. Combinational learning is the process of acquiring new concepts or ideas that are neither more inclusive of nor subordinate to relevant anchoring ideas in the cognitive structure. This type of learning occurs when the new information is related to established knowledge in a general way. In 1978, Ausubel adopted the label assimilation theory to describe the meaningful learning process of subsumption, superordinate learning, and combinatorial learning.

One of the ways to raise students’ science achievement is to equip them with learning strategies such as concept mapping to encourage meaningful learning. Some researchers (Asan, 2007; Buntting et al., 2006; Roth & Roychoudhury, 1993) investigated the effects of using concept mapping to promote meaningful learning in science classes. Roth and Roychoudhury (1993) designed a study to investigate whether concept mapping encouraged meaningful learning. During the study, students in a university physics course engaged in concept mapping to demonstrate their understanding of textbook readings and laboratory experiments. As the course progressed, the concept maps illustrated an increase in the quality and quantity of concepts and propositions included in the maps. Additionally, the students expressed that the concept maps encouraged the subsumption of new knowledge with pre-existing knowledge. Some of the students stated that while concept mapping they were forced to reorganize their prior knowledge to accurately integrate new knowledge. In essence, the students were experiencing meaningful learning instead of rote learning because they were consciously integrating the new information learned.

Asan (2007) designed a study to determine the effects of incorporating concept mapping on the achievement of fifth-grade students in science class. Students in both the control and experimental groups were taught the same content on heat and temperature. In addition, all of the students were given the same pretest and posttest. The primary difference between the two groups was that students in the experimental group engaged in concept mapping during the study. The concept maps produced in the study demonstrated that the students were able to identify and develop relationships between concepts. Moreover, the concept maps illustrated that the students engaged in meaningful learning while concept mapping because the main concepts in the maps were seamlessly integrated with each other and were arranged in a definite hierarchy to create a logical network of ideas. According to Ausubel (1961), meaningful learning occurs when students actively discover relationships between concepts.

In a study designed by Buntting et al. (2006), the researchers aimed to investigate the effects of concept mapping on students' ability to make and explain connections between concepts. The study included students from two separate university level biology courses at a university. During the study, students were offered six tutorial sessions each week; two of the six tutorials involved teaching the students how to use concept mapping as a learning tool. Following the study, the researchers administered surveys to the students who attended the tutorial sessions. The results of the surveys revealed that some of the students identified that the concept mapping strategy helped them understand the relationships between concepts. Furthermore, students who attended the training sessions outperformed students who did not attend the training sessions on assessment questions that required an understanding of relationships between concepts. The researchers suggested that the results of the study demonstrate that concept mapping precipitated meaningful learning because it required students to identify relationships between concepts.

In the current study, the students engaged in three concept mapping strategies (concept identifying, proposition identifying, student generated) while learning about the circulatory system. According to Ausubel's (1962) assimilation theory, the students integrated the information learned into their pre-existing cognitive structure. The circulatory system is a hierarchical system with different components working together to circulate blood through the body. The circulatory system content was used during the study because its hierarchical nature could be illustrated using the three different types of concept maps. The students assimilated new knowledge of the circulatory system subordinately, superordinately, or coordinately.

Background and Need

In this section, a background of concept mapping will be provided as well as a justification as to why the current study is needed. To begin, an explanation of the importance of science education is provided followed by information regarding students' science achievement. Next, several aspects of concept mapping are discussed as follows: (a) definitions and characteristics of concept maps, (b) benefits of concept mapping, (c) different domains in which concept maps are used, and (d) concept mapping in the science domain.

Importance of Science Education

After high school, fewer United States students pursue science and engineering degrees than students in other countries (National Academy of Sciences, 2007). The lack of scientific knowledge and ability of students in the United States to pursue science related careers is detrimental to our country and may reduce the ability of the United States to compete in a scientifically literate world. In 2001, President George W. Bush declared that science and technology have never been more essential to the defense of the nation and health of our economy (U.S. Commission of National Security, 2001). During the last decade, international competition has led many United States companies to outsource their work which allows employers to reassign some jobs by contracting them to specialty firms that can do the jobs better or more cheaply (National Academy of Sciences, 2007). As a result of this, the United States economy is suffering from low employment rates and increased competition among United States citizens.

The United States was once the leader in science, technology, engineering, and mathematics (STEM); however, other countries are challenging the competitive edge of the United States by producing more STEM professionals and students who outperform their United States counterparts on international achievement measures (Parsons, 2008). It is imperative for the United States educational system to enhance students' science achievement and future participation in scientific fields.

The domain of science is exceptionally critical to the United States prosperity in the 21st century. The products of science education are evident in everyday life in the United States and other industrialized nations. Historically, many individuals suffered from infectious diseases, such as smallpox, polio, and cholera, which are no longer a threat due to scientific advancements such as vaccinations. Without scientific research and knowledge, the United States may not be equipped to continue the search for cures for diseases such as cancer, which threaten the lives of individuals. Science education and research in plant and animal genetics have also led to an increase in farm production within the United States. Over the last half-century, yields per acre have increased approximately 2.5 times (National Academy of Sciences, 2007). Continued efforts in scientific research are necessary to increase farm production in the United States in order to fuel our economy.

To ensure the continued growth of the biotechnology industry in the United States, it is vital to increase the science achievement of students. Success in the biotechnology domain has led to an increase in molecular biology, which in turn has led to new health therapies. The introduction of various health therapies increases the quality of life, as well as creates more job opportunities in the medical field for individuals in the United States (National Academy of Sciences, 2007). Fundamentally, if the United States continues to lose its scientific competitive edge in the ongoing international competition, our country's economy and well-being may suffer as a result of an increased dependency on the scientific accomplishments of other countries.

Science Achievement

In comparison to elementary school students, middle school students in the United States are not excelling in science (NAEP, 2009). Snead and Snead (2004) emphasized that middle school science is critical to the achievement of students since it is the gateway to high school science classes. Given that complex science concepts build upon basic science concepts, it is crucial for students to attain basic science concepts earlier in their education in order to have a solid foundation to build upon. If middle school students lack a concrete scientific foundation, more complex science concepts learned in high school will not be solidified. Inevitably, the inability of students to build upon basic scientific knowledge leads to poor science achievement.

Students who attend urban middle schools face the same challenges as their non-urban middle school counterparts; however, students in urban middle schools are confronted with additional challenges that impede their scientific achievement (Johnson, 2009; Ruby, 2006). One of the challenges urban middle school students face is that schools in urban areas employ the least prepared teachers, many of whom are teaching out of their content area or without teaching certification (Johnson, Kahle, & Fargo, 2006). The high attrition rates of teachers in urban school districts leads administrators to seek out novice teachers and/or teachers with any type of valid teaching credential. Oftentimes, the teacher’s credential is not aligned with the subject matter the teacher is teaching. To compound the situation, these teachers teach with limited guidance and support due to inadequate materials, curriculum, and professional development in urban school districts (Johnson et al., 2006). Essentially, not only are the teachers unprepared, but they are also unsupported. Guastello et al. (2000) suggested that as students progress through grade levels they spend more time reading informational text; unfortunately, students in urban settings experience more problems comprehending informational text because it may be far removed from their daily life experiences.

In an attempt to alleviate the difficulties of learning science in an urban middle school, some teachers incorporate the use of learning strategies in their classrooms. As mentioned earlier, some of the learning strategies include underlining, note-taking, discussing with co-learners, and outlining (Hilbert & Renkl, 2008). Based on the results of science achievement tests, such as those administered by the NCES, it is evident that these learning strategies have been unsuccessful in raising students' science achievement. One reason why the learning strategies may not be effective is because they do not engage students in active learning. Instead, the learning strategies engage students in rote learning that does not require students to integrate newly acquired knowledge with pre-existing knowledge. On the other hand, the concept mapping learning strategy may be a viable solution in raising students' science achievement. The concept mapping learning strategy may be effective because it promotes meaningful learning by requiring students to actively integrate new information learned with pre-existing knowledge. Additionally, the concept mapping learning strategy requires students to identify relationships among concepts.

Definitions and Characteristics of Concept Maps

Historically, the concept map can be traced back to Joseph D. Novak and Bob Gowin. Novak, Gowin, and Johansen (1983) defined the concept map as a hierarchical display of text material in a two-dimensional, spatial, node-link network. Since the development of the concept map, several educational researchers have defined it in various ways. Plotnick (2001) defined a concept map as "a graphical representation where nodes (points or vertices) represent concepts, and links (arcs or lines) represent the relationships between concepts" (p. 42). Guastello et al. (2000) stated that concept maps made use of figures, lines, arrows, and spatial configurations to demonstrate how concepts are organized and related, while Douglas (2007) defined a concept map as “a two-dimensional, graphic schematic diagram illustrating the interconnections, and often the hierarchy, of a particular concept or topic” (p. 74). Although researchers have fashioned their own definitions of concept maps, Wang and Dwyer (2004) synthesized that “concept maps are most commonly defined as two dimensional diagrams that consist of concepts or nodes linked by labeled lines to show relationships between and among those concepts” (p. 371). For the purposes of this study, the preceding definition of a concept map by Wang and Dwyer will be used.

Novak (1998) described the various characteristics of a concept map, explaining that the nodes, which take the shape of a circle, square, or rectangle, represent concepts. He defined a concept as “a perceived regularity (or pattern) in events or objects, or records of events or objects, designated by a label” (p. 1304). When the nodes are joined together with appropriate one-way, two-way, or non-directional links or lines accompanied with linking words that explain the relationships among the nodes, the node-link network describes a proposition (Novak, 1998). Propositions consist of two or more concepts connected using linking words to form a meaningful statement (Novak & Canas, 2008). Another characteristic feature of concept maps are cross-links. Cross-links are the lines depicting the relationships between concepts in different segments of the concept map (Novak & Canas, 2008). In essence, cross-links assist in demonstrating how two concepts or sub-concepts may be related to one another. Finally, an important feature of a concept map is its hierarchical structure. The hierarchical structure of a concept map places the most general, highly inclusive concepts at the top with the more specific, less generalized concepts arranged appropriately in a lower position (Novak, Gowin, & Johansen, 1983). Additionally, the concepts are organized into groupings, regions, or branches that specify a particular level of relationship or divergence. Figure 1 is an example of a basic structure for concept maps that Hill (2005) adapted from Novak and Gowin (1984).

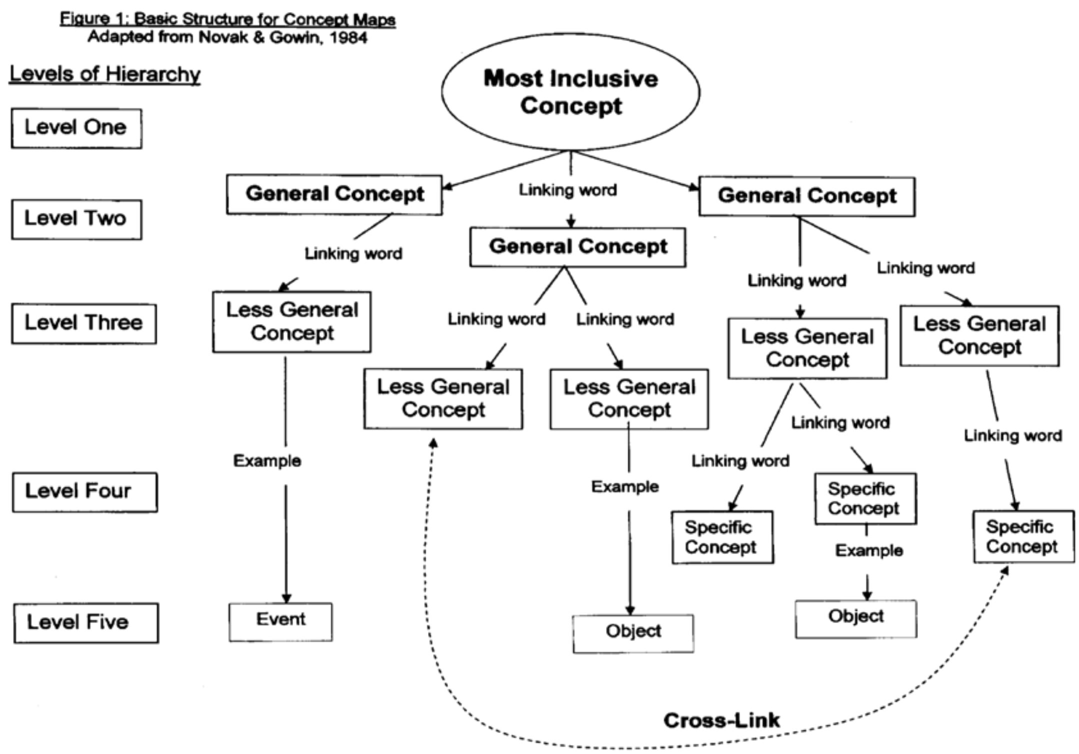

Figure 1. Basic structures for concept maps.

A more practical example is as follows: an over-arching concept that would be placed at the node on the top of a concept map could be science. Below, there could be nodes labeled life topics, earth topics, and physical topics that would each be connected to the over-arching science node by linking words that explain the relationship between the over-arching theme of science with life, earth, and physical topics. The concept map would continue with additional nodes branched off of the life, earth, and physical topics nodes. For instance, the nodes below life topics could include botany and zoology and the linking words connecting the two concepts to life topics would describe their relationship. Additional concepts can be placed under the nodes, such as plants under botany and animals under zoology with linking words describing their relationships. Figure 2 demonstrates the concept map described above.

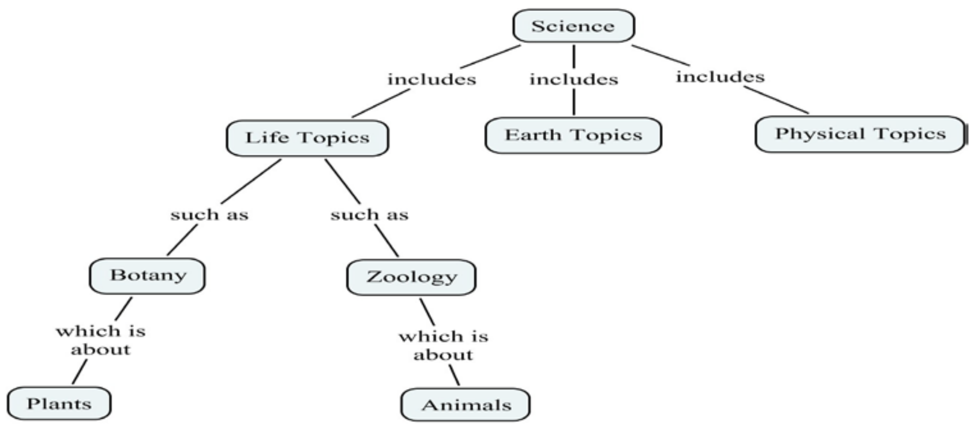

Figure 2. Example of concept map.

In essence, concept maps are pictorial representations of information that illustrate how concepts can be interrelated while also identifying specific differences among concepts (Gahr, 2003).

Benefits of Concept Mapping

Concept mapping can benefit students across disciplines, grade levels, and student populations (Asan, 2007). Concept mapping has been shown to reduce test and content anxiety, help students learn course material more deeply, raise student achievement, assist in evaluating students' differences in learning, and detect misconceptions in student thinking (Plotnick, 2001). There are four valuable ways that concept maps can be used to improve the learning and teaching in science classrooms: (1) as a learning strategy, (2) as an instructional strategy, (3) as a tool in the instructional design process, and (4) as a means to assess the students' understanding of science concepts (Wang & Dwyer, 2006). Concept mapping can be used by students as a learning strategy when learning new information, wherein students can produce concept maps to incorporate relevant information into their pre-existing knowledge base. Finding relationships between pre-existing knowledge structures and integrating them with new knowledge encourages meaningful learning while concept mapping. Teachers can use concept maps as an instructional strategy by presenting concept maps to students in order to demonstrate the relationship between concepts. In addition, teachers may also use concept maps to plan instruction by creating a concept map of the instructional themes they plan to teach. This process may provide teachers with an outline of the concepts that need to be introduced first (those higher in the hierarchy) and the related concepts that will be taught next (those lower in the hierarchy). Lastly, similar to the current study, concept maps can be used to assess students' understanding. The concept maps can be evaluated to gain insight on students' understanding as well as misconceptions.

Domain of Concept Maps

Although the concept mapping strategy has been researched in a variety of domains, such as mathematics, social studies, and special education, the majority of the research has been conducted in the science domain. Gerstner and Bogner (2009) explained that since science education is interdisciplinary, containing a variety of concepts from many different fields, the concept mapping strategy is effective in consolidating newly acquired knowledge and integrating it with pre-existing knowledge.

For example, when understanding the genetics concept of cell division, it is important to integrate that knowledge into pre-existing biological knowledge of the composition of a cell and how the organelles work harmoniously to fuel the process of cell division. As students learn new science concepts, they engage in the cognitive process of constructing meaning and making sense by consciously or subconsciously integrating these new ideas with their existing knowledge (Vanides, Yin, Tomita, & Ruiz-Primo, 2005).

Investigations designed to determine the effectiveness of concept mapping on reading comprehension have also been centered on science texts. Oliver (2009) posited that reading comprehension strategies such as concept mapping should be utilized when constructing meaning from unfamiliar expository texts, such as science texts. He further explained that expository texts are often embedded with relational structures, including comparative (X is different from Y), causative (X results in Y), explanatory (X is also known as Y), and sequential (X precedes Y); therefore, the concept mapping strategy is valuable in comprehending expository science texts because students can identify and express how two linked concepts are related.

Concept Mapping in the Science Domain

Research on using concept mapping as a learning strategy to learn science content is broad and diverse. Studies performed by Bulunez and Jarrett (2009) and Clariana and Koul (2008) investigated the effectiveness of collaborative concept mapping on students' science achievement. In the study by Bulunez and Jarrett (2009), the researchers found that the group concept mapping activity was helpful to undergraduate early childhood education students because they were provided the opportunity to clarify and discuss the science content with one another. Clariana and Koul (2008) discovered that the concept mapping groups that included education graduate students who had prior knowledge in the content area produced more comprehensive concept maps in comparison to the concept mapping groups that did not include students with significant prior knowledge in the content area. Wang and Dwyer (2004, 2006) compared the effects of three concept mapping strategies: concept identifying, proposition identifying, and student generated concept mapping on undergraduate students' science achievement. In both studies, Wang and Dwyer (2004, 2006) found that the concept identifying groups outperformed the student generated and proposition identifying concept mapping groups.

One of the ways to raise students' science achievement is to equip them with learning strategies such as concept mapping to encourage meaningful learning. Some researchers (Asan, 2007; Buntting et al., 2006; Roth & Roychoudhury, 1993) investigated the effects of using concept mapping to promote meaningful learning in science classes. In all three studies, the researchers found that the concept mapping learning strategy encouraged meaningful learning. Roth and Roychoudhury (1993) established that the students in the study were actively integrating new knowledge into their pre-existing cognitive structure instead of acquiring the knowledge through rote learning. Asan (2007) and Buntting et al. (2006) collected evidence that demonstrated that students who used the concept mapping strategy were developing meaningful relationships between concepts as opposed to learning the concepts as isolated terms.

Although there is research to support that concept mapping precipitates meaningful learning in the science domain, there are an insufficient number of studies that have been conducted in middle school settings. Moreover, the few concept-mapping studies that have been performed in middle school settings have limitations. For example, Guastello et al. (2000) investigated the effects of the concept mapping strategy on seventh-grade students' science achievement at an inner-city middle school. The results of the study indicated that the students in the concept-mapping group outperformed the students in the control group on the posttest. One of the limitations was that the students only received one day of concept mapping training. The researchers did not provide the students with time to practice the concept mapping strategy before they received instruction and were asked to create concept maps. Hence, the concept-mapping group may have been creating inaccurate concept maps while still outperforming the control group. Guastello et al. (2000) also stated the need for additional research that evaluates the effectiveness of the various concept-mapping strategies.

Snead and Snead (2004) conducted a study that examined the effects of concept mapping on the science achievement of middle grade science students. The researchers found that the concept-mapping group did not significantly outperform the control group. Therefore, the results are inconsistent with the results of the study conducted by Guastello et al. (2000). A positive attribute of the study designed by Snead and Snead (2004) was that the students participated in a few weeks of concept mapping training. On the other hand, similar to the study by Guastello et al. (2000), the students only engaged in one of the concept mapping learning strategies (student generated). Consequently, there is a need for more research to be conducted in the middle school setting that includes extensive concept mapping training, as well as the analysis of the different types of concept mapping learning strategies.

Some researchers (Lim, et al., 2009; Wang & Dwyer, 2004, 2006) have attempted to determine the effectiveness of the various concept-mapping strategies. In the two studies designed by Wang and Dwyer (2004, 2006), the researchers examined the effects of three concept-mapping strategies (concept identifying, proposition identifying, student generated) on college students' science achievement. In both studies, the researchers found that the concept identifying groups outperformed the proposition identifying and student generated groups. A study conducted by Lim et al. (2009) investigated the impact of the four concept mapping strategies (teacher generated, student generated, concept identifying, proposition identifying) on college students' science achievement. The researchers discovered that the students in the student generated concept mapping group outperformed the students in the other three concept mapping groups. The inconsistent results of the three studies mentioned above demonstrate the need for additional research on the effects of the various concept- mapping strategies. Furthermore, these studies add to the plethora of concept mapping studies conducted in higher education, highlighting the need for research in the middle school setting.

In addition to being a useful learning tool, concept maps are useful assessment tools for understanding the student's cognitive structure. The process of completing and/or creating a concept map involves the integration of new knowledge with pre-existing knowledge. There are several concept map scoring rubrics developed by various researchers (Kinchen & Hay, 2000; Lomask, Baron, Greig, & Harrison, 1992; McClure & Bell, 1990; Novak & Gowin, 1984; White & Gunstone, 1992) that differ based on the element of a concept map being scored.

Although there are scoring methods available for researchers to utilize, many of the concept-mapping studies do not involve the evaluation of concept maps. Most often, the concept maps are used as a learning strategy and the final assessment of student achievement is a criterion-referenced posttest. However, Francisco, Nakhleh, Nurrenbern, and Miller (2002) designed a study that involved the evaluation of student generated concept maps. The researchers found that the concept maps revealed useful information about the students' conceptions and understanding of the content. In another study by BouJaoude and Attieh (2008), the researchers correlated students' posttest scores with the corresponding student generated concept map scores and found significant correlations on application and above level questions. The two studies mentioned above demonstrate that assessing concept maps can be a useful tool to learn about students' cognitive structures. There is a need for more research that evaluates the different types of concept maps and also investigates if one concept mapping strategy is superior over another.

The current study also investigated how the student generated concept maps produced by the concept identifying and proposition identifying groups compared to the concept maps produced by the student generated group. There are a few reasons why it was important to investigate the accuracy of the student generated concept maps produced by the students in the concept identifying and proposition identifying groups. First, the studies by Roth and Roychoudhury (1993), Asan (2007), and Buntting, Coll, & Campbell (2006) suggested that the student generated concept mapping strategy demonstrated effective engagement of students in meaningful learning. Second, in both of the studies conducted by Wang and Dwyer (2004, 2006), the results suggested that the concept identifying groups were superior in performance on three criterion tests (identification, terminology, and comprehension), compared to the student generated and proposition identifying groups. Alternatively, the results from the study by Lim, Lee, and Grabowski (2009) revealed that the students in the student generated concept mapping group outperformed the students in the partially completed and teacher generated concept mapping groups on the posttest. Due to the inconsistency of the results, and the possibility that engagement in the student generated concept mapping learning strategy is more effective than the concept identifying and/or proposition identifying groups, the goal was to determine if training in either the concept identifying or the proposition identifying concept mapping strategy would lead to the construction of more accurate student generated concept maps.

Research Questions

1. What is the effect of three concept mapping strategies (concept identifying, proposition identifying, student generated) on urban middle school students' science knowledge as measured by their posttest circulatory system test scores?
2. What is the effect of three concept mapping strategies (concept identifying, proposition identifying, student generated) on urban middle school students' science knowledge as measured by rubric scores on their respective concept maps?
3. What are the differences in the rubric scores of student generated concept maps constructed by students in the concept identifying or proposition identifying groups compared to rubric scores of the student generated concept maps constructed by the student generated group?

Summary

Students need to be taught learning strategies that promote meaningful learning and increase science achievement (Hilbert & Renkl, 2008). Concept mapping is a learning strategy that has been shown to increase students' science achievement (Bulunez & Jarrett, 2009; Clariana & Koul, 2008; Guastello et al., 2000); however, additional research is necessary. The conflicting results regarding the effectiveness of the varied concept mapping strategies, the lack of research in urban middle school settings, and the insufficient number of studies evaluating concept maps suggests the need for additional research. The current study contributed to the literature by examining the effects of three different concept-mapping strategies on middle school students' science achievement.

Definition of Terms

Combinational Learning: The process of acquiring new concepts or ideas that are neither more inclusive of nor subordinate to relevant anchoring ideas in the cognitive structure (Ausubel, Novak, & Hanesian, 1978).

Cognitive Structure: A learner's overall memorial structure or integrated body of knowledge (Ausubel, 1963b).

Concept: A perceived regularity (or pattern) in events or objects, or records of events or objects, designated by a label (Novak, 2004).

Concept Map: Two-dimensional diagrams that consist of concepts or nodes linked by labeled lines to show relationships between and among those concepts (Wang & Dwyer, 2004).

Concept Identifying Concept Map: Partially completed map that students fill in the nodes to complete (Wang & Dwyer, 2006).

Correlative Subsumption: The elaboration or modification of a pre-existing concept or idea by the subsumption of new ideas learned (Ausubel, Novak, & Hanesian, 1978).

Cross-link: A line depicting the relationships between concepts in different segments of a concept map (Novak & Canas, 2008).

Derivative Subsumption: The learning of new examples that are illustrative of an established concept or previously learned idea (Ausubel, Novak, & Hanesian, 1978).

Discovery Learning: When individuals are required to internalize the information presented by rearranging it and integrating it with existing cognitive structure (Ausubel, 1961).

Learning Strategy: An activity that an individual uses to improve their learning of new information (Liu, 2009).

Meaningful Learning: The non-arbitrary, substantive relating of new ideas into cognitive structure (Ausubel, 1968).

Node: Takes the shape of a circle, square, or rectangle and represent concepts (Novak, 2004).

Proposition Identifying Concept Map: Partially completed map that students fill in the linking words to complete (Wang & Dwyer, 2006).

Proposition: Two or more concepts connected using linking words to form a meaningful statement (Novak & Canas, 2008).

Rote Learning: The arbitrary, verbatim, non-substantive incorporation of new ideas into the cognitive structure (Ausubel, 1968).

Reception Learning: When an individual learns material that is presented with all of the content to be learned in its final form (Ausubel, 1961).

Student Generated Concept Map: Concept map created entirely by the student (Novak & Gowin, 1984).

Subsumption: The attachment of new ideas and details to anchoring ideas in a subordinate fashion (Ausubel, 1962).

Superordinate Learning: The generation of new, inclusive concepts or ideas which pre-existing ideas or examples can be subsumed (Ausubel, Novak, & Hanesian, 1978).

Teacher Generated Concept Map: Concept map created entirely by the teacher (Lim et al., 2009).

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

The purpose of this quasi-experimental study was to measure the effects of three concept-mapping learning strategies, student generated, concept identifying, and proposition identifying, on seventh-grade students' understanding of the circulatory system as measured by performance on an achievement test and concept identifying, proposition identifying, and student generated concept maps at an urban middle school. The first section of the literature review will provide an overview of meaningful learning, then, proceed with studies related to concept mapping for meaningful learning. The second section analyzes concept mapping studies conducted in middle schools and concludes with a review of studies that investigated the effectiveness of the various concept mapping strategies. To conclude, the third section includes information regarding the use of concept maps as assessment tools. This section discusses: (a) assessing concept maps, (b) concept map scoring methods, and (c) previous research on concept map scoring methods.

Meaningful Learning

Meaningful learning, derived from Ausubel's (1968) assimilation theory of cognitive learning, is the theoretical foundation for concept mapping (Clayton, 2006; Hilbert & Renkl, 2008; Simone, 2007). According to Ausubel (1968), meaningful learning is defined as the non-arbitrary, substantive relating of new ideas into cognitive structures, cognitive structure referring to any knowledge stored in an individual's memory. In essence, meaningful leaning occurs when learners can assimilate new knowledge to something they already know (Novak, Gowin, & Johansen, 1983). For meaningful learning to occur, the new ideas must have potential meaning and the learner must possess relevant concepts that can anchor new ideas (Odom & Kelly, 2001).

When individuals acquire new knowledge through the process of meaningful learning, they engage in active learning. In contrast, rote learning is arbitrary, non-substantive acquisition of knowledge in cognitive structures without the learner integrating new knowledge to pre-existing cognitive structures (Cardellini, 2004). Essentially, during rote learning, the learner simply acquires new knowledge and stores it in cognitive structures without attempting to relate it to pre-existing knowledge. For example, if an individual stored five science facts in memory through rote learning, the facts would be stored as separate items although in real life they are related to each other. When an individual learns facts through rote learning, the brain stores them as distinct, unrelated knowledge that can only be recalled individually. For instance, thinking about fact five would not lead the individual to think about facts one through four. If such information is stored in long-term memory at all, it is stored unconnected to, and isolated from, other related information (Chularut & DeBacker, 2004). Acquisition of knowledge through rote learning may be unfavorable for all assessments except ones that only require verbatim recall of information or definitions held in short-term memory (Cardellini, 2004).

The creation of concept maps is an active learning process that engages students in meaningful learning because it involves cognitive structures in the brain (Hill, 2005). Novak (1998) stated that knowledge that is acquired through meaningful learning is long lasting because it is relevant and related to an individual's pre-existing knowledge structure. For example, if an individual learned five science facts through meaningful learning, the facts would be stored in a relational manner. Specifically, the brain stores them together because they are related to each other; therefore, when one fact is recalled, the other facts are also recalled at the moment. In other words, recalling fact five activates the memory for facts two and four, and this in turn leads to recalling facts one and three. The cognitive learning theory proposes that the brain learns most effectively by engaging in meaningful learning and that meaningful learning requires purposeful effort to link new knowledge with higher-order, more inclusive concepts in a person's cognitive structure (Ausubel, Novak, & Hanesian, 1978; Novak, 1998). Fundamentally, when learners actively acquire new knowledge and organize it in relevant cognitive structures, they are making sense of the information and determining how it relates to what they already know.

Meaningful Learning and Concept Mapping

Since the introduction of concept mapping by Novak in the 1970s, research indicates that concept mapping is an effective strategy that leads to meaningful learning in children (Asan, 2007) and adult learners (Novak & Gowin, 1984), and in an assortment of domains, such as biology (Buntting, Coll, & Campbell, 2006; Odom & Kelly, 2001), earth science (Bulunuz & Jarrett, 2009; Snead & Snead, 2004; Snead & Young, 2003), chemistry (BouJaoude & Attieh, 2008; Schreiber & Abegg, 1991), physics (Roth & Roychoudhury, 1993), geology (Gobert & Clement, 1999), reading comprehension (Chang, Sung, & Chen, 2002; Guastello, Beasley, & Sinatra, 2000; Oliver, 2009; Scevak, Moore, & Kirby, 1993), social studies (Armbruster & Anderson, 1980; Griffin, Malone,

& Kameenui, 1995), mathematics (Braselton & Decker, 1994), and special education (Bos & Anders, 1992; Ritchie & Volkl, 2000). For the purpose of this study, the focus will be on research related to the effectiveness of concept mapping in the science domain. Specifically, research conducted by Roth and Roychoudhury (1993), Asan (2007) and Buntting et al. (2006) will be discussed in further detail.

Roth and Roychoudhury (1993) demonstrated that concept mapping precipitated meaningful learning among elementary education majors enrolled in a physics course at a university. The physics course consisted primarily of collaborative small group experiments and problem solving. The 27 students involved in the study were introduced to concept mapping at the beginning of the course. As the course progressed, students were responsible for reading various sections of the course text and engaging in whole-class discussions. During these discussions, the teacher created concept maps to summarize the key ideas of each of the relevant readings. Throughout the course, the participants worked in collaborative groups (nine groups of two to four members) to create student generated concept maps that summarized textbook chapters, expressed theoretical background of their laboratory experiments, and represented their learning during the laboratory experiments.

Analysis of the concept maps revealed that as the course progressed, the quality and quantity of concepts and propositions included on the concept maps increased (Roth & Roychoudhury, 1993). In addition, the latter concept maps included more cross-links that identified relationships between distant concepts. Novak and Gowin (1984) explained that the presence of cross-links is indicative of higher-order thinking. Through interviews, some students explained that they had difficulty understanding the connections between concepts, forcing them to go back and learn more about the topic in order to create more accurate concept maps. Other students revealed that through the construction of concept maps they were able to relate concepts they learned to information they already knew about the topic, thus, resulting in meaningful learning. The students were not acquiring knowledge arbitrarily through rote learning; instead, they were attempting to integrate new knowledge with pre-existing knowledge.

One of the limitations of the study conducted by Roth and Roychoudhury (1993) was that the concept maps were not created individually. The collaborative nature of the concept mapping activity convolutes the results of the study due to the possibility that a single group member created the concept map. In essence, there were no controls to ensure that all students participating in the study contributed to the construction of the concept maps and that the concept maps reflected meaningful learning among all of the students. A second limitation to the study was that the researchers did not include how the concept maps were evaluated. There was no information provided on whether the concept maps were scored or who was involved in the evaluation of the maps. Lastly, it was not indicated how many concept maps were produced and analyzed during the study.

The current study is connected to the study designed by Roth and Roychoudhury (1993) in a few ways. First, both studies involved students interacting with science content and concept maps. Second, similar to the study by Roth and Roychoudhury (1993), the concept maps in the current study were analyzed for accuracy and evidence of meaningful learning. However, the current study is an extension of the study by Roth and Roychoudhury (1993) because the concept maps were evaluated using a scoring rubric and the effects of three different concept mapping strategies were investigated.

In another study aimed to demonstrate that concept mapping leads to meaningful learning, Asan (2007) assigned 23 fifth-grade students into either a control or experimental group. Throughout the study, both groups were exposed to the same heat and temperature content as outlined in the class textbook. To begin the study, the teacher introduced the chapter and the objectives for learning to the control group. Following the introduction of the unit, the control group engaged in three days of instruction involving lectures, overhead transparencies, and worksheets on heat and temperature. On the fourth day, the students in the control group were given 60 minutes to complete a teacher-constructed, 20-item multiple-choice pretest on heat and temperature. Following the pretest, the teacher conducted an oral review of the week's material. The oral review included a question/answer session and discussion of the important concepts introduced during the week. On the fifth and final day of the study, the students in the control group were given 60 minutes to complete a posttest identical to the pretest.

In contrast, during the first day of the study, students in the experimental group were exposed to a short lesson on how to create concept maps using a computer program named *Inspiration*. After participating in the concept mapping training, the teacher placed the students into groups of three and they were asked to engage in a short concept mapping activity. The concept mapping activity was implemented to determine if the students understood how to construct accurate concept maps. Shortly after, the teacher introduced the chapter and the objectives for learning to the students in the experimental group. Similar to the control group, the students in the experimental group engaged in three days of instruction involving lectures, overhead transparencies, and worksheets on heat and temperature. On the fourth day of the study, the students were given 60 minutes to complete the same 20-item, teacher-constructed, multiple-choice prettest that was given to the control group. Following the prettest, the concept mapping session began with a class discussion. During the discussion, the students in the experimental group identified 22 concepts related to the heat and temperature content. Next, the students worked individually to create concept maps using the *Inspiration* concept mapping program. On the fifth day of the study, the students were given 60 minutes to complete a posttest identical to the pretest.

Analysis of the pre and posttest results for students in the control group demonstrated that there was no statistically significant difference between the scores on the two tests at an alpha level of 0.05. Conversely, participants in the experimental group who engaged in the concept mapping learning strategy performed significantly higher on the posttest at an alpha level of 0.05. Newmann, Bryk, and Nagaoka (2001) asserted that assignments that involve more authentic intellectual work improve student scores on conventional tests. In addition to analyzing students' performance on the pre and posttest, 13 concept maps from the experimental group were scored using a scoring rubric created by the researcher. The scoring rubric consisted of analyzing the concepts and links between the concepts. Following analysis of the assessments and concept maps, Asan (2007) concluded that concept mapping helped students to develop a better understanding of important concepts. The concept maps demonstrated that students were able to identify and develop interrelationships between concepts. The concept mapping strategy enhanced meaningful learning because it required the students to attempt to understand concept meanings, organize concepts hierarchically and develop meaningful relationships between concepts to form a logical, integrated network of the material learned (Asan, 2007).

The study conducted by Asan (2007) had a few limitations. One of the limitations involved with the study was the small sample size. Only 23 students were involved in the study and only 13 concept maps were scored. Another limitation of the study was that the researcher did not provide information on the reliability and/or validity of the concept mapping scoring rubric used in the study. Additionally, it was not stated who or how many individuals scored the concept maps. There is a possibility of subjectivity involved in the scoring process if the researcher was the only individual scoring the concept maps. If more than one individual was involved, inter-rater reliability was not included in the study.

The current study is an extension of the study conducted by Asan (2007) because the effectiveness of three concept mapping strategies were investigated instead of just one. In addition to using pre and posttests to measure science achievement, the concept maps produced in the current study were scored by two individuals in order to decrease subjectivity of scoring. Finally, the current study included three weeks of science instruction instead of only three days. This helped to ensure that the students were creating concept maps with adequate knowledge of the content.

Buntting et al. (2006) revealed that concept mapping could enhance meaningful learning for topics that require students to make and explain connections between concepts. The researchers conducted a study in two entry-level biology courses at the university level. The two 12-week courses were not offered at the same time; instead, they were offered during consecutive semesters. The two entry-level biology courses used in the study included a different cohort of students. Although the two courses focused on different content (plant biology and molecular biology), the courses were similar in structure and pedagogy. For example, both courses included three 50-minute lectures each week, as well as a weekly laboratory. The course lectures consisted primarily of teacher-directed lessons.

In addition to the course lectures and laboratory, six tutorial sessions were offered each week. The tutorial sessions were 50-minutes in length and attendance was voluntary. Due to its voluntary nature, student attendance at tutorial sessions fluctuated from week to week. During each 12-week course, approximately 100 students attended four or more tutorials and approximately 35 students attended nine or more tutorials. Two of the six tutorials offered each week were dedicated to teaching students how to use concept mapping as a learning tool. Buntting et al. (2006) stated that the rationale for teaching concept mapping during the tutorial sessions was threefold: (1) to encourage students to form explicit links between new concepts and concepts they already knew, (2) to assist students with more limited prior knowledge to recognize and fill in any gaps in their prior knowledge, and (3) to help students to become active constructors of meaning. The third author taught all of the concept mapping tutorial sessions. The remaining tutorial sessions were taught by tutors and were conducted in a conventional manner that consisted of the tutor working-out and answering pre-set questions.

Using an exploratory research design to investigate students' perceptions of concept mapping, the researchers surveyed students from both courses who attended the voluntary 50-minute tutorials. The response rate for both courses was 100% due to the captive nature of the administration. In addition, Buntting et al. (2006) administered course assessments to the students in both courses and analyzed students' test results to determine if concept mapping influenced student learning.

The surveys revealed that 67% of the students found the concept mapping strategy useful in learning science. Additionally, 33% of the students also identified that concept mapping helped them to identify relationships between concepts (Buntting et al., 2006). In order to determine what influence concept mapping may have on student learning, the researchers pre-selected two types of questions from the assessment that they would use as part of the data analysis. One type of question could be answered by rote memorization of the course lecture notes while the second type of question could only be answered if the students had an understanding of a range of biological concepts, and were able to link these concepts together in an innovative way. Student achievement on the pre-selected items from the assessment were correlated with tutorial attendance and analyzed for differences using a chi-square test for independence. Tutorial attendance was used as a correlate to identify students who engaged in the concept mapping strategy. The results demonstrated that students who attended the concept mapping tutorials were more likely to score statistically significantly higher on assessment questions that required an understanding of relationships between concepts. Conversely, there were no differences in responses between students who attended the concept mapping tutorials and those who did not on questions that did not require conceptual organization of material, but could be answered by repeating facts learned by rote memorization. These results suggest that during concept mapping the students engaged in meaningful learning by determining how the concepts were related to one another and, as a result, they were able to recall the information for the assessment (Buntting et al., 2006).

Although the two studies are related, the current study is an extension of the study by Buntting et al. (2006) in several ways. First, students in the current study were required to attend concept mapping training that consisted of an introduction to concept mapping, guided practice, and independent practice. Second, during the training, the students were provided feedback on their concept maps. Buntting et al. (2006) did not indicate what the concept mapping training consisted of or whether the students received feedback during the training. Lastly, the current study is an extension of the study by Buntting et al. (2006) because the concept maps produced by the students were evaluated for accuracy.

The common theme illustrated in the description of the three studies on meaningful learning and concept mapping is that the concept mapping strategy has demonstrated effective engagement of students in meaningful learning. The propositions in the concept maps constructed by the students revealed that the students were making connections between closely related concepts. Additionally, the presence of cross-links in the concept maps demonstrated that the students were identifying associations between distantly related concepts and ideas.

Concept Mapping in Science

Middle Schools

Although concept-mapping research suggests that it is an effective strategy to promote meaningful learning, to date, there are only a few studies that have investigated the effectiveness of concept mapping in middle schools. Guastello et al. (2000) designed a quantitative pretest/posttest study to compare the use of a student generated concept mapping procedure with a traditional "read, recite, discuss, and test" instructional sequence on the acquisition of circulatory system content as measured by a teacher-created criterion-referenced test.

Similar to the current study, the researchers included low-achieving seventh-grade students enrolled at an inner-city middle school. The sample of 124 low-achieving seventh-grade students was selected from a larger pool of 147 seventh-grade students in the same school. The low-achieving students were selected for the study based on their test scores on the Comprehensive Assessment Program (CAP) (American Testronics, 1989) and criterion-referenced tests. Twenty-three of the seventh-graders were ineligible to participate due to their above grade level science and reading scores as indicated on the CAP.

Two indicators of student outcomes were measured. The first indicator was the CAP, a standardized achievement test. The CAP was administered to the students three months before the experiment to determine their eligibility. The standardized test measured the students' achievement in reading, basic skills, and content areas (Guastello et al., 2000). To ensure comparability of the experimental and control groups, science and reading grade equivalent scores were obtained from the CAP. The second indicator was a teacher-created, 20-question, criterion-referenced test. The test was developed based on the content and vocabulary of the 27-page science chapter entitled *The Circulatory System* (Sund, Adams, Hackett, & Moyer, 1985). The test included 20 short-answer questions that assessed the students' knowledge of the circulatory system and how it functioned.

To begin the study, the 124 students were randomly assigned to either the experimental (concept mapping) group or the control (traditional) group. Prior to any instruction on the circulatory system, the criterion-referenced test was administered as a pretest to both groups. The study was conducted over a period of eight school days with the science classes being taught by the same teacher during four 50-minute sessions per week.

Students in the control group received traditional teacher-directed instruction of the circulatory system. On the first day, the teacher activated students' background knowledge of the circulatory system by utilizing the K-W-L strategy to determine what they already knew (K) and what they wanted (W) to learn. Following the completion of the K and W columns on the K-W-L chart, the teacher provided the students with a global overview of the lesson and introduced the main objectives, which included understanding the three main parts of the circulatory system, identifying the subcategories of the circulatory system, and describing the subcategory characteristics and functions (Guastello et al. 2000). At the end of the first day's lesson, the students engaged with the K-W-L chart again by writing what they had learned (L) from the lesson. During the second through fifth day of the study, the students read the chapter with the teacher and received no additional visual reinforcement other than the text. The teacher monitored the students' comprehension of the text by posing questions and prompting discussions. On the sixth day of the study, the students completed their K-W-L charts by writing additional information they had learned about the circulatory system during the study. On the seventh day of the study, the students were given their textbooks to take home and reread in preparation for the posttest. The control group concluded the study on the eighth day with the administration of the criterion-referenced test as a posttest.

The experimental group received the same instruction as the control group during the first day of the study. Conversely, the students engaged in instruction and activities that differed from the control group for the remainder of the study. On the second day, the teacher used familiar content to demonstrate concept mapping. The teacher graphically illustrated how subordinate ideas and details were related to the main concept. During days two through six of the study the students read the chapter with the teacher and constructed a concept map as they engaged and discussed the text. Each day the students added new information to their concept maps with the assistance of the teacher, creating a network of related ideas for the unit. On the seventh day of the study the students took home their concept maps in preparation for the posttest. Similar to the control group the criterion-referenced test was administered as a posttest on the eighth day of the study.

Results of the pretest and CAP test revealed that the control and experimental groups performed similarly on both tests. On the other hand, a difference in the posttest gain scores was discovered. Guastello et al. (2000) performed an ANCOVA with pretest scores as the covariate and found a strong and statistically significant treatment effect favoring the concept mapping group.

There were several limitations of this study. First, the teacher-created criterion-referenced test may not have been a suitable assessment to measure meaningful learning. The criterion-referenced test alone does not demonstrate if students are accurately subsuming new information with previous knowledge. Students' thought processes may not be deciphered from a short-answer test. Second, teaching students how to create a concept map in one day may not have been sufficient. The students were not assessed on their concept mapping abilities before they took the posttest; therefore, there would be inadequate evidence to conclude that the students created accurate concept maps that may have contributed to their performance on the posttest. There is a possibility that the students were creating incorrect concept maps, but the act of engaging in the text by attempting to create concept maps may have helped them perform better than the control group on the posttest. Third, there are a few issues with the review material the students were allowed to utilize. Students in the control group may not have been motivated or able to thoroughly review and comprehend all 27 pages of the circulatory system chapter. In addition, no information was gathered on how long the students reviewed the material or the quality of the review. Finally, the researchers did not state whether the concept maps created by the students were analyzed for accuracy before they were used as a review.

The researchers recommended that future research evaluating the effectiveness of the different types of concept maps should be conducted. The current study is an extension of Guastello et al.'s (2000) study because the effectiveness of three different concept mapping strategies (concept identifying, proposition identifying, student generated) were analyzed. Additionally, the current study was also conducted in an inner-city seventh-grade classroom to contribute to the scarce literature on concept mapping in middle school science.

Recognizing that middle school science is considered a gateway for almost all science courses in high school, Snead and Snead (2004) attempted to examine the effects of concept mapping on the science achievement of middle grade science students. The researchers performed a nine-week experiment using 182 eighth-grade earth science students. The students were grouped in eight intact science classes by ability level (above average and average/low). Ability level was determined by students' performance on the California Achievement Test (Snead & Snead, 2004). The California Achievement Test measures reading, language, and mathematical skills. The school counselor was responsible for student placement without the input of the teacher or researcher. The eight intact classes were evenly assigned to either an experimental or control group and two teachers were assigned two experimental groups and two control groups, which included both above average and average/low ability levels.

Similar to the current study, the experimental groups received extensive training on the concept mapping strategy before the study began. At the beginning of the study, all students in the control and experimental groups completed a 34-item weather pretest consisting of 27 multiple-choice items and seven short-answer items. During the study, the same weather unit, which was constructed by the researcher, was taught to all groups and six performance assessment items were given at regular intervals throughout the study. The performance assessments were open-ended multi-step questions related to the weather concepts the students had been learning. For example, the second performance assessment was a two-part question that asked students to explain the process of cloud formation and then diagram and describe six processes in the water cycle. In addition to the performance assessments, the experimental groups used key words, phrases, or concepts provided by the teacher to create concept maps at selected intervals during the study. Throughout the study, the students were allowed to revise their concept maps as understanding of the concepts became clearer. At the end of each sub-unit, the concept maps were kept by the researcher and quantitatively scored based on information gathered from Novak, Gowin, and Johansen (1983), Malone and Dekker (1994), and Mason (1992). Students in the control groups engaged in activities, such as interpretative discussions, inquiry, and hands-on learning.

At the conclusion of the nine-week study, all of the students completed a posttest that was identical to the pretest. Using the pretest as a covariate, an analysis of covariance (ANCOVA) was used to analyze the results. The adjusted means posttest scores indicated that the scores for the concept-mapping group were higher, but not statistically significantly higher than scores for the control group. Additionally, the six performance assessment items were analyzed and the results revealed that concept mapping had no significant effect on students' academic performance. Yet, the results did show a statistically significant interaction between ability level and instructional method on the performance assessment total analysis. The average/low ability students who used concept mapping demonstrated significant improvements over control group students for two of the performance assessment items and the total performance assessment.

The study designed by Snead and Snead (2004) had a few notable aspects that rendered it stronger than the study conducted by Guastello et al. (2000). To begin, the students were exposed to the concept mapping strategy over a few weeks before the study. They had more time to become familiar with the concept mapping strategy before the actual study began. Next, students in the control group were engaging in instructional activities rather than solely reading from a textbook. Essentially, the only difference between the two groups was the presence or absence of the concept mapping strategy.

The study conducted by Snead and Snead (2004) had some limitations. Even though the students were exposed to the concept mapping strategy for a few weeks, the researchers did not assess the students' concept mapping abilities prior to the concept mapping intervention. No evidence was collected to determine if the students were capable of creating accurate concept maps. In addition, although the researchers evaluated the content of the student-generated concept maps, they did not indicate if there was a relationship between the concept maps and achievement on the posttest. Also, there were two teachers involved in the study and the researchers did not implement controls to determine if the instructional unit was taught similarly by both of the teachers. The proposed study extends the study described above by including a similar average/low ability population in a middle school.

The current study is similar to the study designed by Snead and Snead (2004) because the study was conducted in a middle school setting and the students received five days of concept mapping training. Additionally, as an extension of the study conducted by Snead and Snead (2004), the students in the current study received feedback on the construction of their concept maps during the training. The feedback allowed students to adjust their concept mapping skills before the instructional unit began. The current study was also an extension of the study designed by Snead and Snead (2004) because the concept maps produced by the students were scored for accuracy.

From the results of the two studies summarized above, it is evident that there are conflicting findings in the literature and additional concept mapping research is required. The study conducted by Guastello et al. (2000) resulted in the concept-mapping group outperforming the control group significantly; however, the study conducted by Snead and Snead (2004) did not result in the concept-mapping group significantly outperforming the control group. Furthermore, both studies were designed to only measure the effects of one of the four types of concept mapping strategies (student generated). As recommended by Guastello et al. (2000), there is clearly a need for more concept mapping research that investigates the effectiveness of the various concept-mapping strategies in middle school settings.

Varied Concept Mapping Strategies

The effectiveness of the four types of concept mapping strategies on student learning has been researched; however, the results are inconsistent (Kenny, 1995; Lee & Nelson, 2005; Smith & Dwyer, 1995). In this section, three concept mapping studies that were designed to evaluate the effectiveness of various concept mapping strategies will be discussed.

In 2004, Wang and Dwyer conducted a study that examined the effects of three concept-mapping strategies (concept identifying, proposition identifying, student generated) on students' achievement of different educational objectives in a web-based learning environment. Wang and Dwyer (2004) identified that, despite the pre-existing literature on concept mapping, it could not be implied that all of the concept mapping strategies were equally effective for various learning objectives. The study included 156 college students who were randomly assigned to one of four groups: control, concept identifying mapping, proposition identifying mapping, and student generated mapping. A week prior to the study, six one-hour concept-mapping workshops were provided to the students in the various concept mapping treatment groups. During the study, the students were given a 2,000-word expository text describing the human heart including its parts, locations, and functions during systolic and diastolic phases. Student achievement was measured using three criterion tests (identification, terminology, and comprehension). The objective of the identification test was to measure transfer of learning. The objective of the terminology test was to evaluate students' knowledge of references for specific symbols. The objective of the comprehension test was to measure understanding of the heart, its parts and functions. Finally, the total criterion test consisted of the items in the identification, terminology, and comprehension tests to provide a total criterion score. The total criterion score was used to measure students' total performance on the three individual criterion measures (Wang & Dwyer, 2004). The students in the control group did not use any of the concept mapping strategies and took the criterion tests after engaging with the instructional material. The concept identifying, proposition identifying, and student generated mapping groups interacted with the instructional material then used their respective concept mapping strategies to individually summarize the instructional material. Finally, the students finished by taking the criterion tests.

The results of the study indicated that there were significant differences between the control group and the concept identifying mapping group on all of the criterion tests, with the concept identifying mapping group performing better. One possible explanation for these results is that through the process of focusing primarily on the concepts, the students were able to remember the concepts and were better equipped to understand other dimensions of the content since the concepts are the foundation from which comprehension can be built (Wang & Dwyer, 2004). The student generated mapping group also performed significantly higher on the identification, terminology, and total tests compared to the control group. Wang and Dwyer suggested that the absence of significant differences between the control and student generated mapping groups on the comprehension test resulted from the highly cognitively demanding characteristic of the student generated mapping strategy. They stated that during the creation of the concept map the students might not have been persistent enough to make extensive connections between concepts (Wang & Dwyer, 2004). Lastly, the results indicated that there were no significant differences between the achievement of the students in the control group and proposition identifying mapping group on any of the criterion tests. Analysis of the concept maps produced by the students in the proposition identifying group revealed that they had a difficult time accurately completing them; consequently, the proposition identifying concept mapping strategy failed to facilitate learning.

One of the positive attributes about the study performed by Wang and Dwyer (2004) was that the researchers were able to obtain a holistic view of students' understanding of the circulatory system by implementing three different tests to measure performance. Another positive aspect of the study was that the students were offered six workshops on concept mapping before the study began. Nonetheless, although the students had the opportunity to participate in the six concept-mapping workshops, the researchers were not transparent about how many of the students actually received the training and what the training entailed. For example, it was not stated if the students were provided the opportunity to create concept maps and, if they did, it was not mentioned whether or not they received feedback.

One of the central reasons why the current study is related to the study conducted by Wang and Dwyer (2004) is because both studies were designed to investigate the effectiveness of concept identifying, proposition identifying, and student generated concept maps. The current study is also similar to the Wang and Dwyer (2004) study because the students received five days of one-hour concept mapping training. In contrast to the study by Wang and Dwyer (2004), the concept mapping training in the current study was required for all students to attend. Moreover, the students received feedback on the accuracy of their concept maps during the training. The current study is also an extension of the study conducted by Wang and Dwyer (2004) because the students in the current study engaged in the instructional unit over a period of three-weeks compared to a one-day interaction with the instructional material. Additionally, the three types of concept maps were analyzed for accuracy.

In a follow-up study, Wang and Dwyer (2006) performed a similar experiment aimed to investigate the instructional effects of three concept mapping strategies in facilitating student achievement. Two hundred and ninety undergraduate students were randomly assigned to one of four treatment groups: control, concept identifying, proposition identifying, and student generated. Similar to the previous study, concept mapping workshops were conducted one week prior to the experiment. After the students interacted with a 2,000-word expository text of the human heart on the web, all students except those in the control group individually engaged in their assigned concept mapping strategies and then completed the identification, terminology, and comprehension criterion tests.

Analysis of the results indicated that the three concept mapping strategies were not equally effective in facilitating achievement of different educational objectives. The superior concept mapping strategy on all of the criterion tests was the concept identifying mapping. The students in the student generated concept mapping group only demonstrated significantly higher scores in achievement at the conceptual level when compared to the control group. One possible explanation that Wang and Dwyer (2006) offered for these results is that since the students began the mapping procedure at the factual level by identifying and selecting key concepts, then proceeded to the conceptual level to develop propositions between the concepts, many of the students did not effectively make it to the last level of reorganizing the information using rules and principles to show internal structure of the content. Hence, because reorganizing the concepts and propositions was a highly metacognitive activity, students did not persevere and remain at the conceptual level of learning. The proposition identifying mapping strategy was not effective in facilitating achievement of the educational objectives as measured by the criterion tests when compared to the other three treatments. Wang and Dwyer (2006) identified that the ineffectiveness of the proposition identifying mapping strategy on students' achievement may have been a result of the ambiguity associated with the map itself. Based on the learning material, the students may have perceived the concepts without links in a way that differed from what the map provider expected them to see. According to Steward (1979), there could be "…numerous valid propositions that could be generated to link two nodes" (p. 400).

Similar to their previous study, a positive characteristic of the Wang and Dwyer (2006) study was that during the pre-experiment phase students were offered concept mapping workshops. In the 2006 study, the researchers identified that the workshops included an explanation of the nature of concept maps, uses of concept maps, and procedures for concept mapping. In addition, the students were required to practice concept mapping and were provided feedback on their concept maps. In spite of this, Wang and Dwyer (2006) identified that the students were not sufficiently prepared with the concept mapping strategies.

The current study is related to the 2006 study designed by Wang and Dwyer in several ways. First, the current study was also designed to investigate the effectiveness of concept identifying, proposition identifying, and student generated concept maps. Second, the students in the current study were also involved in concept mapping training that included an explanation of the nature of concept maps, uses of concept maps, and procedures for concept mapping. Third, similar to the study conducted by Wang and Dwyer (2006), the students in the current study also received feedback on the construction of their concept maps during the training. As indicated earlier, an extension of the Wang and Dwyer 2004 and 2006 studies was that the students in the current study interacted with the instructional material over a period of three-weeks instead of a single day. Furthermore, all of the concept maps produced during the current study were analyzed for accuracy.

In a recent study conducted by Lim, Lee, and Grabowski (2009), the researchers aimed to identify the impact of teacher generated, student generated, and partially completed (concept and/or linking words omitted) concept maps on student learning. One hundred and twenty four undergraduate students were randomly assigned to one of the three concept-mapping treatment groups. The students in the student generated and partially completed concept mapping groups were provided written instructions on “how to create a concept map,” while the students in the teacher generated concept mapping group received written instructions on “how to use a concept map” (Lim et al., 2009). Each student studied the same web-based learning material about the human heart and utilized their assigned concept mapping strategy. After studying the learning material and interacting with the concept maps, the students turned in their concept maps and were administered a posttest to assess their learning. The students completed all of the tasks in one sitting.

Results from the posttest revealed that students in the student generated concept mapping group significantly outperformed the students in the teacher generated concept mapping group (Lim et al., 2009). The mean scores for the student generated, partially completed, and teacher generated concept mapping groups were 26.72, 23.93, and 21.38 with standard deviations of 8.96, 8.48, and 8.73, respectively. Lim et al. (2009) also discovered that that there were no significant differences between the teacher generated concept mapping group and the partially completed concept mapping group, or between the partially completed concept mapping group and the student generated concept mapping group.

One of the strengths of the study by Lim et al. (2009) was that they designed specific concept mapping instruction for the treatment groups. For example, the student generated concept mapping group received instruction on “how to create a concept map” whereas the partially completed concept mapping group received instruction on “how to use a concept map." This may have assisted students in focusing on strategies that would help them either create or use the concept maps.

The study designed by Lim et al. (2009) had a few limitations. One of the weaknesses of the study was that it was conducted in one day. The students were taught how to create or use concept maps, learn the instructional material, and take the posttest all in one day. It would have been useful if the students had more time to practice creating or using the concept maps. Another limitation of the study was that the concept maps produced by the students were not analyzed for breadth or depth of understanding of the circulatory system. The researchers did not evaluate the concept maps to find out if the students created accurate concept maps of the circulatory system. The students may have created inaccurate concept maps while performing well on the posttest.

The study designed by Lim et al. (2009) is similar to the current study because both studies aimed to evaluate the effectiveness of the various concept mapping strategies. The current study builds upon the study by Lim et al. (2009) in several ways. First, the students in the current study received five days of concept mapping training and feedback before they engaged with the instructional material. Similar to the study by Lim et al. (2009), the students received specific training on the concept mapping strategy they were assigned to. Second, the students had the opportunity to learn the instructional material over a three-week period compared to the one-day interaction with the instructional material provided in the Lim et al. (2009) study. Third, the concept maps produced in the current study were evaluated for accuracy.

Although researchers have conducted studies to investigate the effectiveness of the varied concept mapping strategies, none of the studies have been carried out in a middle school setting. The majority of concept mapping studies have taken place in high school and undergraduate/graduate school settings. Additionally, further research is necessary because the results of the effectiveness of the varied concept mapping strategies are inconsistent. In both of the studies conducted by Wang and Dwyer (2004, 2006), the results suggested that the concept identifying groups were superior in performance compared to the student generated and proposition identifying groups. Alternatively, the results from the study by Lim et al. (2009) revealed that the students in the student generated concept mapping group outperformed the students in the partially completed and teacher generated concept mapping groups. Evidently, there is a need for additional research that compares the effectiveness of the varied concept mapping strategies.

Concept Maps as Assessment Tools

Assessing Concept Maps

Currently, there are several types of standardized assessments that measure student ability and learning, such as, multiple-choice tests that report scores using norm-referenced or criterion-referenced scales (Neill & Medina, 1989). Yet, according to Kleinsasser (1995), these types of assessments do not accurately reflect the students' progress or cognitive structure. In 2001, the National Research Council released a report that highlighted the importance of using classroom assessments that evaluate cognitive structure. Students may be able to perform well on objective assessments by simply memorizing facts; however, a deeper understanding of the content is necessary in order to construct a comprehensive, well-integrated concept map (Jacobs-Lawson & Hershey, 2002). Consequently, to create a concept map, students must have the basic information required to complete objective standardized assessments and also need to be able to integrate that information into a coherent structure.

Koul, Clariana, and Salehi (2005) posited that assessing concept maps are useful ways to measure students' structural knowledge of content. Structural knowledge is defined as the interrelationships of ideas within an individual's cognitive structure (Stoyanov, 1997). For example, a representation of structural knowledge would be making the connection that plants not only grow because of food but also need sunlight. In essence, understanding that food and sunlight is needed for plants to grow demonstrates an interrelationship between the two topics. Structural knowledge is viewed as an important component of understanding in a subject domain, especially in science since many scientific topics are interrelated (Novak, 1990; Novak & Gowin, 1984).

Evaluating cross-links and propositions on concept maps can provide valuable information regarding the depth and breadth of students' understanding of a topic. For example, the presence or absence of cross-links gives insight to the depth of student's knowledge (Jacobs-Lawson & Hershey, 2002). If students create concept maps that include accurate cross-links, they are demonstrating an understanding of the interconnectedness of the sub-topics. Additional analysis of concept maps reveals whether the students have general or specific knowledge of the topic. For instance, students with general knowledge of the topic create propositions that are within close proximity to the central concept (near the top of the page), as opposed to students who have specific knowledge of the topic and create propositions that are farther away from the central concept (near the bottom or edges of the page) (Jacobs-Lawson & Hershey, 2002).

In addition to assessing concept maps to explore how well students understand the correct connections among concepts, they can also be used to identify students' misconceptions. When students engage in concept mapping, they produce a representation of their knowledge of a specific topic. Analysis of the concept map may reveal deficiencies in the students' understanding of a topic and can be used to plan future instruction (Francisco, Nakhleh, Nurrenbern, & Miller, 2002). Moreover, by examining their own concept maps, students can identify unconnected concepts. Clymer and Wiliam (2007) stated that research studies from around the world have shown that assessment can help students to learn science, as well as to measure how much science they have learned. All in all, the concept map is a vigorous assessment strategy for exploring students' structural knowledge, as well as identifying misconceptions.

Concept Map Scoring Methods

Since the introduction of concept mapping, researchers have been interested in developing ways to measure meaningful learning by using concept maps as assessment tools. Koul et al. (2005) explained that the interpretation and scoring of concept maps involves judgments along numerous dimensions that represent the breadth, depth, and connectedness of the knowledge all based on only the concepts, propositions, cross-links, and levels of hierarchy in the concept map. One of the critical components of a scoring method is that the concept map score strongly relates to the student's actual understanding of the content. Hence, it is especially important to select an appropriate scoring method since different scoring methods will result in different scores for the same set of maps.

In 1984, Novak and Gowin developed the first comprehensive concept map scoring system. The scoring system consists of evaluating concept maps based on the number of valid components in a map. The valid components include propositions, levels of hierarchy, cross-links, and examples. The propositions are worth one point and are evaluated based on the presence of a meaningful, valid relationship between two concepts indicated by a connecting line and linking word(s). Five points are allotted for each level of hierarchy that displays subordinate concepts that are more specific and less general than the concepts drawn above it. Cross-links that exhibit meaningful connections between one segment of the concept hierarchy and another segment that are both significant and valid are given 10 points. On the other hand, cross-links that are valid but do not illustrate a significant connection between sets of related concepts or propositions are only given two points. Finally, one point is allotted for every concept that is accompanied by a valid example. After all of the components of the concept map are scored, they are added together to establish the final score.

An alternative scoring method by McClure and Bell (1990) focuses exclusively on propositions included in a concept map. The three aspects of the propositions that are scored are: (1) the relation between the concepts, (2) the label, and (3) the direction of the arrow indicating either a hierarchical or casual relationship between concepts. If there is a relationship between the subject and object, the label indicates a possible relationship between the words, and the direction of the arrow indicates a hierarchical or causal relationship between the words that is compatible with the label, then the proposition is given three points. The absence of a relationship between the subject and object results in zero points; however, the presence of a relationship between the subject and object is assigned one point. If there is a relationship between the subject and object and the proposition includes a label that indicates a possible relationship between the words, two points are assigned.

A more recent scoring system developed by Kinchin and Hay (2000) consists of analyzing the overall organization or structure of the map. This scoring system is based on the idea that knowledge structure is a more holistic variable rather than a "sum of the individual components" type variable. A concept map score is assigned after the evaluator judges the overall structure of the map and identifies progressive levels of understanding.

The scoring methods described above are useful for scoring specific types of concept maps. For example, the scoring method by Novak and Gowin (1984) would be useful for scoring student generated concept maps since all aspects including concepts, propositions, cross-links, and examples are evaluated. In contrast, the scoring method designed by McClure and Bell (1990) would only be useful for evaluating proposition identifying maps because the propositions are the only components of the concept map evaluated using this specific scoring method. The scoring method by Kinchin and Hay (2000) evaluates the overall organization of the concept map so it would be useful for scoring student generated concept maps. Concept identifying and proposition identifying concept maps would not be scored effectively using this scoring method because the maps are already partially organized. A scoring method designed by Lomask, Baron, Greig, and Harrison (1992), was better suited to score the concept identifying, proposition identifying, and student generated concept maps produced in the current study.

The scoring system created by Lomask et al. (1992) entails arriving at an overall score by counting the number of concepts and the correct links between the concepts. Initially, Lomask et al. scaled both the count of concepts and the count of links. The "size" of the count of concepts was expressed as a proportion of terms in an expert concept map mentioned by a student. This proportion was scaled from complete (100%) to substantial (99%-67%) to partial (66%-33%) to small (32%-1%) to none (0%). Similarly, they characterized the "strength" of the links between concepts as a proportion of necessary, accurate connections with respect to the expert map. Strength ranged from strong (100%) to medium (99%-50%) to weak (49%-1%) to none (0%). Next, Lomask et al. created a rubric (Table 1) that produced scores taking into account both "size" of concepts and "strength" of links.

The concept identifying, proposition identifying, and student generated concept maps produced in the current study were evaluated based on the scoring method created by Lomask et al. (1992). The justification for utilizing this particular scoring method was that previous research has demonstrated that scoring approaches with the highest reliability and criterion-related validity compare specific features in student concept maps to those in expert concept maps (Taricani & Clariana, 2006). Furthermore, the scoring method developed by Lomask et al. (1992) could be used to score the three different types of concept maps produced in the current study because it involves evaluating the concepts and links independently.

Table 1

Scores Based on Combinations of "Size" and "Strength" of Students' Concept Maps

	Strength (Links)			
Size (Concepts)	Strong (100%)	Medium (99%-50%)	Weak (49%-1%)	None (0%)
Complete (100%)	5	4	3	2
Substantial (99%-67%)	4	3	2	1
Partial (66%-33%)	3	2	1	1
Small (32%-1%)	2	1	1	1
None/Irrelevant (0%)	1	1	1	1

Lomask et al. (1992)

Previous Research on Concept Map Scoring Methods

The majority of the previously conducted concept mapping research does not include an evaluation of the concept maps produced by students. Generally, the researchers determine the effectiveness of the various concept-mapping strategies by analyzing differences between pretest and posttest achievement scores. However, there are two notable studies that have evaluated students' concept maps: Francisco et al. (2002) and BouJaoude and Attieh (2008).

Francisco et al. (2002) implemented an action research model of planning, action, observation, and reflection to investigate how students' conceptual understanding of chemistry concepts changed through the use of concept mapping as a study and assessment technique. The study design consisted of three research cycles. In cycle one, 446 students, enrolled in an introductory level chemistry course for science and engineering majors, participated in the study. During class lectures, the students received concept mapping training and opportunities to practice constructing their own concept maps. Following the training, students were directed to construct concept maps for homework and for two thermodynamics related laboratories. Before each of the two laboratories, the students were expected to individually construct a concept map in preparation for the laboratory. After the second laboratory, students worked in groups of eight to construct concept maps related to the laboratory. A year later, 437 students, enrolled in the same introductory level chemistry course, participated in cycle two. The students received similar instruction on the construction of concept maps as the students in cycle one. During cycle two, students were assigned to construct weekly concept maps. In addition, five of the nine quizzes given during the semester required students to construct a concept map. In the last cycle of the investigation, the participants included 345 students enrolled in the second semester of an introductory chemistry course for science and engineering majors, a continuation of the first semester course discussed in cycles one and two. The instruction and training of the concept mapping strategy was similar to the first two cycles. During cycle three, concept maps were constructed for class assignments. In addition, the quizzes and exams given during cycle three also contained optional items that required students to construct concept maps.

Francisco et al. (2002) scored five randomly selected post laboratory concept maps created by students from cycle one of the study. The researchers evaluated the linking phrases (propositions) on the concept maps by coding them as correct, correct but noninformative, incorrect, or duplicate. Next, the following scoring algorithm was developed by the researchers to score the concept maps:

$$\frac{\text{\# correct (linking phrases) - \# wrong or noninformative (linking phrases)}}{\text{total \# of connections made}} \times 5$$

Interrater reliabilities of 10 randomly selected concept maps from the first quiz given in cycle two were evaluated using the scoring algorithm to determine the consistency of the codes for scoring concept maps. Two volunteers and the fourth author evaluated the 10 concept maps; the reliability values comparing the volunteers to the fourth author were .84 and .80, demonstrating good internal consistency of the scoring procedure.

Based on the information received from the professors and teaching assistants who scored the concept maps, Francisco et al. (2002) affirmed that valuable information could be gleaned from the evaluation of concept maps. The researchers found that the concept maps displayed relevant information about conceptions that students held regarding science topics. They learned that some students were displaying a thorough understanding of the topics and interrelatedness of sub-topics; yet, some students created two isolated concept maps and had difficulty connecting the two related maps to form one comprehensive map. The information illustrated on the concept maps could be used to inform and/or differentiate future instruction.

Francisco et al. (2002) also discovered that the teaching assistants and students expressed concern with the evaluation of the concept maps. For instance, some students questioned the fairness and consistency of grading concept maps, while the teaching assistants expressed concern about other teaching assistants' ability to grade concept maps accurately and efficiently. The researchers learned that when evaluating concept maps using the scoring method, teaching assistants should be well informed about what designates informative and important linking phrases. They also suggested that students should be thoroughly educated about the importance of making informative and accurate connections between concepts. They identified that the concept mapping training should be both informative and rigorous, allowing students sufficient opportunities to practice constructing concept maps while providing constructive feedback.

There were several limitations associated with the study conducted by Francisco et al. (2002). First, different students participated in the study during each cycle. As a result, there was no way to track students in order to learn how their concept mapping skills or achievement improved over time. A second limitation of the study was that the students were not provided feedback on their concept maps during the study. The researchers scored the concept maps after the study was completed; subsequently, the students were not informed whether their concept maps were being constructed correctly. Third, the quizzes and exams given to students in cycle three included optional concept mapping items. The students were not required to actually construct concept maps for the assessments. Finally, only the propositions of the concept maps were evaluated. The researchers did not use a holistic scoring method to evaluate students' overall understanding of the concept being taught.

One strength of the study designed by Francisco et al. (2002) was that even though only the propositions were evaluated on the concept maps, the researchers were interested in the accuracy of the maps. They used the information on the concept maps to identify students' understanding of the concepts. This information could be useful in designing future instruction. The current study extends the study conducted by Francisco et al. (2002) by investigating the effects of implementing concept mapping as a learning strategy, while providing constructive feedback to students and evaluating student generated concept maps.

In another study conducted by BouJaoude and Attieh (2008) who scored concept maps, the researchers aimed to investigate the effect of using concept maps as study tools on achievement in chemistry. According to the school's policy, the 60 tenth-grade participants were randomly divided into two sections based on achievement. The researchers randomly assigned one group as the experimental group and the other group as the control group. To begin the study, students in both groups were given a teacher-constructed pretest. The pretest consisted of the majority of the items being comprehension level and above multiple-choice and short-answer items that measured students' prior knowledge of topics related to the ones covered during the study. The remaining treatment period was divided into two parts. During the first part of the study, which consisted of two weeks, the students in the experimental group received training on how to construct concept maps. The concept map training consisted of an introduction to concept mapping, examples of concept maps, guided practice, and feedback on the student generated concept maps. The concept maps were scored using an expert concept map created by the researchers and a scoring rubric. The scoring method consisted of a combination of qualitative and quantitative components of analyzing the concept maps. The qualitative portion of the scoring process utilized the scoring rubric created by Kinchin and Hay (2000) which analyzes the overall structure of the concept map. The quantitative portion of the scoring process used the scoring rubric developed by McClure and Bell (1990), which assigns a value of zero to three based on the link's validity. The researchers identified that the intention of scoring the concept maps was to help students improve their concept mapping skills.

During the first part of the study, the students in the control group were taught by a different instructor than the experimental group and were engaged in the content by completing assignments that did not entail creating concept maps. During the second part of the study, which consisted of four weeks, the students in the experimental group were required to submit a concept map twice per week. The control group continued to complete traditional assignments. At the conclusion of the six-week study, students in both the experimental and control groups were given a posttest. The teacher-constructed posttest consisted of multiple-choice and short-answer items that measured students' knowledge of the content introduced during the study.

At the conclusion of the study, the concept maps created during the second part of the study were evaluated. After correlating the experimental group students' chemistry test scores with the corresponding total concept map scores, the researchers reported that the total scores on the concept map showed a significant correlation with the scores on the application and above level questions. On the other hand, the total concept map scores demonstrated non-significant correlations with the knowledge and comprehension level questions. The researchers concluded that evaluating concept maps and correlating them to achievement tests can offer insight to the type of questions concept mapping techniques help with the most.

One of the limitations of the study conducted by BouJaoude and Attieh (2008) is that the control and experimental groups were taught by different instructors. Even though the science content was the same, there may have been inconsistency with the way the instruction was delivered to the students resulting in differences in achievement. Another limitation of the study was that the pretest and the posttest were not the same. The pretest measured students' prior knowledge of the content to be learned in the study and the posttest measured what the students' actually learned during the study.

One of the strengths of the study designed by BouJaoude and Attieh (2008) was that the concept mapping group was provided feedback during the concept mapping training. The students had the opportunity to improve on their concept mapping skills before the actual study began. Another strength of the study was that the concept maps were scored holistically. The researchers were interested in learning if the students were making connections among closely and distantly related concepts. The current study was similar to the study conducted by BouJaoude and Attieh (2008) because students were provided feedback during concept mapping training and the student generated concept maps were scored to assess student knowledge.

Summary

The review of the concept mapping literature highlights the importance of the need for additional research. The research has demonstrated that the concept mapping strategies can effectively enhance meaningful learning. Furthermore, the research conducted in science classes revealed that the concept mapping strategies may increase science achievement; however, the results are inconsistent. Additionally, most of the concept mapping studies have been conducted in high school and undergraduate/graduate school classes; hence, more studies that involve middle school classes are necessary.

Only a few studies have investigated the effects of the varied concept mapping strategies, and the results are conflicting. The current study contributed to the literature by researching the effects of three concept mapping strategies on students' science achievement. Based on the preexisting literature, students in the student generated, concept identifying, and proposition identifying groups outperformed the students in the teacher generated concept mapping group; therefore, the teacher generated concept mapping strategy was not included in the study.

CHAPTER III

METHODOLOGY

This study was designed to investigate the effects of three concept mapping learning strategies (student generated, concept identifying, proposition identifying) on seventh-grade students' understanding of the circulatory system as measured by performance on an achievement test and concept identifying, proposition identifying, and student generated concept maps at an urban middle school. This section includes: (a) a restatement of the research questions, (b) description of the research design, (c) description of sampling procedures, (d) qualifications of the researcher (e) human subjects considerations, (f) instrumentation, (g) procedures and treatment, and (h) data analysis methods.

Research Questions

The research questions are as follows:

1. What is the effect of three concept mapping strategies (concept identifying, proposition identifying, student generated) on urban middle school students' science knowledge as measured by their posttest circulatory system test scores?
2. What is the effect of three concept mapping strategies (concept identifying, proposition identifying, student generated) on urban middle school students' science knowledge as measured by rubric scores on their respective concept maps?"
3. What are the differences in the rubric scores of student generated concept maps constructed by students in the concept identifying or proposition identifying

groups compared to rubric scores of the student generated concept maps constructed by the student generated group?

Research Design

This quasi-experimental study was implemented with 95 students enrolled in three intact seventh-grade science classes at an urban middle school. Each of the three intact classes was randomly assigned to one of the three concept mapping groups representing each level of the independent variable: concept identifying, proposition identifying, and student generated. The study began with the administration of a circulatory system pretest. Next, all participants received five days (one-hour each day) of their respective concept identifying, proposition identifying, or student generated concept mapping training by the researcher. The training included an introduction to concept mapping, guided practice, independent practice, and feedback on the concept maps. Following the concept mapping training, the researcher began the intervention by teaching the same three-week unit on the circulatory system to each class. The circulatory system instruction consisted of a total of 15 days of instruction (one hour each day). During this time, the participants engaged in their respective concept mapping strategies by completing concept identifying or proposition identifying concept maps, or creating student generated concept maps. The concept maps were scored and given back to the participants with feedback that could be used to improve their concept mapping skills. At the conclusion of the intervention, all participants were given a posttest identical to the pretest to measure their understanding of the circulatory system. Additionally, after the posttest, each participant created a concept map on the circulatory system using their respective concept mapping strategies (i.e., students in the concept identifying group completed a concept identifying concept map). Lastly, participants in the concept identifying and proposition identifying groups also created student generated concept maps on the circulatory system.

Participants

The Northern California urban middle school where the study was conducted includes the sixth, seventh, and eighth grades. All of the students enrolled at the school are qualified to receive free lunch due to their families' socioeconomic status. There are approximately 65% Hispanic students, 30% African American students, and 5% Asian students enrolled at the middle school. All students in the seventh-grade were required to enroll in the science class which covers life science related topics, such as: cells, evolution, digestive system, respiratory system, circulatory system, reproductive system, and plants. Initially, the participants in this study included a convenience sample of 95 seventh-graders enrolled in one of three science classes. The three intact science classes were assigned to one of the three treatment groups. The students attended the science class five days a week for one hour each day. Prior to the study being conducted, none of the students had exposure to the content or materials being used in the study.

The 95 participants consisted of 40 males and 55 females who ranged in age from 11 to 14 years. Due to attrition, posttest and concept map scores were only collected from 89 students. Three of the students who initially participated in the study moved to different schools during the study. The other three students were not present during the concept map and/or circulatory system instruction phase of the study due to family related issues, suspensions, or illnesses. The demographic information of the 89 participants is presented in Table 2.

Table 2

Demographic Information of Participants

Demographic	Concept ID (N = 30)	Proposition ID (N = 32)	Student Generated (N = 27)	All Groups Combined (N=89)
Gender	18 Females	19 Females	14 Females	51 Females
	12 Males	13 Males	13 Males	38 Males
Ethnicity	53% Hispanic	46% Hispanic	48% Hispanic	51% Hispanic
	47% African American	50% African American	51% African American	48% African American
		4% Other	1% Other	1% Other

Qualifications of the Researcher

The lead researcher is also the current teacher of the three seventh-grade science classes participating in the study. The teacher holds a Bachelors Degree in Biology and a Masters Degree in Education. Additionally, the teacher holds a Single Subject Science Teaching Credential and has three years of experience teaching seventh-grade science at the same urban middle school.

Protection of Human Subjects

Permission to conduct the study was granted from The University of San Francisco Institutional Review Board for the Protection of Human Subjects (Appendix A), as well as to the research and assessment department of the school district (Appendix B).

Additionally, a permission letter to conduct research at the middle school was obtained from the site administrator (Appendix C). After being granted approval to conduct the study from all constituencies, informed consent was requested from each participant. Since the participants were under the age of 18, parental consent for research participation was also obtained (Appendix D). In addition to the informed consent letter, a cover letter describing the purpose, research design, instruments, and confidentiality of the study was provided to participants (Appendix E). The rights of all participants involved in the study were protected and there were no physical, mental or emotional risks associated with the study.

Instrumentation

The dependent variables of the study were the circulatory system posttest scores and rubric scores of the concept identifying, proposition identifying, and student generated concept maps. The instrument that was used for the pretest and posttest was a multiple-choice circulatory system assessment. Three other instruments that were used were the circulatory system concept identifying, proposition identifying, and student generated concept maps. Lastly, the concept identifying, proposition identifying, and student generated concept maps were evaluated using a scoring instrument created by Lomask, Baron, Greig and Harrison (1992). Measuring student knowledge of the circulatory system by assessing the concept maps was a technique to measure meaningful learning. The scoring instrument involved obtaining an overall score by comparing the number of correct concepts and/or links between the students' concept identifying, proposition identifying, and/or student generated concept maps to a teacher generated concept map.

Circulatory System Test

The Circulatory System Test was used as both the pretest and the posttest. The circulatory system content was selected because of the hierarchical nature of the material. The hierarchy of parts and sub-parts, and the flow of blood circulation lent itself well to identifying nodes and links and meaningful relationships among them (Lim, Lee, & Grabowski, 2009). The classroom teacher created the 20-item multiple-choice test (Appendix F) using a compact disc provided by the *CPO Focus on Life Scien*ce (CPO Science, 2007) textbook company that included multiple-choice test items. The teacher reviewed the circulatory system unit and then proceeded to select multiple-choice test items to include on the test. The items were selected based on the vocabulary and concepts that were going to be taught in the circulatory system instruction phase. Nine of the multiple choice items included on the circulatory system test assessed students' knowledge of the vocabulary words taught during the instruction phase. Six of the nine vocabulary items were included on the concept maps. For example, one of the items asked students to select the correct answer choice that defined the function of white blood cells. The teacher generated concept map included two nodes, one node was, "white blood cells" and the other node was, "to produce antibodies to destroy invaders." The two nodes were connected with the linking word, "function." Four of the multiple choice items assessed students' ability to identify the composition of parts of the circulatory system. For example, one of the items asked students to identify what the outer layer of an artery is made of. All of the information needed to answer the identification items was included on the concept maps. Lastly, seven of the items on the circulatory system test assessed students' understanding of circulatory system processes. For instance, one of the items asked students to identify what happens during the first stage of the heart contracting. The information for five of the seven process items was included on the concept maps.

After creating the Circulatory System Test, two other seventh-grade science teachers from the same school district evaluated the 20-item multiple-choice test for content validity and clarity. One of the teachers had three years of experience teaching seventh-grade life science and the other had 11 years of experience. In addition, both teachers used the same *CPO Focus on Life Science* (CPO Science, 2007) textbook in their classrooms to teach the circulatory system unit. The teachers were provided with details regarding the unit to be taught in the *CPO Focus on Life Science* (CPO Science, 2007) textbook, along with a list of the main concepts to be included in the instruction phase. The evaluators agreed that the content of the Circulatory System Test was valid and did not have any suggestions to further improve the instrument. Each question on the pre and posttest was worth one point and the total scores were calculated by determining how many of the 20 questions were answered correctly.

Concept Identifying and Proposition Identifying Concept Maps

The teacher first created a concept map using the circulatory system content that was planned to be taught during the study (Appendix G). The main topics and sub-topics were mapped out to create a comprehensive map that illustrated the relationships between the circulatory system concepts that were taught during the study. Upon completion of the teacher generated concept map, the same two seventh-grade science teachers who evaluated the Circulatory System Test evaluated the concept map for content validity.

The evaluators agreed that the teacher generated concept map was valid and represented the topics and sub-topics that were to be introduced in the study. The concept identifying and proposition identifying concept maps that were used in the final assessment (Appendix G) were created by deleting the concepts (concept identifying map) or propositions (proposition identifying map) from the teacher generated concept map.

Concept Map Scoring Instrument

The concept map scoring instrument that was used to evaluate the concept identifying, proposition identifying, and student generated concept maps was created by Lomask et al. (1992). The scoring method involves arriving at an overall score by comparing the concepts and the correct links between the concepts on the student concept maps to a teacher generated concept map. Lomask et al. (1992) generated a rubric (Table 2) to assist in the scoring of concept maps. The first column, the “size” of the count of concepts is expressed as a proportion of terms in a teacher generated concept map mentioned by a student. For example, if the concept map included 100% of the concepts from a teacher generated concept map, five points were given for the concepts. If 99%-67%, 66%-33%, 32%-1%, or 0% (none) of the concepts were included in the concept maps then four, three, two, or one point were given, respectively, for the concepts. The second through fourth columns of the scoring instrument created by Lomask et al. (1992) was used to determine the points allotted for the “strength” of the links between concepts. The links between the concepts on the maps were compared to the links present on a teacher generated concept map. For example, if the links between the concepts were 100% accurate and as complete as the links on the teacher generated concept map, five points were given. If the links were 99%-50%, 49%-1%, or 0% accurate, then four, three, or two points were given, respectively. There were five total possible points for each concept map. Five points were given to a concept map that included 100% of the concepts and links as compared to the teacher generated concept map.

Table 3

Scores Based on Combinations of "Size" and "Strength" of Students' Concept Maps

		Strength (Links)		
Size (Concepts)	Strong (100%)	Medium (99%-50%)	Weak (49%-1%)	None (0%)
Complete (100%)	5	4	3	2
Substantial (99%-67%)	4	3	2	1
Partial (66%-33%)	3	2	1	1
Small (32%-1%)	2	1	1	1
None/Irrelevant (0%)	1	1	1	1

Lomask et al. (1992)

The complete rubric created by Lomask et al. (1992) was used to score all of the student generated concept maps. The concept identifying maps were scored by comparing the concepts on the students' maps to the teacher generated map. If students had 100% of the concepts, they were given five points, if they had 99%-67% of the concepts they were given four points, if they had between 66%-33% of the concepts they were given three points, if they had 32%-1% of the concepts they were given two points, and if they had 0% of the concepts they were given one point (Table 4). The proposition identifying maps were scored by comparing the links on the students' maps to the teacher generated map. If students had 100% of the links they were given five points, if they had 99%-50% of the links they were given four points, if they had between 49%-1% of the links they were given three points, and if they had 0% of the links they were given two points (Table 5).

Table 4

Scoring Rubric for Concept Identifying Map

% Concepts in Map	Score
Complete (100%)	5
Substantial (99%-67%)	4
Partial (66%-33%)	3
Small (32%-1%)	2
None/Irrelevant (0%)	1

Modified from Lomask et al. (1992)

Due to the subjectivity involved with the teacher scoring the concept maps, the researcher and another seventh grade science teacher scored the final concept maps produced at the conclusion of the study. The second scorer was one of the same teachers

Table 5

Scoring Rubric for Proposition Identifying Map

% Links in Map	Score
Strong (100%)	5
Medium (99%-50%)	4
Weak (49%-1%)	3
None (0%)	2

Modified from Lomask et al. (1992)

who reviewed the Circulatory System Test and concept maps for content validity. The teacher had three years of experience teaching a seventh grade science class in the same district where the study was performed.

A pilot test was conducted two weeks prior to the start of the study in order to determine inter-rater reliability of scoring the concept maps. During the pilot test, students from a different seventh-grade science class completed concept identifying, proposition identifying, and student generated concept maps. Next, the teacher and the second scorer scored six concept maps together (two of each type), to calibrate the scoring. Subsequently, each scorer individually scored five of the same concept identifying, proposition identifying, and student generated concept maps.

Inter-rater reliability was calculated to be 1.0 for the scoring of the student generated concept maps. Both scorers' assigned identical scores to each of the five student generated concept maps. Inter-rater reliability for the scoring of the concept identifying concept maps was calculated to be 0.80. The two scorers differed in the scoring of one of the concept identifying concept maps. After discussing the differences in the scoring of the concept map, it was evident that the difference was caused by there being more than one acceptable answer for two of the concepts. The two scorers came to an agreement on the final score of the concept map. Lastly, inter-rater reliability for the scoring of the proposition identifying concept maps was calculated to be 0.60. Following analysis of the two proposition identifying concept maps that received different scores, it was evident that the contrasting scores were a result of more than one acceptable linking word(s) that accurately connected the two concepts. The two scorers came to an agreement on the final scores of the proposition identifying concept maps.

The concept identifying, proposition identifying, and student generated concept maps completed during the current study were scored by the researcher as well as the same teacher who assisted in scoring the pilot test concept maps. Inter-rater reliability was calculated to be 0.93 for the scoring of the concept identifying maps. Inter-rater reliability for the scoring of the proposition identifying concept maps was calculated to be 0.90. Lastly, inter-rater reliability for the scoring of the student generated maps was calculated to be 0.91. The increase in inter-rater reliability scores between the concept identifying and proposition identifying concept maps completed during the pilot study and current study was a result of refining the concept map scoring process. After discussing the differences in the scoring of the concept maps, it was apparent that the difference was caused by the use of synonyms for concepts, a variety of linking words utilized, and/or illegible handwriting. The two scorers came to an agreement on the final scores of the concept maps.

Procedures and Treatment

Prior to the study, the students in the seventh-grade science classes were provided with a cover letter, informed consent form, and a parent consent form. During this time the teacher explained the purpose of the study. In addition, the teacher read aloud all of the documents and answered any clarifying questions from the students. The students were asked to return the informed consent forms to the researcher before the study began. Additionally, the students were informed that participation in the study was strictly voluntary and that there would not be any negative consequences of choosing not to participate in the study. Once the informed consent forms and parent consent forms were returned, each student was randomly assigned an identification number from 1-96 to ensure confidentiality. The student work and assessments of the students who did not participate in the entire study were not used in the final data analysis.

The treatment was divided into four phases. In the first phase, the participants were given a circulatory system pretest to measure prior knowledge. Next, all participants were given one week of concept mapping training. The third phase consisted of three weeks of circulatory system instruction and concept mapping. In the fourth and final phase of the study, all participants were given a circulatory system posttest identical to the pretest to measure student achievement. During this phase, the participants in the student generated, concept identifying, and proposition identifying concept mapping groups created or completed their respective circulatory system concept maps. This phase of the study concluded with the participants in the concept identifying and proposition identifying groups also constructing student generated circulatory system concept maps to identify if students in the concept identifying or proposition identifying groups produced more accurate student generated maps.

Pretest Phase

During the pretest phase of the study, the participants were assessed on their prior knowledge of the circulatory system. The 20-item multiple-choice pretest (Appendix F) was given one week before the concept mapping training began. All participants were assessed on the same day during science class. The teacher informed the participants that the material on the pretest may appear difficult but that they should try their best to complete it. The pretest was distributed to the participants and they were given 30 minutes to complete it. Once the students were finished, the pretest was collected by the teacher and locked in a file cabinet for security purposes.

Concept Mapping Training Phase

Two days following the administration of the pretest, the participants received five, 60-minute concept mapping trainings. The structure and function of the deoxyribonucleic acid (DNA) molecule was the instructional content taught during the concept mapping training phase. The training began with a one-day introduction to concept mapping. During the introduction, the researcher showed an example of a concept map and explained the vocabulary associated with the concept maps. For example, the concepts, nodes, and cross-links were identified on the map. In addition, the researcher highlighted the hierarchical structure of the concept map. During the second day, the teacher used a script to introduce each group to their respective concept identifying, proposition identifying, or student generated concept maps (Appendix H). The teacher had created a teacher generated, concept identifying, and proposition identifying concept map of the DNA molecule (Appendix I). On the second day, through guided practice, the students were expected to complete or create a concept map that explained that the DNA molecule has a double helical shape made of two strands that could unwind to create another strand. Day three consisted of more guided practice along with instructor feedback. On day three the students were expected to complete or create a concept map that illustrated that the two strands of the DNA molecule are made of sugar and phosphate molecules. In addition, they were expected to include that the middle rungs of the DNA molecule are made of bases called adenine, thymine, guanine, and cytosine. To conclude the concept mapping training, the students independently practiced their respective concept mapping strategies during the fourth and fifth days. During days four and five of the concept mapping training, students were expected to complete or create a concept map that demonstrated that one side of the DNA molecule can be transcribed or copied to form a ribonucleic acid (RNA) molecule. The students were also expected to include that the RNA molecule is a single strand that substitutes the base uracil for the base thymine. In addition, the students were to include that the RNA molecule goes to the ribosome where the proteins are made. On the final day of the training, students were asked to complete or create an entire concept map on what they had learned about the DNA molecule throughout the week. The teacher provided the participants immediate feedback on their concept maps during the concept mapping training and after analyzing the complete concept maps created on the fifth day.

Circulatory System Instruction Phase

The three-week circulatory system instruction phase began the week following the concept mapping training. The teacher taught the circulatory system curriculum during the entire three weeks. The participants received input on the circulatory system through teacher-directed lessons accompanied by textbook readings (CPO Science, 2007). The justification for using teacher-directed lessons during the circulatory system instruction phase was that the researcher was attempting to replicate the setting of most urban school districts. Teachers in most urban school districts deliver content through teacher-directed lessons due to the lack of resources or teaching experience. A sample lesson plan from the circulatory instruction phase is included in Appendix J. During the first week of the instruction phase the teacher introduced the heart as the main concept. The sub-concepts included the structure and function of the heart. During the second week of the instruction phase the participants received instruction on the blood vessels as the main concept. The structure and function of the arteries, capillaries and veins were the sub-concepts introduced during the second week. Finally, the third week of the instruction phase proceeded with instruction on blood. The sub-concepts introduced in the final week included the composition of blood and the functions of platelets, plasma and cells.

In efforts to ensure fidelity of instruction, the teacher kept a daily journal. In the journal, the teacher recorded any changes that were made to the instruction of the circulatory system. No major changes were documented in the journal during the instruction phase of the study. A sample journal entry is included in Appendix K. Additionally, the assistant principal was provided with lesson plans (sample lesson plan in Appendix J) of the circulatory system instruction phase and made classroom observations every Monday, Tuesday, and Wednesday to ensure that the instruction was being carried out with fidelity. The principal confirmed that the circulatory system instruction phase was carried out with fidelity and according to the lesson plans.

Throughout the instruction phase participants in the three science classes engaged in their respective concept mapping learning strategies. The participants in each concept mapping group completed and turned in one concept map per week. The concept maps were evaluated by the researcher and given back to the participants so that they could use the feedback to clarify their understanding of the topic and to adjust their concept mapping techniques if necessary.

Posttest Phase

In the final posttest phase of the study, the participants were given a 20-item multiple-choice circulatory system posttest identical to the pretest. The posttest was used as a measure of science achievement. The participants completed the posttest two days following the last day of the instruction phase. The posttest was distributed to the participants and they were given 30 minutes to complete it. Once the participants were finished, the posttests were collected by the teacher and secured in a locked file cabinet.

The day following the administration of the circulatory system posttest, the participants in the concept identifying, proposition identifying, and student generated concept mapping groups were given 45 minutes to complete their respective circulatory system concept maps. The concept maps were collected by the teacher and secured in a locked file cabinet. To conclude the posttest phase of the study, the participants in the concept identifying and proposition identifying groups were given 45 minutes to construct student generated concept maps on the circulatory system on the following day. The concept maps were collected by the teacher and locked in a file cabinet.

Data Analysis

Research Question 1

In order to answer the first research question, “What is the effect of three concept mapping strategies (concept identifying, proposition identifying, student generated) on urban middle school students’ science knowledge as measured by their posttest circulatory system test scores?” the data from the circulatory system pretest and posttest were analyzed. Paired sample t-tests were conducted to determine if there was a significant difference between the pretest and posttest for each group. In addition, Cohen’s d was calculated to measure the effect size.

Research Question 2

The second research question, “What is the effect of three concept mapping strategies (concept identifying, proposition identifying, student generated) on urban middle school students’ science knowledge as measured by rubric scores on their respective concept maps?” was answered using the data from the concept maps generated by the students. The accuracy of the three concept maps was evaluated using a scoring rubric created by Lomask et al. (1992) that analyzes the number of concepts and the correct links between the concepts. The students’ posttest mean scores were also correlated with their respective concept identifying, proposition identifying, or student generated concept map scores using the Pearson product-moment correlation.

Research Question 3

To answer the third and final research question, “What are the differences in the rubric scores of student generated maps constructed by students in the concept identifying or proposition identifying groups compared to rubric scores of the student generated concept maps constructed by the student generated group?” the data from the concept identifying, proposition identifying, and student generated concept maps were analyzed. As stated above, the student generated concept maps were scored using the rubric created by Lomask et al. (1992). The normality and homogeneity of variance assumptions were met, thus, an ANOVA was used to analyze the student generated concept map rubric scores.

Summary

This study was designed to explore the effects of three different concept mapping learning strategies on urban middle school students’ science achievement. The independent variable of the study was the concept mapping strategy with three levels: concept identifying, proposition identifying, and student generated. The dependent variables of the study were student achievement on the circulatory system posttest and content accuracy of the concept identifying, proposition identifying, and student generated concept maps. Three intact seventh-grade science classes at a school located in an urban school district were randomly assigned to one of the three concept mapping learning strategies. Prior to treatment, the participants in each group completed a circulatory system pretest to assess students’ prior knowledge. Next, the participants received five days of concept mapping training. Following the concept mapping training, the participants received three weeks of instruction on the circulatory system. During the instructional phase, the participants engaged in their randomly assigned concept mapping strategies. The treatment concluded with all participants completing a circulatory system posttest identical to the pretest. In addition, participants in the concept identifying and proposition identifying groups completed their respective circulatory system concept maps and all participants constructed student generated concept maps on the circulatory system.

CHAPTER IV

RESULTS

The purpose of this study was to measure the effects of three concept mapping learning strategies (concept identifying, proposition identifying, student generated) on urban middle school students' understanding of the circulatory system. This study examined differences in performance on a circulatory system pretest/posttest and concept maps completed among students in three intact seventh-grade science classes at an urban middle school. At the beginning of the study all of the students were given a circulatory system pretest. During the circulatory system instruction phase, the participants engaged in their respective concept mapping strategies by completing concept identifying or proposition identifying concept maps, or creating student generated concept maps. The concept maps were scored and given back to the participants with feedback that could be used to improve their concept mapping skills. At the conclusion of the intervention, all participants were given a posttest identical to the pretest to measure their understanding of the circulatory system. In addition, after the posttest, each participant created a concept map on the circulatory system using their respective concept mapping strategies (i.e. students in the concept identifying group completed a concept identifying concept map). To conclude the study, participants in the concept identifying and proposition identifying groups also created student generated concept maps on the circulatory system.

The concept map scoring instrument that was used to evaluate the concept identifying, proposition identifying, and student generated concept maps was created by Lomask, Baron, Greig, and Harrison (1992). The scoring method designed by Lomask et al. (1992) entails comparing the concepts and links on the student concept maps to a teacher generated concept map. Lomask et al. (1992) generated a rubric that involves determining a score for the concept maps based on the percentage of accurate concepts and links on the student map compared to a teacher generated map. The complete rubric created by Lomask et al. (1992) was used to score all of the student generated concept maps. The concept identifying maps were scored using only the part of the rubric relevant to the concepts on the maps by comparing the concepts on the students' maps to the teacher generated map. The proposition identifying maps were scored using only the part of the rubric relevant to the links on the concept maps by comparing the links on the students' maps to the teacher generated map.

Research Question 1

What is the effect of three concept mapping strategies (concept identifying, proposition identifying, student generated) on urban middle school students' science knowledge as measured by their posttest circulatory system test scores?

The first research question was designed to investigate whether there was an effect of the three concept mapping learning strategies on students' understanding of the circulatory system as measured by their performance on a multiple-choice test. At the beginning of the study all of the students completed a 20-item multiple-choice circulatory system pretest. The pretest covered vocabulary and processes related to the circulatory system that were included in the instruction phase of the study. Specifically, the pretest included items associated with the heart, blood vessels, and blood.

Following three weeks of instruction on the circulatory system, the students completed a posttest that was identical to the 20-item multiple-choice pretest. Overall, the mean and standard deviation of the total pretest scores of all students was 6.85 and 2.43, respectively. It was expected that the students' posttest mean scores would be higher than the pretest mean scores after participating in three weeks of circulatory system instruction and concept mapping. Table 6 illustrates that there was increase from mean pretest scores to mean posttest scores for all three groups. Paired sample t-tests were conducted for each concept mapping group using the pretest and posttest scores. The results showed that there were significant differences between the pretest and posttest scores for the concept identifying group (t (29) = 18.94, p = 0.00, d = -4.71). Similarly, there were significant differences between the pretest and posttest scores for the proposition identifying group (t (31) = 18.53, p = 0.00, d = -3.88) and student generated group (t (26) = 21.08, p = 0.00, d = -3.07).

Table 6

Means, Standard Deviations, Pretest, Posttest

	Concept ID (N = 30) Mean (SD)	Proposition ID (N = 32) Mean (SD)	Student Generated (N = 27) Mean (SD)	All Groups Combined (N= 89) Mean (SD)
Pretest	7.80*	6.09*	6.70*	6.85
	(2.26)	(2.29)	(2.53)	(2.44)
Posttest	16.9*	15.7*	16.5*	16.3
	(1.51)	(2.65)	(1.26)	(2.39)

*Indicates a statistically significant difference (p<.0001) between pretest and posttest scores.

The 20-item circulatory system test included nine items that assessed students' knowledge of vocabulary, seven items that assessed students' knowledge of circulatory system processes, and four identification items that assessed students' ability to identify parts of the circulatory system. A descriptive analysis of student performance on the posttest questions was performed. Table 7 reports the percentage of students who accurately answered each of the three types of items (vocabulary, process, identification) correct.

Table 7

Percentages of Students Who Answered Posttest Items Correctly

Item Type	Concept ID (N = 30)	Proposition ID (N = 32)	Student Generated (N = 27)	All Groups Combined (N=89)
Vocabulary	90%	76%	89%	85%
Process	91%	75%	67%	77%
Identification	91%	79%	94%	88%

The results displayed in Table 7 suggest that students in the concept identifying group outperformed students in the proposition identifying and student generated groups on all types of posttest items except one. A higher percentage of students in the student generated group accurately answered identification type items on the posttest. The students in the proposition identifying group performed the lowest on all of the vocabulary and identification items, except they outperformed the students in the student generated group on the process items. Overall, all three concept mapping groups performed the best on identification items, followed by the vocabulary items, then the process items.

Research Question 2

What is the effect of three concept mapping strategies (concept identifying, proposition identifying, student generated) on urban middle school students' science knowledge as measured by rubric scores on their respective concept maps?

The second research question aimed to investigate whether the concept identifying, proposition identifying, and student generated concept maps impacted students' science knowledge. The concept identifying concept maps were scored by comparing the *concepts* on the students' maps to the *concepts* on the teacher generated map. Following the identification of the correct number of concepts on the maps, the concept portion of the scoring rubric created by Lomask et al. (1992) was used to assign a score that ranged from one to five to each map. There were a total of 42 concepts that were compared between the concept identifying and teacher generated concept maps. The mean number of correct concepts for the concept identifying maps was 38.6 (91%). Based on Lomask et al.'s rubric, the majority of the students (N = 20) in the concept identifying group earned a score of four on their concept maps. These students correctly identified 67%-99% of the concepts that were present on the teacher generated concept map. Additionally, based on Lomask et al.'s (1992) scoring rubric, a score of four means that the size of the students' knowledge of the concepts was "substantial." The mean overall score of the concept identifying maps was 4.23 (SD = .504). Table 8 includes the distribution of scores among students in the concept identifying group. Examples of concept identifying concept maps that had approximately 99% of the concepts correct and concept maps that had approximately 67% of the concepts correct are included in Appendix K.

Table 8

Distribution of Concept Identification Students' Scores

% Concepts in Map	Score	# of Students
Complete (100%)	5	9
Substantial (99%-67%)	4	20
Partial (66%-33%)	3	1
Small (32%-1%)	2	0
None/Irrelevant (0%)	1	0

The proposition identifying concept maps were scored by comparing the *links* on the students' maps to the *links* on the teacher generated map. There were a total of 42 links that were compared between the proposition identifying and teacher generated concept maps. The mean number of correct links for the proposition identifying maps was 32.5 (77%). The scoring rubric created by Lomask et al. (1992) was used to assign a score that ranged from two to five points for each map. The majority of the students (N = 25) earned a score of four on their concept maps. These students correctly identified 50%-99% of the links on their concept maps. Based on Lomask et al.'s (1992) scoring rubric, a score of four means that the strength of the students' knowledge of the relationships between concepts was "medium." Table 9 displays the distribution of the proposition identifying students' scores. The mean overall score of the proposition identifying maps was 4.09 (SD = .466). Examples of proposition identifying concept maps that had approximately 99% of the links correct and concept maps that had approximately 50% of the links correct are included in Appendix L.

Table 9

Distribution of Proposition Identifying Students' Scores

% Links in Map	Score	# of Students
Strong (100%)	5	5
Medium (99%-50%)	4	25
Weak (49%-1%)	3	3
None (0%)	2	0

The student generated concept maps were scored using the complete scoring rubric created by Lomask et al. (1992). The concept maps were compared to the teacher generated concept map and were assessed based on the accuracy of both the concepts and links. Each student generated map was assigned a score that ranged from one to five points. There were a total of 42 concepts and 42 links that were compared between the student generated concept maps and teacher generated concept maps. The mean number of correct concepts for the student generated maps was 32.9 (78%). Thirteen of the students correctly identified 67%-99% of the concepts on their concept maps. Table 10 reports the distribution of the accurate number of concepts identified by students. The mean number of correct links for the student generated maps was 28.5 (67%). Additionally, 14 of the students had 50%-99% of the links correct on their concept maps. The mean overall score of the student generated maps was 3.07 (SD = 1.26). Table 11 displays the distribution of the accurate number of links identified by students. An example of a student generated concept map that had closer to 99% of the concepts and links correct on the concept map and an example of a student generated map that had closer to 67%-50% of the concepts and links correct on the concept maps are included in Appendix M.

Table 10

Distribution of Concepts Identified by Students

% Concepts in Map	Score	# of Students
Complete (100%)	5	8
Substantial (99%-67%)	4	13
Partial (66%-33%)	3	4
Small (32%-1%)	2	2
None/Irrelevant (0%)	1	0

Table 11

Distribution of Propositions Identified by Students

% Links in Map	Score	# of Students
Strong (100%)	5	5
Medium (99%-50%)	4	14
Weak (49%-1%)	3	7
None (0%)	2	1

Table 12 displays the percentage of correct concepts and links along with the means and standard deviations of concept map scores for all three concept mapping groups. The results demonstrate that students in the concept identifying group correctly identified more concepts than the student generated group. Moreover, the students in the proposition identifying group correctly identified more relationships between concepts than the student generated group.

Table 12

Percentages, Means, and Standard Deviations of Concept Map Scores

	Concept ID (N = 30)	Proposition ID (N = 32)	Student Generated (N = 27)	All Groups Combined (N=89)
% of Correct Concepts	91%	N/A	71%	N/A
% of Correct Links	N/A	77%	67%	N/A
Concept Map Score	M = 4.23 SD = .504	M = 4.09 SD = .466	M = 3.07 SD = 1.26	M = 3.83 SD = .944

It was also investigated whether there was a relationship between the students' respective concept mapping strategies and their mean scores on the posttest. It was predicted that the students' performance on the concept maps would indeed be related to students' performance on the circulatory system posttest. As described earlier, the concept identifying, proposition identifying, and student generated concept maps were scored using three different scales; therefore, a comparison of concept maps between the three groups would not be appropriate.

A correlation was performed using the concept identifying groups' posttest scores and concept identifying concept map scores. Based on Pearson's product-moment correlation, there was a moderate significant correlation of $r\ (28) = .52$, $p = .003$ was calculated for the concept identifying group. Next, a correlation was performed using the proposition identifying groups' posttest scores and proposition identifying concept map scores. Similar to the concept identifying group, a moderate significant correlation of $r(30) = .54$, $p = .001$ was calculated for the proposition identifying group. Lastly, a correlation was performed using the student generated groups' posttest scores and student generated map scores. The correlation was calculated to be $r(25) = .60$, $p = .001$, a significant correlation which was higher than both the concept identifying and proposition identifying groups. The significant moderate correlations between the students' respective concept mapping strategies and posttest scores suggest that the students' concept map rubric scores were related to their posttest mean scores. Table 13 reports the correlations of all three of the concept mapping groups.

Table 13

Correlations of Concept Identifying, Proposition Identifying, and Student Generated Groups

Group	r	r^2	F	p
Concept Identifying	.52	.27	10.81	.003
Proposition Identifying	.54	.29	12.61	.001
Student Generated	.60	.36	14.48	.001

Research Question 3

What are the differences in the rubric scores of student generated concept maps constructed by students in the concept identifying or proposition identifying groups compared to rubric scores of the student generated concept maps constructed by the student generated group?

At the beginning of the study, the students in the three groups (concept identifying, proposition identifying, student generated) were given specific training on their respective concept mapping learning strategies. Furthermore, the students only practiced their respective concept mapping strategies throughout the study. Following the posttest and completion of the concept identifying and proposition identifying circulatory system concept maps, the students in the aforementioned concept mapping groups created student generated concept maps of the circulatory system.

The student generated concept maps constructed by the three groups were scored using the complete scoring rubric created by Lomask et al. (1992). The concept maps were compared to the teacher generated concept map and were assessed based on the accuracy of both the concepts and links. Each student generated map was assigned a score that ranged from one to five points. There were a total of 42 concepts and 42 links that were compared between the student generated concept maps and teacher generated concept maps. The mean number of correct concepts for the student generated maps constructed by the concept identifying group was 31.9 (75%), while the mean number of correct links was 27.2 (64%). For the proposition identifying group the mean number of correct concepts was 22.1 (52%), and the mean number of correct links was 19.7 (46%). As stated earlier, the results of the second research question revealed that the mean number of correct concepts for the students in the student generated concept mapping group was 32.9 (71%), and the mean number of correct links was 28.5 (67%).

Table 14 displays the percentage of correct concepts and links along with the means and standard deviations of the student generated concept map scores for all three concept mapping groups. As anticipated, the results illustrate that students in the student generated group constructed the most accurate student generated concept maps with a mean of 3.07 (SD = 1.26), followed by the concept maps produced by the concept identifying group having a mean of 2.83 (SD = 1.36). Lastly, the concept maps constructed by students in the proposition identifying group had a mean of 2.06 (SD = 1.45).

Table 14

Percentages, Means, and Standard Deviations of Student Generated Concept Map Scores

	Concept ID (N = 30)	Proposition ID (N = 32)	Student Generated (N = 27)	All Groups Combined (N = 89)
% of Correct Concepts	75%	52%	71%	66%
% of Correct Links	64%	46%	67%	59%
Student Generated Concept Map Score	M = 2.83 SD = 1.36	M = 2.06 SD = 1.45	M = 3.07 SD = 1.26	M = 2.63 SD = 1.42

An ANOVA was used to compare the rubric scores of the student generated maps produced by the three groups. The results of the ANOVA revealed a statistically significant difference $F(2, 86) = 4.48$, $p = .01$. Since there was a statistically significant difference, it was necessary to determine which concept mapping groups had a statistically significant difference in their mean concept map scores. Accordingly, a Tukey post-hoc was conducted. The Tukey post-hoc demonstrated that there was a statistically significant difference between the student generated concept maps produced by the proposition identifying and student generated concept mapping groups (mean difference = 1.01, p = .02) with the student generated group outperforming the proposition identifying group. Although the mean score of the student generated concept maps created by the students in the concept identifying group was higher than those of students in the proposition identifying group, there was not a statistically significant difference between the means (mean difference = .77, p = .08). Moreover, there was no significant difference between the mean scores of the student generated concept maps produced by the students in the concept identifying and student generated concept mapping groups.

Summary of Results

The purpose of this study was to measure the effects of three concept mapping learning strategies (concept identifying, proposition identifying, student generated) on urban middle school students' understanding of the circulatory system. The first research question aimed to explore whether there was an effect of the three concept mapping learning strategies on students' understanding of the circulatory system as measured by their performance on a multiple-choice posttest. It was determined that there was a significant increase in mean pretest scores to mean posttest scores for all three groups.

The second research question investigated the effects of the three concept mapping strategies on students' knowledge of the circulatory system as measured by rubric scores on their respective concept maps. Students in the concept identifying group performed especially well (91%) suggesting that they learned most of the concepts and students in the proposition identifying group accurately identified an average of 77% of the links. Students in the student generated group performed average on both the identification of the concepts (71%) and the links (67%). Additionally, the students' posttest scores were correlated with their respective concept map scores. The significant moderate correlations between the students' respective concept maps and posttest scores suggest that the concept maps and posttests were related measures of students' science knowledge.

Finally, the third research question examined if there was a difference between the student generated concept maps produced by students in all three groups. The results suggested that the students in the student generated concept mapping group statistically significantly outperformed the students in the proposition identifying concept mapping group on the construction of the student generated concept maps. The concept identification group performed more similarly to the student generated group on the identification of concepts with the concept identifying group correctly identifying 75% of the concepts and the student generated group correctly identifying 71% of the concepts. The concept identification group also correctly identified 64% of the links, while the student generated group correctly identified 67% of the links. The proposition identifying group performed lower on the identification of the concepts (52%) and links (46%). Additionally, the scores of the students in the concept identifying group were higher than those of the students in the proposition identifying group; however, the differences were not statistically significant. These results illustrated that the concept identifying learning strategy helped students identify more concepts and links on student generated maps than the proposition identifying learning strategy.

CHAPTER V

CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

The purpose of the study was to investigate the effects of three concept mapping learning strategies (concept identifying, proposition identifying, student generated) on urban middle school students' understanding of the circulatory system. This section begins with a summary of the study and is followed by a detailed discussion of the results organized by the research questions. Subsequently, conclusions are made and limitations associated with the study are reported. Lastly, research and educational implications are discussed.

Summary of the Study

This study was designed to examine the effects of three different concept mapping strategies on seventh-grade students' science achievement. The independent variable of the study was the concept mapping strategy with three levels, concept identifying, proposition identifying, and student generated. The dependent variables were scores on a circulatory system multiple-choice posttest and rubric scores on concept maps. Ninety-five seventh-grade students enrolled in three intact science classes at an urban middle school were assigned to one of the three concept mapping groups: concept identifying, proposition identifying, and student generated.

The study began with the administration of a circulatory system multiple-choice pretest to assess prior knowledge of students in all three groups. After the pretest, all participants received five days (one-hour each day) of their respective concept identifying, proposition identifying, or student generated concept mapping training by the researcher. Following the concept mapping training, the researcher began the intervention by teaching the same three-week unit on the circulatory system to each class. The circulatory system instruction consisted of a total of 15 days of instruction (one hour each day). During this time, the participants engaged in their respective concept mapping strategies by completing or creating concept identifying, proposition identifying, or student generated concept maps. The students in each concept mapping group completed and turned in one concept map each week. The concept maps were scored and given back to the participants with feedback that could be used to improve their concept mapping skills.

At the conclusion of the circulatory system unit, all participants were given a posttest identical to the pretest to measure their understanding of the circulatory system. Paired sample t-tests were conducted using students' circulatory system pretest and posttest scores for each concept mapping group. The scores demonstrated that there was an increase from mean pretest scores to mean posttest scores for all three groups. Furthermore, after the posttest, each participant created a concept map on the circulatory system using their respective concept mapping strategies (i.e., students in the concept identifying group completed a concept identifying concept map). The concept maps were scored and the means and standard deviations of the concept maps were calculated. According to the rubric created by Lomask, Baron, Greig, and Harrison (1992), the concept maps demonstrated that most of the students in the concept identifying mapping group had a substantial understanding of the concepts and most of the students in the proposition identifying group had a medium understanding of the links between the concepts. The student generated concept maps also demonstrated that most of the students had a substantial understanding of the concepts and a medium understanding of the links. Next, the students' posttest scores were correlated with their concept map scores. The significant moderate correlations between the students' respective concept mapping strategies and posttest scores suggest that the two assessments are related measures of students' science knowledge.

To conclude the study, participants in the concept identifying and proposition identifying groups also created student generated concept maps on the circulatory system. An ANOVA was used to compare the scores of the student generated maps produced by the three groups. The ANOVA revealed statistical significance and a Tukey post-hoc confirmed that there was a statistically significant difference between the student generated concept maps produced by the proposition identifying and student generated concept mapping groups. The student generated group created more accurate maps than the proposition identifying group. Although the mean score of the student generated concept maps created by the concept identifying group was higher than those of the student generated concept maps created by the proposition identifying group, there was not a statistically significant difference between the means.

Discussion of Research Questions

The first research question was aimed to explore the effects of three concept mapping strategies on urban middle school students' science knowledge as measured by circulatory system posttest mean science scores. Addressing this question speaks to two gaps in the current literature related to the use of concept mapping and science learning: (1) the lack of concept mapping studies conducted in urban middle school settings, and

(2) the inconsistent results of the limited number of studies that investigated the effectiveness of the various concept mapping strategies. The majority of the concept mapping studies have been conducted in educational settings other than middle schools. It was important to determine if the results of the concept mapping studies conducted in other educational settings and the results of the few studies that have been conducted in middle school settings may be applied and generalized to students in urban middle school settings.

With regard to the use of concept mapping to improve science learning, studies by Roth and Roychoudhury (1993), Buntting, Coll, and Campbell (2006), Wang and Dwyer (2004, 2006), and Lim, Lee, and Grabowski (2009) suggest that concept mapping is an effective learning strategy that helps raise students' science achievement. However, the aforementioned studies were conducted in undergraduate science courses. Studies conducted by Asan (2007) with fifth-grade students, Guastello, Beasley, and Sinatra (2000) and Snead and Snead (2004) with middle-school students, also found that concept mapping was an effective strategy for raising students' science achievement.

The results of the current study support this previous research and suggest that the three concept mapping strategies (concept identifying, proposition identifying, student generated) can each help raise urban middle school students' science achievement. There was an increase in posttest gain mean scores for students in all three of the concept mapping groups.

The research question was also designed in response to the collection of studies that have explored the relationship between a single type of concept mapping strategy and students' science achievement. Although there are a few studies that have attempted to explore the effectiveness of the different types of concept mapping strategies, there was a need for additional research due to the inconsistent results of the previously conducted studies.

The conflicting results between the two studies conducted by Wang and Dwyer (2004, 2006), and the study conducted by Lim, Lee, and Grabowski (2009) influenced the design of the current study. Wang and Dwyer (2004, 2006) aimed to investigate the effects of three concept mapping learning strategies (concept identifying, proposition identifying, and student generated) on undergraduate students' science achievement. In the studies conducted by Wang and Dwyer (2004, 2006), the researchers established that, overall, the students in the concept identifying concept mapping group performed higher on achievement tests compared to the control group, followed by the students in the student generated concept mapping group. Furthermore, in both studies, the researchers identified that there were not significant differences between achievement of the students in the proposition identifying group and control group on the achievement tests. Lim et al. (2009) designed a study that investigated the effectiveness of the four different concept mapping strategies (concept identifying, proposition identifying, student generated, teacher generated) on undergraduate students' science achievement.

The results of the current study suggest that students in the concept identifying group outperformed students in the proposition identifying and student generated groups on the circulatory system posttest; however, the differences were not statistically significant. The results of the current study are aligned with the results of the Wang and Dwyer (2004, 2006) studies. All three studies suggest that the concept identifying concept mapping strategy is superior in raising students' science achievement in comparison to the proposition identifying and student generated concept mapping strategies. Conversely, the results of this study are inconsistent with the results of the study conducted by Lim, Lee, and Grabowski (2009) that suggest that the student generated concept mapping strategy is the most useful in raising students' science achievement.

The studies conducted by Wang and Dwyer (2004, 2006) also measured students' achievement on three criterion tests (identification, terminology, comprehension). The results of the Wang and Dwyer (2004, 2006) studies revealed that the concept identifying group performed higher on all three of the criterion tests in comparison to the control group, proposition identifying mapping group, and student generated mapping group. Further analysis of student performance on the posttest of the current study involved examining student performance on the three types of test items (vocabulary, process, identification) included on the achievement test. Results of the current study demonstrated that students in the concept identifying mapping group outperformed students in the proposition identifying and student generated groups on the vocabulary and process test items. Students in the student generated group outperformed the students in the concept identifying and proposition identifying groups on the identification items. The proposition identifying group performed the lowest on the vocabulary and identification items; however, they outperformed the student generated group on process items. These results are similar to the results of the studies performed by Wang and Dwyer (2004, 2006) and suggest that the concept identifying mapping strategy may be useful for most types of assessment items. The concept identifying groups may have performed the highest on the vocabulary and process items because the learning strategy encourages students to create their own meanings by using simple linking words. In essence, while using the concept mapping learning strategy the students were provided limited information and challenged to create meaningful statements. On the other hand, the proposition identifying group may have performed the lowest on the vocabulary and identification items because while using their respective concept mapping strategy most of the information (concepts) were already included on the concept maps. The students did not have to create their own concepts, instead they just had to find linking words to create meaningful statements using two concepts.

The second research question aimed to investigate the effects of the three concept mapping strategies on students' science knowledge as measured by rubric scores on their respective concept maps. This question was framed on the basis that there is a limited number of concept mapping studies that actually assessed students' concept maps for accuracy. Most studies merely involve analyzing achievement test scores in order to glean information regarding the effectiveness of the concept mapping learning strategy or strategies.

Of the few studies that involve the analysis of concept maps, Roth and Roychoudhury (1993) analyzed student generated concept maps and discovered that students were demonstrating more meaningful learning with the progressive use of concept maps. The researchers made this conclusion based on the increase of accurate concepts, links, and cross-links present on the latter concept maps produced by the students. A concept mapping study conducted by Asan (2007) involved scoring the student generated concept maps produced by the students by using a scoring rubric created by the researcher. Following the scoring of the concept maps, Asan (2007) identified that the concept maps demonstrated student understanding by the presence of interrelationships between concepts and the hierarchical nature of the concept maps. After evaluating the student generated concept maps produced in their study, Francisco, Nakhleh, Nurrenbern, and Miller (2002) revealed that the concept maps illustrated students' knowledge of the scientific information learned throughout the study. Lastly, in a study conducted by BouJaoude and Attieh (2008), the researchers scored the student generated concept maps produced in the study and correlated the scores with the students' posttest scores. The researchers found that the total scores on the concept map showed a significant correlation with the scores on the application and above level items on the posttest.

In the current study, the final concept maps produced by all three concept mapping groups were scored. Based on the concept map scoring rubric created by Lomask et al. (1992) the results demonstrated that the students in the concept identifying mapping group accurately identified a substantial number of concepts. The students in the proposition identifying groups accurately identified a medium number of links between the concepts. Additionally, the student generated concept mapping group accurately identified a substantial number of concepts and medium number of links on their concept maps. The significant moderate correlation of the students' concept map scores and their respective posttest scores revealed that both are related measures of students' science knowledge. The findings from the current study support findings from previous studies, and suggest that concept maps may be useful artifacts to measure students' knowledge.

The third and final research question was designed to investigate if the student generated maps constructed by all three of the concept mapping groups would vary significantly in accuracy. The research question was developed in response to previous concept mapping studies that investigated the effectiveness of the student generated concept mapping strategy and suggested that it was a helpful strategy to facilitate meaningful learning and increase students' science achievement (Asan, 2007; Buntting, Coll, & Campbell, 2006; Roth & Roychoudhury, 1993). Moreover, as previously stated, the study by Lim, Lee, and Grabowski (2009) demonstrated that students in the student generated concept mapping group outperformed students in the other concept mapping groups. Yet, the studies conducted by Wang and Dwyer (2004, 2006) suggested that the concept identifying mapping learning strategy was the most effective in increasing students' science achievement, followed by the student generated, then proposition identifying mapping groups. This question was structured around the notion that it would be useful to investigate if the student generated concept mapped produced by each group differed significantly and if one of the concept mapping strategies (concept identifying or proposition identifying) would be a useful scaffold in preparing students in the construction of student generated concept maps.

The results of the current study revealed that the students in the student generated group scored the highest on the concept maps. This was expected since the students had received specific student generated concept mapping training and engaged in three weeks of practice in the construction of student generated maps. The students in the concept identifying group scored the second highest, followed by the students in the proposition identifying group. The statistically significant difference between the scores of the student generated maps produced by the proposition identifying and student generated concept mapping groups suggests that the proposition identifying mapping strategy may not be a valuable learning strategy in preparing students for the construction of student generated maps. The results may be a reflection of how students interacted with the proposition identifying concept maps. For example, when completing the proposition identifying concept maps the students did not have to create the concepts in the maps, they were just asked to provide the links that would create an accurate statement between two concepts. Therefore, it is possible that they may have not retained as much information in order to create more accurate student generated concept maps.

Conclusions

One of the significant findings of the study is that the three concept mapping learning strategies (concept identifying, proposition identifying, student generated) may be effective in raising urban middle school students' science achievement. Specifically, the concept identifying concept mapping strategy promotes higher achievement among vocabulary and process items in comparison to the other two concept mapping strategies. Moreover, the student generated concept mapping strategy promotes higher achievement among identification items in comparison to the other two concept mapping strategies. The overarching conclusion is that teaching and encouraging the use of learning strategies such as concept mapping in urban middle school science classes may help increase students' science achievement.

Another key finding of the study is that the concept identifying, proposition identifying, and student generated concept maps are useful measures of students' scientific knowledge. Besides traditional assessment strategies, such as multiple-choice tests, the concept maps may be a unique and/or additional measure of student knowledge. The concept maps can provide teachers with students' understanding and misconceptions of scientific topics. In essence, concept maps completed or created by students should be evaluated in order to understand students' knowledge as well as gaps in knowledge.

Finally, another important conclusion of the study is that the concept identifying learning strategy may be a useful instrument in teaching students how to create student generated concept maps. On the other hand, the proposition identifying concept mapping strategy may not be as conducive in preparing students how to produce student generated concept maps. Overall, although not significantly, the concept identifying concept mapping learning strategy emerged as being superior in helping raise students' science achievement as well as in preparing students to create student generated concept maps.

Limitations

There were a few limitations that were acknowledged before the actual implementation of the study. One of the limitations was that the effects of concept mapping were only assessed in one specific content area, the circulatory system. This limitation renders the results of the study specific to students' science achievement on content related to the circulatory system. The results may not necessarily apply to other science related content. A second limitation was that students only received five hours of concept mapping training. The five hours of concept mapping training may not have been sufficient in order to prepare the students in the completion or construction of the concept maps. A final limitation recognized before the beginning of the study was that the teacher was also the lead researcher of the study. This particular limitation may have interfered in the delivery of instruction and/or subjectivity of scoring of the concept maps.

Following the implementation of the study and analysis of the results, more limitations of the design of the study were found. First, a convenience sample was used for the study. The participants were enrolled in three intact science classes at an urban middle school. Consequently, the results of the study may not be generalizable to a larger population that is not comparable to the population included in the study. Additionally, due to attrition, the pretests, posttests, and concept maps of only 89 students were analyzed.

A second limitation of the study is that the students only received five hours of concept mapping training. Although the five hours of concept mapping training was included as a result of the lack or minimal amount of concept mapping training in previous research, it still may not have been an adequate amount of training. After the concept mapping training it was apparent that some students might have needed additional training. This limitation may have affected the ability of students to demonstrate their scientific knowledge on the concept maps.

A third limitation of the study was related to the design of the circulatory system pretest/posttest. The circulatory system concept maps did not include relevant information to answer five of the items included on the test. The students performed the lowest on two of these items that could not have been answered by the completion or construction of the concept maps. The accuracy of student responses to these five items does not demonstrate the effects of the concept mapping learning strategy on students' science achievement. During the circulatory system test construction, the researcher was focused on including items that were related to the content covered during the instruction phase but did not necessarily confirm whether the information necessary to answer all of the items was included on the concept maps.

Lastly, a fourth limitation is that the three different types of concept maps (concept identifying, proposition identifying, student generated) were scored using different scoring rubrics. Only the student generated concept maps produced by all three concept mapping groups were scored using the same scoring rubric. It would have been useful to find or develop a concept mapping scoring rubric that could have been used to score all three types of concept maps so that the rubric scores could have been compared.

Implications

Based on the design and results of the study, there are several implications for future research and educational practice. First, the research implications are discussed, including modifications that would have been made to the current study, as well as recommendations for future research. Second, the educational implications are presented, including recommendations for classroom teachers.

Research Implications

One of the limitations identified with the current study was related to the amount of concept mapping training the students received. Although the students received five days of concept mapping training in contrast to limited training in previously conducted concept mapping studies, the training provided in future research studies should be strengthened. For instance, not only should sufficient training be provided but the students' concept mapping abilities should be assessed before the instruction phase of the study begins. This would ensure that the concept maps are accurate depictions of students' knowledge and that the possibility of inexperience with the concept mapping strategy does not prevent students from demonstrating their knowledge on concept maps. If students are properly trained on the use of learning strategies, such as concept mapping, they may be more inclined to use the strategies while learning new information. When students implement learning strategies that encourage meaningful learning, they may increase their science achievement and feel more empowered to pursue science related careers. In turn, this may potentially reduce the need for outsourcing science expertise to other countries, fueling the United States economy.

Similar to the recommendations for future research by Guastello, Beasley, and Sinatra (2000), there is a need for additional research that investigates the effectiveness of the three variations of the concept mapping strategy. Since the results of the current study are not completely consistent with other studies that have investigated the effectiveness of the three different concept mapping strategies, more research is required in order for more concrete conclusions regarding the most effective strategy to be made. With continued concept mapping research, researchers and teachers may become more informed on which concept mapping strategies are the most conducive in helping students raise their science achievement. This may also help teachers understand when and how to implement concept mapping learning strategies.

Additionally, future concept mapping studies that are conducted should assess the concept maps produced by students. The majority of the previous researchers have relied on determining the effectiveness of concept mapping by simply measuring gain scores from pretest and posttest assessments. The significant moderate correlations between the concept maps and posttest scores demonstrate that the concept maps are valuable indicators of students' science knowledge. Analyzing concept maps for accuracy can provide researchers with more complete information regarding students' knowledge. When teachers are more aware of students' understanding and needs, they can better tailor future lessons to accommodate students.

Educational Implications

The increase in mean scores between students' circulatory system pretest and posttest suggest that concept mapping is an effective learning strategy in raising urban middle school students' science achievement. On the other hand, the results of the study also demonstrate that the three concept mapping learning strategies may not be equally effective. Based on the results of the posttest scores, students in the proposition identifying group performed the lowest on two of the three types of items (vocabulary and identification) included on the circulatory system test. The concept identification concept mapping group performed the highest on the vocabulary and process items while the student generated group performed the highest on the identification items. Therefore, an implication for educational practice is that the proposition identifying concept maps may not be a beneficial learning strategy for learning vocabulary and identification terms. Moreover, when the objective is for students to understand science-related vocabulary and processes, it may be useful for teachers to encourage the use of concept identifying concept maps. Likewise, when the identification of science-related topics is the focus, teachers should promote the use of the student generated learning strategy.

An additional implication for educational practice is the use of concept mapping as a means of assessing students' scientific knowledge. The assessment of the concept maps completed in the study revealed that the concept identification concept mapping groups had the highest mean score on the circulatory system posttest, followed by the proposition identifying group, then the student generated group. These results suggest that the concept identifying concept maps may be a more useful learning strategy to increase students' science achievement. Nonetheless, most students in each of the three concept mapping groups accurately identified 67% or more of the concepts and 50% or more of the links on their respective concept maps.

Furthermore, since some research studies have identified that the use of the student generated concept mapping learning strategy fosters meaningful learning, the student generated concept mapping strategy should be taught by using the concept identifying mapping strategy as a scaffold. Although not a significant difference, given that the students in the concept identifying group outperformed the students in the proposition identifying group on the construction of student generated maps, the proposition identifying concept maps may not be a useful scaffold in preparing students for the construction of student generated concept maps.

Summary

The purpose of this quasi-experimental study was to measure the effects of three concept mapping learning strategies (concept identifying, proposition identifying, student generated) on urban middle school students' understanding of the circulatory system. The independent variable of the study was the concept mapping learning strategy with three levels (concept identifying, proposition identifying, student generated) and the dependent variables were scores on a circulatory system multiple-choice posttest and rubric scores of concept maps.

The results of the current study demonstrated that all three of the concept mapping learning strategies were effective in raising students' science achievement. The students in the concept identifying mapping group outperformed students in the proposition identifying and student generated concept mapping groups on vocabulary and process test items included on the posttest. The students in the proposition identifying mapping group performed the lowest on all of the test items except they performed higher on the process items compared to the student generated mapping group. Additionally, the moderate significant correlations between the posttest and concept map scores of the current study established that concept maps are a dependable measure of student knowledge. The results of the current study also suggest that the concept identifying mapping strategy may be a useful scaffold in instructing students how to develop student generated concept maps.

There are research and educational implications that can be recommended based on the results of the current study. One of the research implications is the need for more rigorous concept mapping training that involves the assessment of concept maps to determine student performance of the concept mapping process. In addition, continued research that investigates the effectiveness of the three concept mapping learning strategies is necessary due to the inconsistency of results. The concept maps produced in future research studies should also be assessed for accuracy and used as a measure of student knowledge.

In regard to educational implications, the most significant implication is that the concept mapping learning strategies are valuable in raising urban middle school students' science achievement. Furthermore, the concept identifying learning strategy should also be used as a scaffold while teaching students how to create student generated concept maps. Lastly, concept maps should be assessed and used as an illustration of students' science knowledge in the educational context.

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Appendix A

Institutional Review Board Approval Letter

December 6, 2010

Dear Ms. Dosanjh:

The Institutional Review Board for the Protection of Human Subjects (IRBPHS) at the University of San Francisco (USF) has reviewed your request for human subjects approval regarding your study.

Your application has been approved by the committee (IRBPHS #10-117). Please note the following:

1. Approval expires twelve (12) months from the dated noted above. At that time, if you are still in collecting data from human subjects, you must file a renewal application.

2. Any modifications to the research protocol or changes in instrumentation (including wording of items) must be communicated to the IRBPHS. Re-submission of an application may be required at that time.

3. Any adverse reactions or complications on the part of participants must be reported (in writing) to the IRBPHS within ten (10) working days.

If you have any questions, please contact the IRBPHS at (###) ###-####.

On behalf of the IRBPHS committee, I wish you much success in your research.

Sincerely,

Chair, Institutional Review Board for the Protection of Human Subjects
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IRBPHS – University of San Francisco
Counseling Psychology Department
Education Building – Room ###

Appendix B

School District Approval Letter

Research, Assessment & Data

Statement of Research Approval

Title of Research Project: The effects of three concept-mapping strategies on seventh grade students' science achievement at an urban middle school

Researcher: Navdeep Dosanjih
Institution/Organization: University of San Francisco

Date: 12/6/10

To Principals,

The proposed research to be conducted at your school has been approved by the Research Review Committee. The proposed research has been determined to be in compliance with existing legal and ethical research guidelines. The researcher has agreed that the study will not differ significantly from the activities described within the proposal that was submitted to the Research Review Committee. The researcher has stipulated that all participation will be voluntary, and it is understood that approval of the proposal will not obligate any person, school, or department to participate. The researcher ensures that all student or staff data provided by the district will not be shared with other researchers or organizations. The researcher is obligated to submit any amendments to the original proposal to the Research Review Committee for approval before further research is permitted. The researcher agreed to provide the Office of Research & Assessment and each participating school with a copy of the research findings.

Next Steps:

1. You may receive a phone call from the researcher in the next few days.
2. The researcher or his/her assistant will schedule an appointment with you to discuss the proposed study in more detail.
3. You will be asked to approve the proposed study at your school.
4. Although the proposal has been approved by the Research Review Committee, you have the final authority to approve the implementation of the proposed research at your school.
5. If the research includes interactions with children, please request proof of tuberculosis (TB) testing and fingerprinting before the work can proceed.
6. I, the Senior Researcher, will follow up with the researcher to acquire the report after the study has been completed.

I am available to assist you with any questions regarding the research after you have discussed it with the researcher. Please call me if you have any questions about the research before or after it has been conducted.

Sincerely,

External Research Review Committee Representative

APPENDIX C

Permission Letter

November 19, 2010
Institutional Review Board for the Protection of Human Subjects
University of San Francisco
2130 Fulton Street
San Francisco, CA 94117

Dear Members of the Committee:

On behalf of (school name), I am writing to formally indicate our awareness of the research proposed by Ms. Navdeep Dosanjh, a student at USF. We are aware that Ms. Dosanjh intends to conduct her research by administering three to four total assessments of our students. The assessments will be administered to a group of 95 seventh-grade students.

I am responsible for all students at (school name) and am the Principal of the institution. I give Ms. Dosanjh permission to conduct her research at our academic institution.

If you have any questions or concerns, please feel free to contact my office at (###) ###-####.

Sincerely,

Principal Name

Appendix D

Informed Consent

INFORMED CONSENT FORM

UNIVERSITY OF SAN FRANCISCO
CONSENT TO BE A RESEARCH SUBJECT

Purpose and Background

Navdeep Dosanjh, a doctoral student, in the School of Education at the University of San Francisco is doing a study on concept mapping in middle school life science. The science education literature indicates that students' science achievement is decreasing and learning strategies such as concept mapping may help increase science achievement.

Procedures

If I agree to be a participant in this study, the following will happen:

1. I will complete a 20-question multiple-choice pretest

2. I will participate in one week of concept mapping training

3. I will participate in a three-week instruction phase on the circulatory system

4. I will complete a 20-question multiple choice posttest

5. I will complete one concept map

Risks and/or Discomforts

1. It is possible that some of the questions on the pretest and posttest will appear beyond my abilities in the subject of science and could impact my perceived sense of confidence and self-worth in the class. I am free to decline to answer any questions I do not wish to answer or to stop participation at any time.

2. Participation in research may mean a loss of confidentiality. Student records will be kept confidential. No individual identities will be used in any reports or publications resulting from the study. Study information will be coded and kept in locked files at all times. Only study personnel will have access to the files.

Benefits

The anticipated benefit of this study is that the students will learn a new strategy that may help them learn science.

Costs/Financial Considerations

There will be no financial costs to me as a result of taking part in this study.

Questions

I have talked to Ms. Dosanjh about this study and have had my questions answered. If I have further questions about the study, I may call her at (###) ###-####. If I have any more questions or comments about participation in this study, I should first talk with the researcher, Ms. Dosanjh. If for some reason I do not wish to do this, I may contact the IRBPHS, which is concerned with protection of volunteers in research projects. I may reach the IRBPHS office by calling (415) 422-6091 and leaving a voicemail message, by e-mailing IRBPHS@usfca.edu, or by writing to the IRBPHS, Department of Psychology, University of San Francisco, 2130 Fulton Street, San Francisco, CA 94117-1081.

Consent

I have been given a copy of the "Research Subject's Bill of Rights" and I have been given a copy of this consent form to keep. PARTICIPATION IN RESEARCH IS VOLUNTARY. I am free to decline to be in this study, or to withdraw from it at any point. My decision as to whether or not to participate in this study will have no influence on my present or future status as a student at (school name).

My signature below indicates that I agree to participate in this study.

Subject's Signature Date of Signature

Signature of Person Obtaining Consent Date of Signature

PARENTAL CONSENT FOR RESEARCH PARTICIPATION

Purpose and Background

Navdeep Dosanjh, a doctoral student, in the School of Education at the University of San Francisco is doing a study on concept mapping in middle school life science. The science education literature indicates that students' science achievement is decreasing and learning strategies such as concept mapping may help increase science achievement. My child is being asked to participate because he/she is a seventh-grade student in Ms. Dosanjh's class.

Procedures

If my child agrees to be a participant in this study, the following will happen:

1. My child will complete a 20-question multiple-choice pretest

2. My child will participate in one week of concept mapping training

3. My child will participate in a three-week instruction phase on the circulatory system

4. My child will complete a 20-question multiple choice posttest

5. My child will complete one concept map

Risks and/or Discomforts

1. It is possible that some of the questions on the pretest and posttest will appear beyond my child's abilities in the subject of science and could impact my child's perceived sense of confidence and self-worth in the class. My child is free to decline to answer any questions he/she does not wish to answer or to stop participation at any time.

2. Participation in research may mean a loss of confidentiality. Student records will be kept confidential. No individual identities will be used in any reports or publications resulting from the study. Study information will be coded and kept in locked files at all times. Only study personnel will have access to the files.

Benefits

My child will benefit from the study by learning a new strategy that may help him or her learn science.

Costs/Financial Considerations

There will be no financial costs to my child as a result of taking part in this study.

Questions

If I have further questions about the study, I may call her at (###) ###-####. If I have any more questions or comments about participation in this study, I should first talk with the researcher, Ms. Dosanjh. If for some reason I do not wish to do this, I may contact the

IRBPHS, which is concerned with protection of volunteers in research projects. I may reach the IRBPHS office by calling (415) 422-6091 and leaving a voicemail message, by e-mailing IRBPHS@usfca.edu, or by writing to the IRBPHS, Department of Psychology, University of San Francisco, 2130 Fulton Street, San Francisco, CA 94117-1081.

Consent

My child has been given a copy of the "Research Subject's Bill of Rights" and has also been given a copy of this consent form to keep. PARTICIPATION IN RESEARCH IS VOLUNTARY. My child is free to decline to be in this study, or to withdraw from it at any point. My child's decision as to whether or not to participate in this study will have no influence on his/her present or future status as a student at (school name).

My signature below indicates that I agree to allow my child to participate in this study.

Parent/Guardian's Signature　　　　　　　　　　Date of Signature

Signature of Person Obtaining Consent　　　　　　　　　　Date of Signature

Appendix E

Cover Letter

Dear Seventh-Grade Student:

In addition to being your science teacher, I am also a doctoral student in the School of Education at the University of San Francisco. I am doing a study on concept mapping in seventh-grade science. I am interested in learning the effects of three concept mapping learning strategies on students' science achievement. The principal of (school name) has given me permission to conduct this study.

You are being asked to participate in this research study because your presence in the seventh-grade science class. If you agree to participate in this study, you will complete a 20 question pretest. You will then receive one week of concept mapping training. Next, you will receive three weeks of instruction on the circulatory system. After the instruction, you will complete a 20 question posttest. In addition, you will complete one concept map.

It is possible that some of the questions on the pretest or posttest will appear beyond your abilities in the subject of science and could impact your perceived sense of confidence and self-worth in the class. You are free to decline to answer any questions you do not wish to answer or to stop participation at any time. Participation in research may mean a loss of confidentiality. Student records will be kept as confidential as possible. No individual identities will be used in any reports or publications resulting from the study. Study information will be coded and kept in locked files at all times. Only the lead researcher (myself) will have access to the files. Individual results will not be shared with any other students, faculty or staff at (school name).

While there are no direct benefits to you participating in this study, the anticipated benefit of this study is that you will gain a better understanding of how the concept mapping learning strategy may improve your science education. There will be no costs to you as a result of taking part in this study.

If you have questions about the research, you may contact me at (###) ###-####. If you have further questions about the study, you may contact the IRBPHS at the University of San Francisco, which is concerned with protection of volunteers in research projects. You may reach the IRBPHS office by calling (415) 422-6091 and leaving a voicemail message, by e-mailing IRBPHS@usfca.edu, or by writing to the IRBPHS, Department of Psychology, University of San Francisco, 2130 Fulton Street, San Francisco, CA 94117-1080.

PARTICIPATION IN RESEARCH IS VOLUNTARY. You are free to decline to be in this study, or to withdraw from it at any point. (School Name) is aware of this study but does not require that you participate in this research and your decision as to whether or not to participate will have no influence on your present or future status as a student at (school name).

Thank you for your attention. If you agree to participate, please complete the attached consent form, ask a parent or guardian to complete the attached consent form, and return the form to me in the envelope provided.

Sincerely,

Navdeep Dosanjh

Learning and Instruction Doctoral Student

University of San Francisco

Appendix F

Circulatory System Pre/Post Test

Circulatory System Test

ID #: _____

Directions: Identify the choice that best completes the statement or answers the question.

_____ 1. Your body's transport system is the:
- a. respiratory system
- b. circulatory system
- c. endocrine system
- d. male reproductive system

_____ 2. Vessels that carry blood away from the heart are:
- a. arteries
- b. capillaries
- c. veins
- d. valves

_____ 3. Blood is:
- a. used to carry carbon dioxide to each body cell.
- b. made up of arteries and veins
- c. made of only red blood cells and white blood cells
- d. circulating connective tissue

_____ 4. The fluid part of the blood that contains water, dissolved nutrients, sugars, and protein is:
- a. the platelets
- b. the plasma
- c. floating red blood cells
- d. floating white blood cells

_____ 5. Red blood cells:
- a. fight infections
- b. transport hormones
- c. transport oxygen to the cells
- d. produce antibodies to destroy invaders

_____ 6. In the first stage of the heart contracting:
- a. the ventricles contract together
- b. the atria contract together
- c. the hemoglobin grabs onto oxygen molecules
- d. the white blood cells produce antibodies

_____ 7. The middle layer of a vein is made up of:
- a. epithelial tissue
- b. connective tissue
- c. muscle tissue
- d. dermal tissue

_____ 8. In the second stage of the heart contracting:
   a. the white blood cells produce antibodies
   b. the atria contract together
   c. the ventricles contract together
   d. the hemoglobin grabs onto oxygen molecules

_____ 9. Collecting oxygen-poor blood from the body and pumping it to the lungs is a function of the:
   a. atria
   b. left side of the heart
   c. valves
   d. right side of the heart

_____ 10. Valves found in the heart do the following **except**:
   a. keep blood away from flowing to the heart
   b. help fight the force of gravity
   c. keep blood flowing toward the heart
   d. open and close to allow blood to flow in one direction

_____ 11. Without hemoglobin, your cells cannot:
   a. fight infections
   b. "grab" oxygen
   c. remove waste from cells
   d. prevent blood loss

_____ 12. White blood cells:
   a. are the fluid part of the of blood
   b. transport hormones
   c. carry oxygen to the cells
   d. produce antibodies to destroy invaders

_____ 13. Blood is made up of all of the following **except**:
   a. arteries
   b. cells
   c. plasma
   d. platelets

_____ 14. Which of the following is true?
   a. Blood moves most quickly in the capillaries.
   b. Heart valves force blood through the heart.
   c. More than half of your blood is made of red blood cells.
   d. Large veins have one-way valves to channel blood back towards the heart.

______ 15. In which vessels do the exchange of oxygen and carbon dioxide occur?
a. valves
b. arteries
c. veins
d. capillaries

______ 16. Which of the following is **not** a blood vessel?
a. arteries
b. capillaries
c. plasma
d. veins

______ 17. The outer layer of an artery is made up of:
a. muscle tissue
b. epithelial tissue
c. skeletal tissue
d. connective tissue

______ 18. Vessels that carry blood to the heart are:
a. arteries
b. capillaries
c. veins
d. valves

______ 19. The function of platelets is to:
a. prevent blood loss
b. grab onto oxygen molecules
c. fight infections
d. transport oxygen to cells

______ 20. The flap of tissue that prevents the backflow of blood is called the:
a. artery
b. vein
c. capillary
d. valve

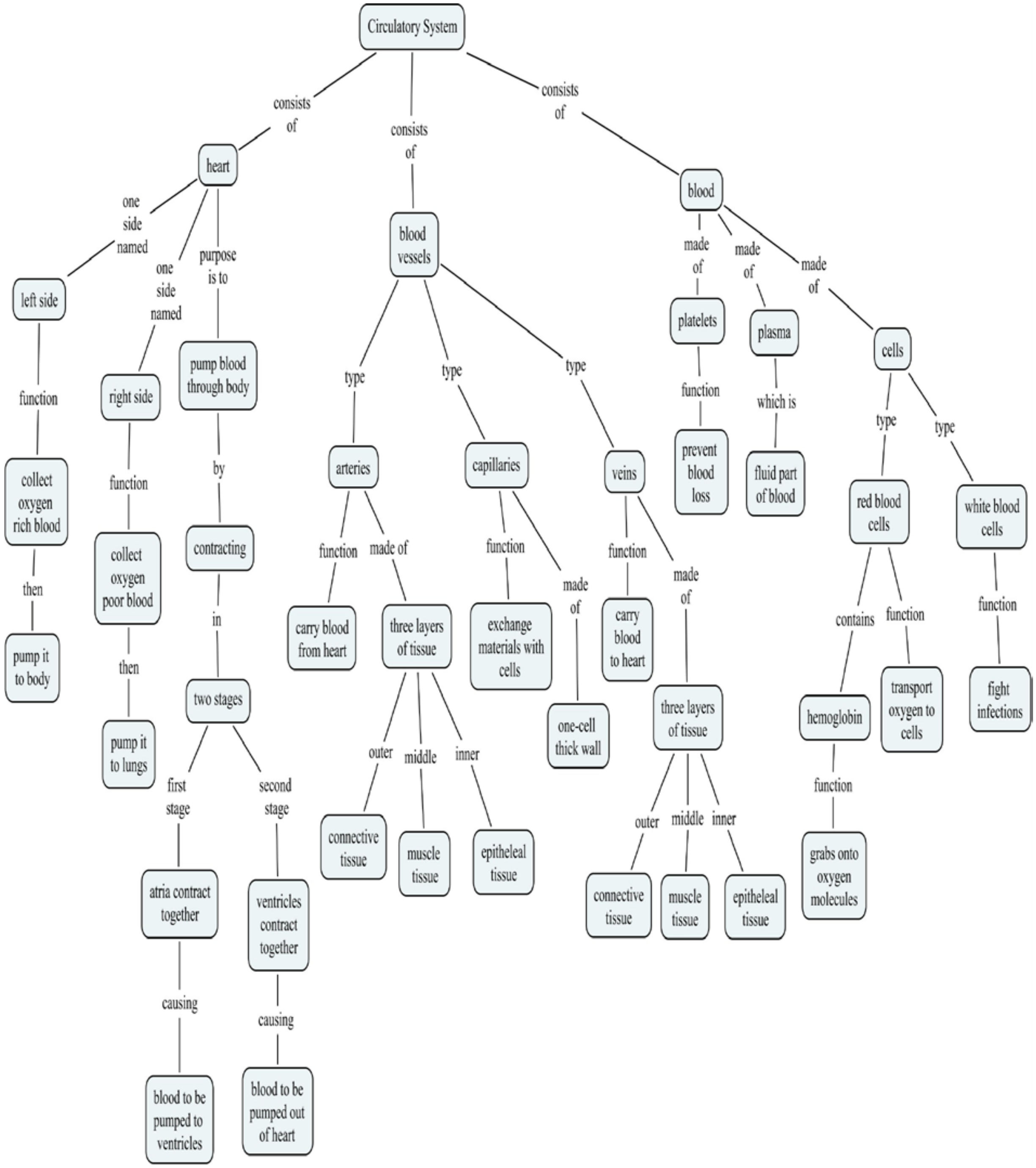
Answer Key

1. B
2. A
3. D
4. B
5. C
6. B
7. C
8. C
9. D
10. A
11. B
12. D
13. A
14. D
15. D
16. C
17. D
18. C
19. A
20. D

Appendix G

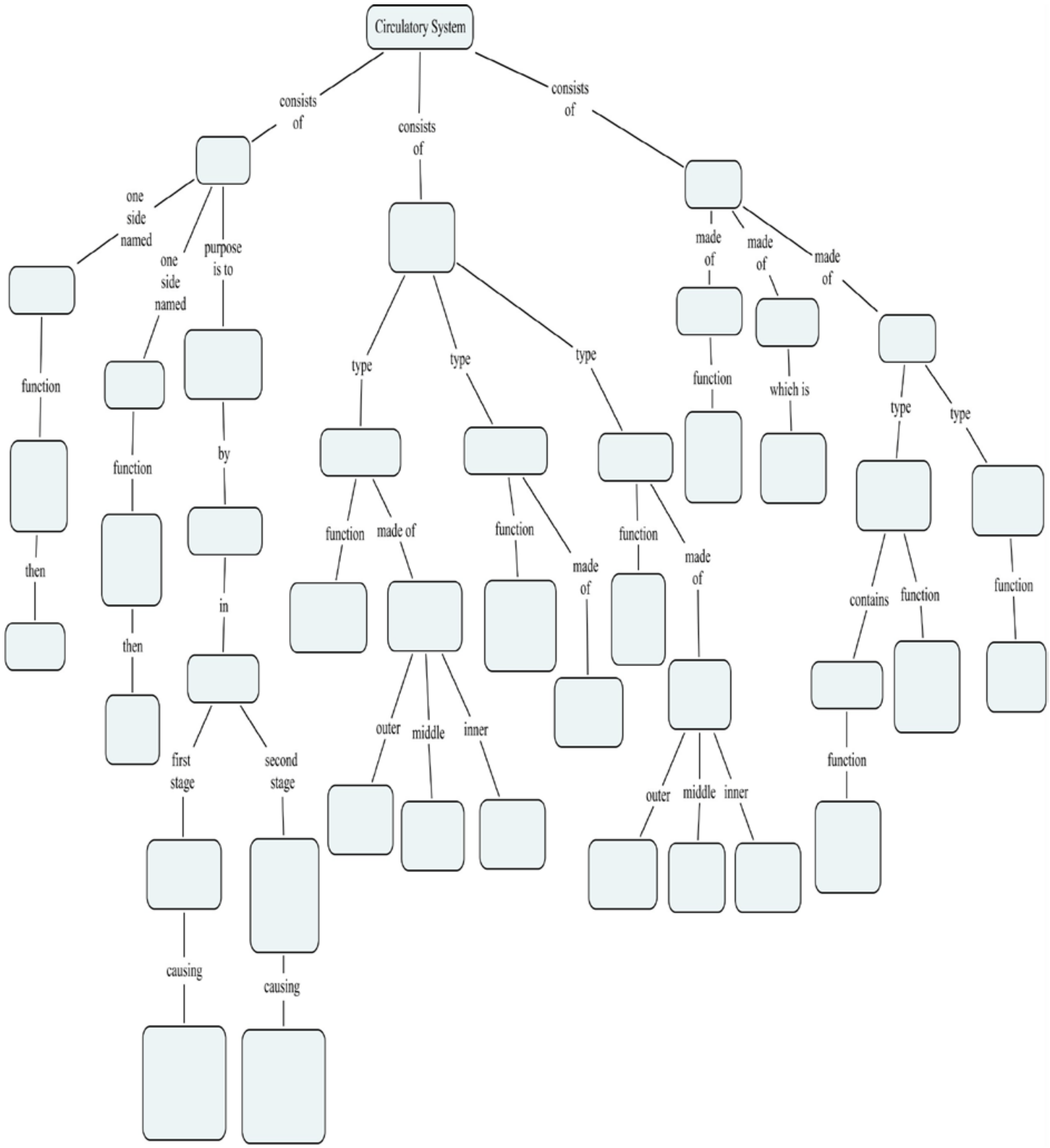
Concept Maps

Teacher Created Concept Map



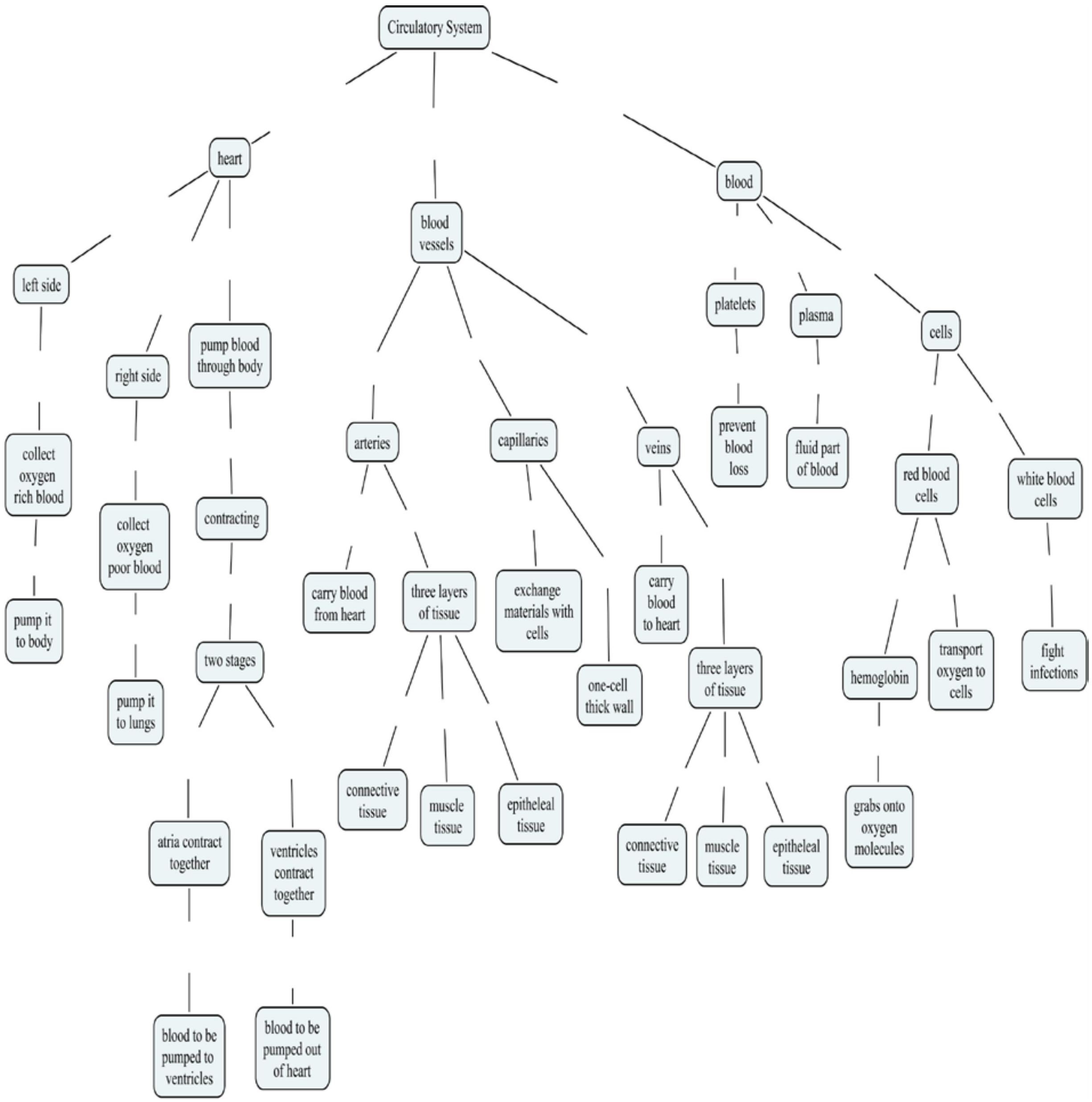
Concept Identifying Concept Map ID #: _____

Directions: Fill in the concepts to complete the circulatory system concept map.



Proposition Identifying Concept Map ID #: _____

Directions: Fill in the linking words or phrases between the concepts to complete the circulatory system concept map.



Student Generated Concept Map ID #: _____

Directions: Create a concept map of the circulatory system.

Circulatory System

Appendix H

Concept Mapping Training Scripts

Student Generated Concept Mapping Group

1. The objective of creating a student generated concept map is to demonstrate your understanding of a particular theme by including general and specific concepts that are joined together by linking word(s). The first step is to make a list of the concepts covered in the particular unit. Start by asking yourself: “What was the lecture/reading about?” Your answer will provide the starting, most general concepts. As you think about these further, your list of concepts should grow.

2. Rank the concepts in your list from most general to most specific, being aware that several concepts may have the same generality. If you get stuck trying to determine the relative ranks of two related concepts, try asking yourself: “Which one could be understand without reference to the other?” The answer is probably the more general concept.

3. Place the most general concept at the top of the page in the center and draw a circle around it.

4. Below the most general concept, arrange the next most general rank of concepts in a way that will leave enough space below them to add the next rank. Circle these concepts and add lines, linking them to the most general concept.

5. Label the linkages with short phrases, or even single words that properly relate the linked concepts. When you place Concept 1, a linkage phrase and Concept 2 in sequence, a sensible phrase should result.

6. Work down the page, adding ranks of even more specific concepts. The most specific concepts should end up at the bottom of your map. When linkage lines must cross each other, use a bridge symbol.

7. Search for crosslinks between concepts throughout the map. Use dashed lines with arrowheads to indicate the crosslinks.

Concept Identifying Concept Mapping Group

1. The objective of completing the concept identifying concept map is to identify concepts that are related in some way. The first step is to start with the general concepts at the top of the concept map.

2. The linking words are included in the concept map so the task is to identify which two concepts can be included that make sense with the linking words. In essence, you are trying to create a statement among two concepts and the linking word(s).

3. Once you identify two concepts that may show a relationship, try to read the general concept, linking word(s), and more specific concept to see if you can develop a sentence.

4. Next, move down the concept map and continue identifying concepts that can produce statements using the linking words.

Proposition Identifying Concept Mapping Group

1. The objective of completing the proposition identifying concept map is to identify linking word(s) that demonstrate a relationships between two concepts. The first step is to start with the missing linking word(s) at the top of the concept map.

2. The concepts are included in the concept map so the task is to identify which linking word(s) can be included to explain a relationship between two concepts. In essence, you are trying to create a statement among two concepts and the linking word(s).

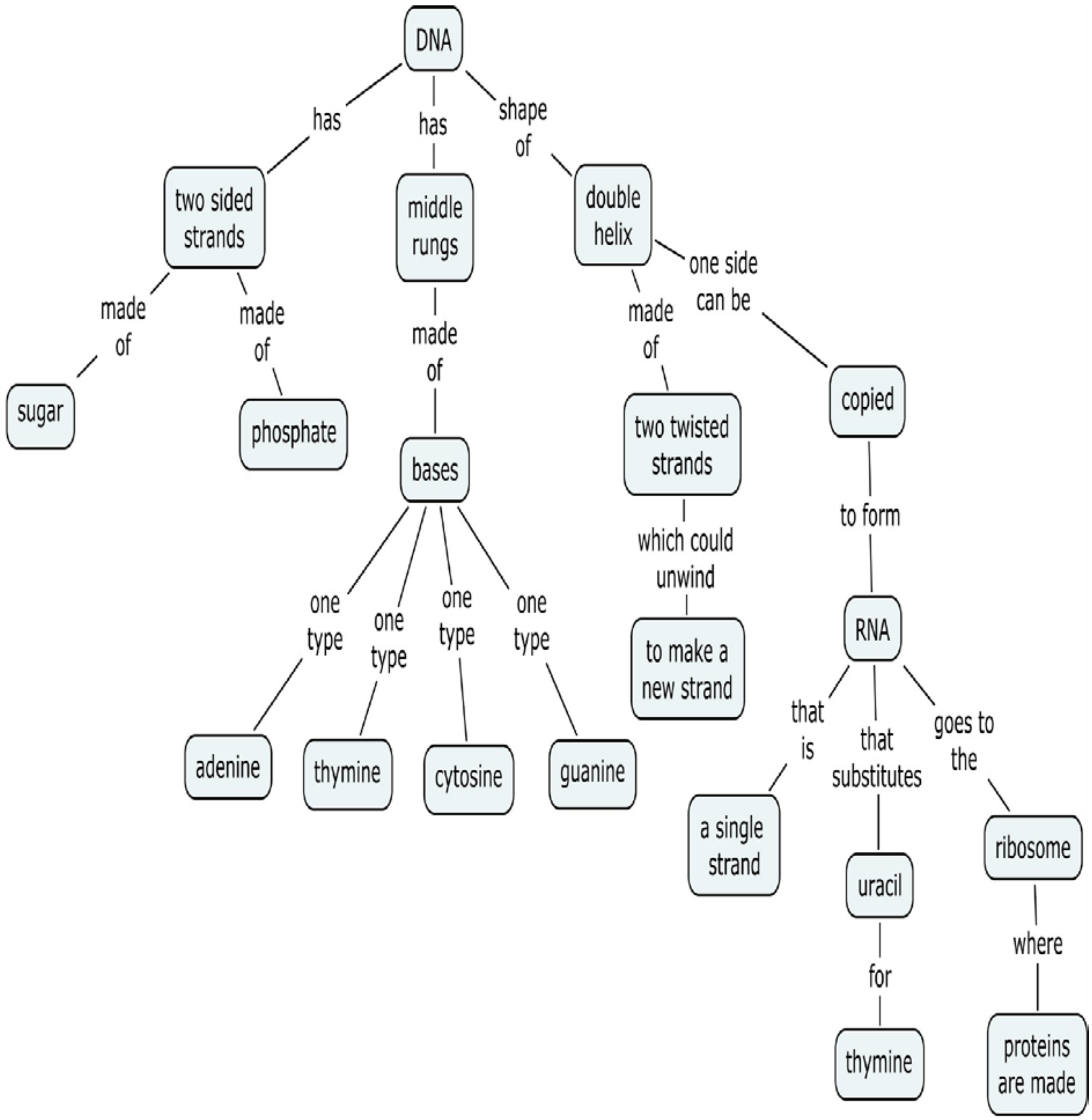
3. Once you identify linking word(s) that may show a relationship between two concepts, try to read the general concept, linking word(s), and more specific concept to see if you can develop a sentence.

4. Next, move down the concept map and continue identifying linking word(s) that can produce statements using the concepts and linking word(s).

Appendix I

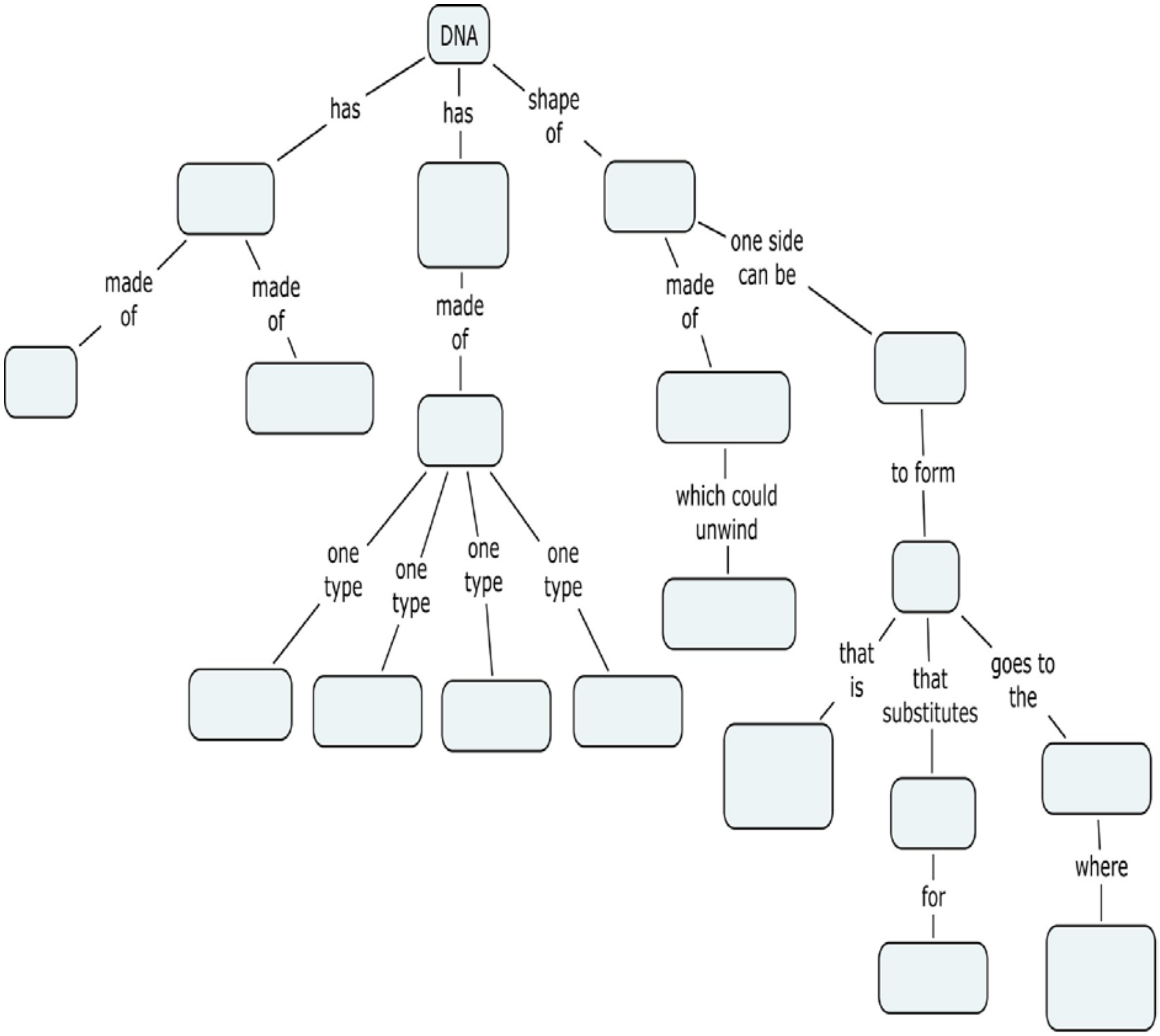
Training Concept Maps

Teacher Generated DNA Concept Map



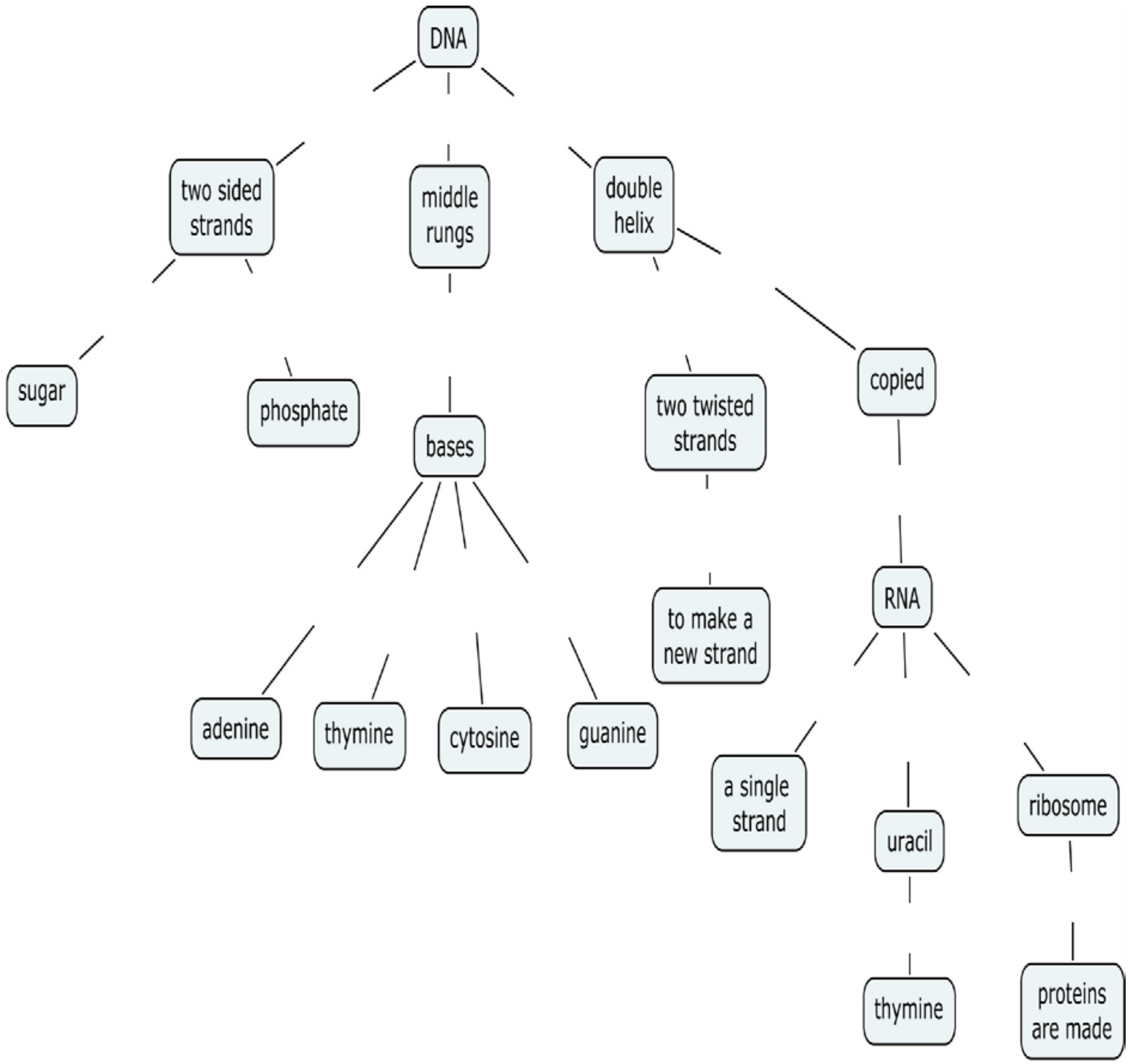
Concept Identifying Concept Map ID #: _____

Directions: Fill in the concepts to complete the DNA concept map.



Proposition Identifying Concept Map ID #: _____

Directions: Fill in the linking words or phrases between the concepts to complete the DNA concept map.



Student Generated Concept Map ID #: _____

Directions: Create a concept map of DNA.

Appendix J

Sample Lesson Plan

February 15th, 2011 Lesson Plan

PRE-PLANNING: KNOW, SO, SHOW	OBJECTIVE.	
	Students will be able to explain the function of arteries and name the three layers of arteries.	
	KEY POINTS.	
	1. Arteries are a type of blood vessel 2. Arteries carry blood from the heart 3. The outer layer is called connective tissue 4. The middle layer is called muscle tissue 5. The inner layer is called epitheleal tissue	
LESSON CYLCE: GO	OPENING.	MATERIALS.
	-The lesson will start with an overview of the functions of the left and right side of the heart. -The function and importance of blood vessels will be discussed	-STUDENT NOTES
	INTRODUCTION TO NEW MATERIAL.	
	-Students will read the blood vessels section of the textbook that discusses the arteries -They will take notes on the function and composition of arteries	-CPO LIFE SCIENCE TEXTBOOK
	GUIDED PRACTICE.	
	-The students will be asked to read aloud the blood vessels section related to arteries -The teacher will help students summarize what they read and take notes -The notes will include the function of arteries -The layers of the arteries (inner, middle, and outer) will be drawn in the notes	-CPO LIFE SCIENCE TEXTBOOK
	INDEPENDENT PRACTICE.	
	-The students will review their notes from the lesson and will complete or create their respective concept maps on arteries. -They will include the function of arteries and also the names of the inner, outer, and middle layers that the arteries are made of. -The teacher will be circulating the room assisting students who need help.	-CONCEPT IDENTIFYING CONCEPT MAPS -PROPOSITION IDENTIFYING CONCEPT MAPS -STUDENT GENERATED CONCEPT MAPS
	CLOSING.	
	-The students will be asked to share their concept maps with their partners. -The teacher will cold-call on students to identify the function and layers of arteries. -The teacher will preview the next lesson on capillaries.	

APPENDIX K

Sample Journal Entry

Concept Mapping - Study
February 14th - February 18th

2/14 - Introduction to blood vessels
Vocabulary - arteries
capillaries
veins

2/15 - Arteries - function + layers
inner, outer, middle

2/16 - Capillaries - function + layer
one cell thick

2/17 - Veins - function + layers
inner, outer, middle

Guided + independent practice w/ feedback

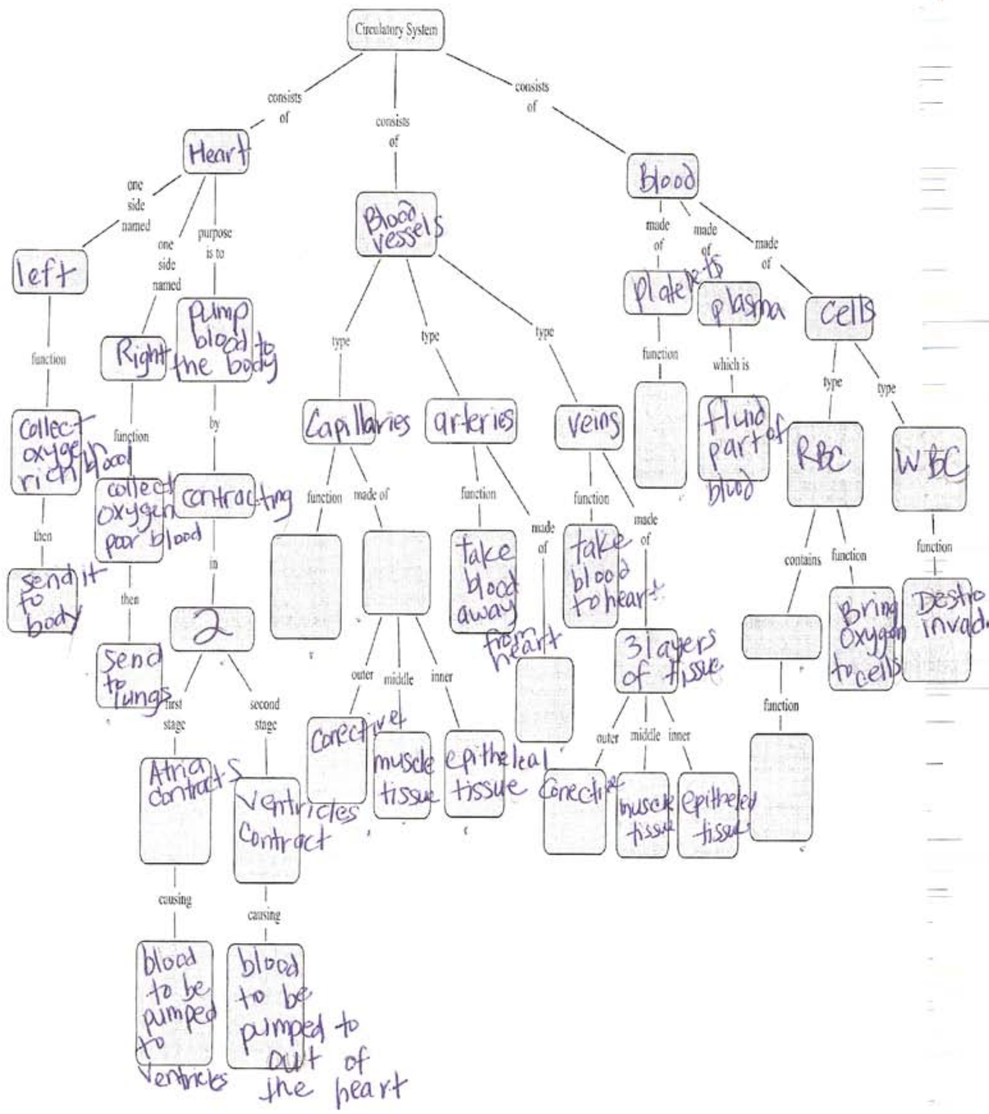
2/18 - Independent practice of blood vessels section of Circulatory System concept map (feedback)

Appendix L

Examples of Concept Identifying Concept Maps

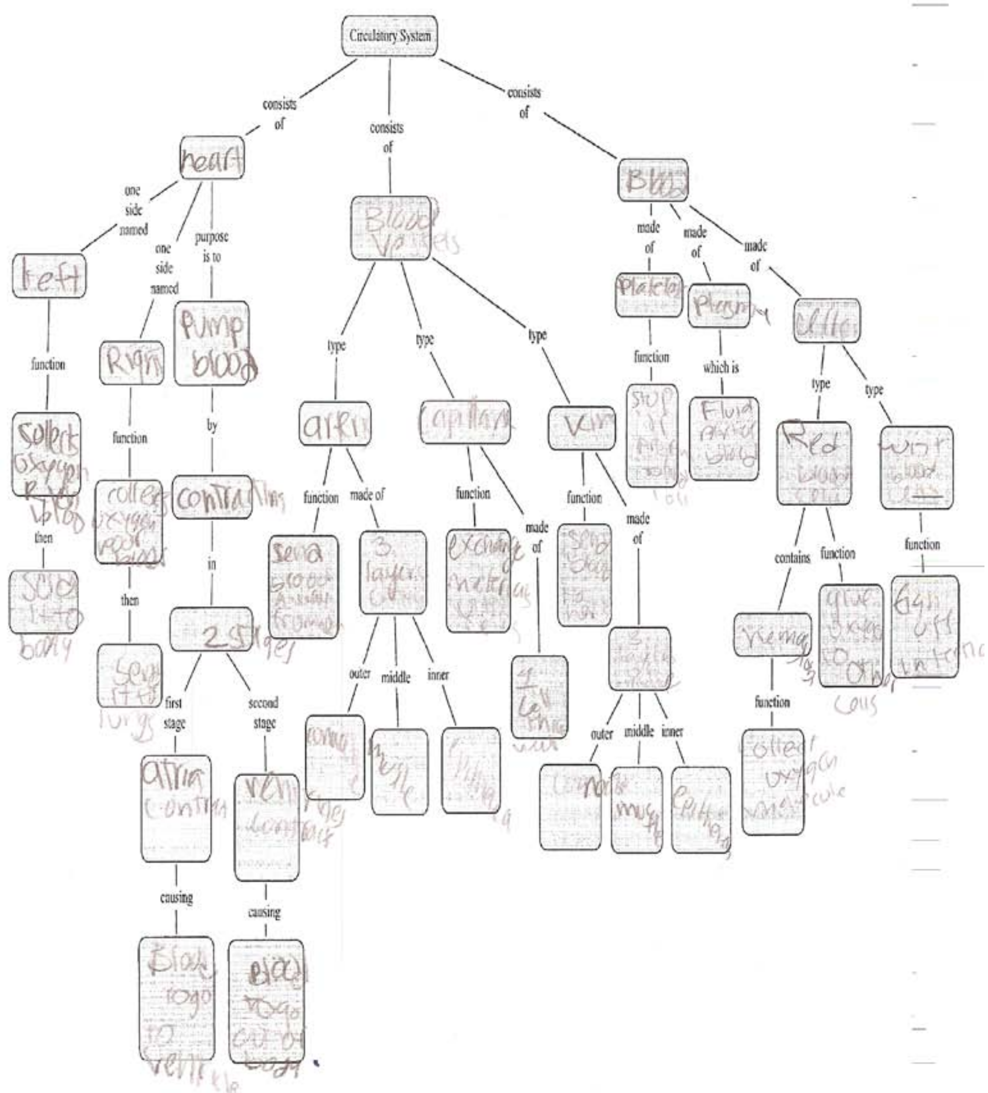
Concept Identifying Concept Map ID #: 21

Directions: Fill in the concepts to complete the circulatory system concept map.



Concept Identifying Concept Map ID #: 10

Directions: Fill in the concepts to complete the circulatory system concept map.

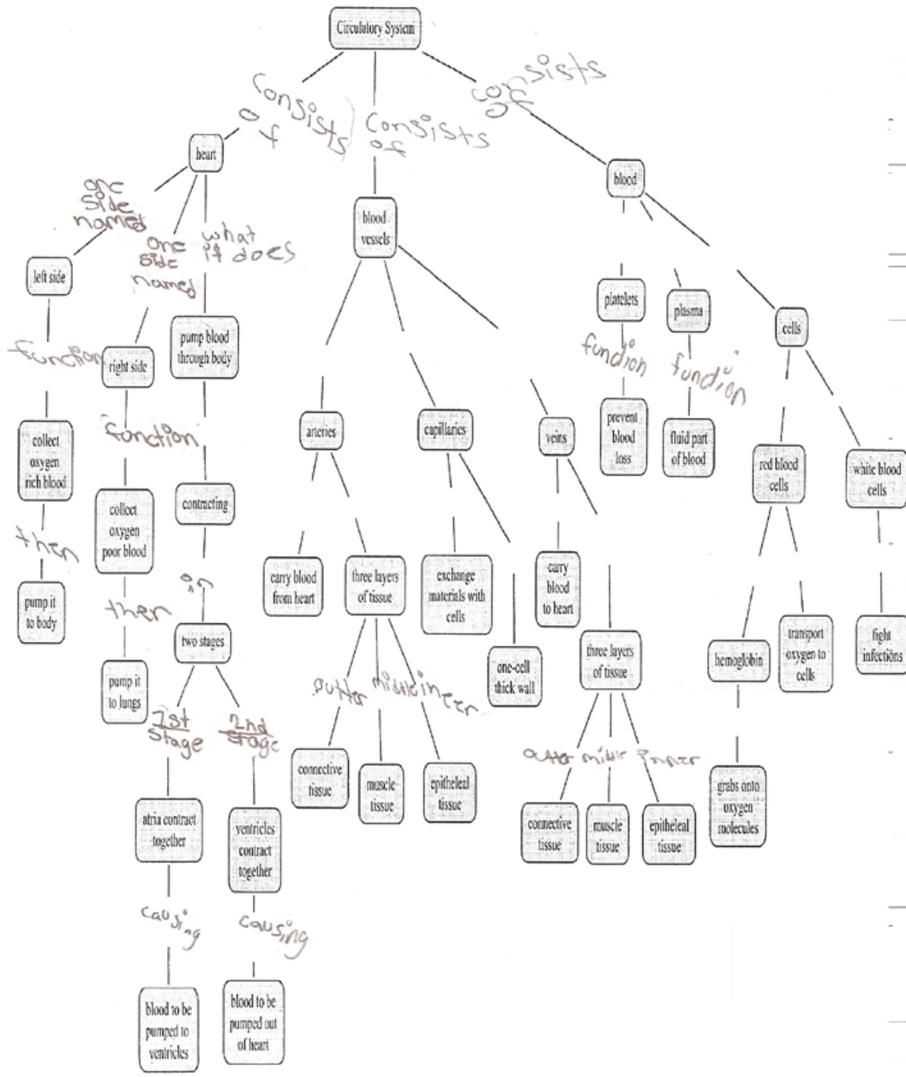


Appendix M

Examples of Proposition Identifying Concept Maps

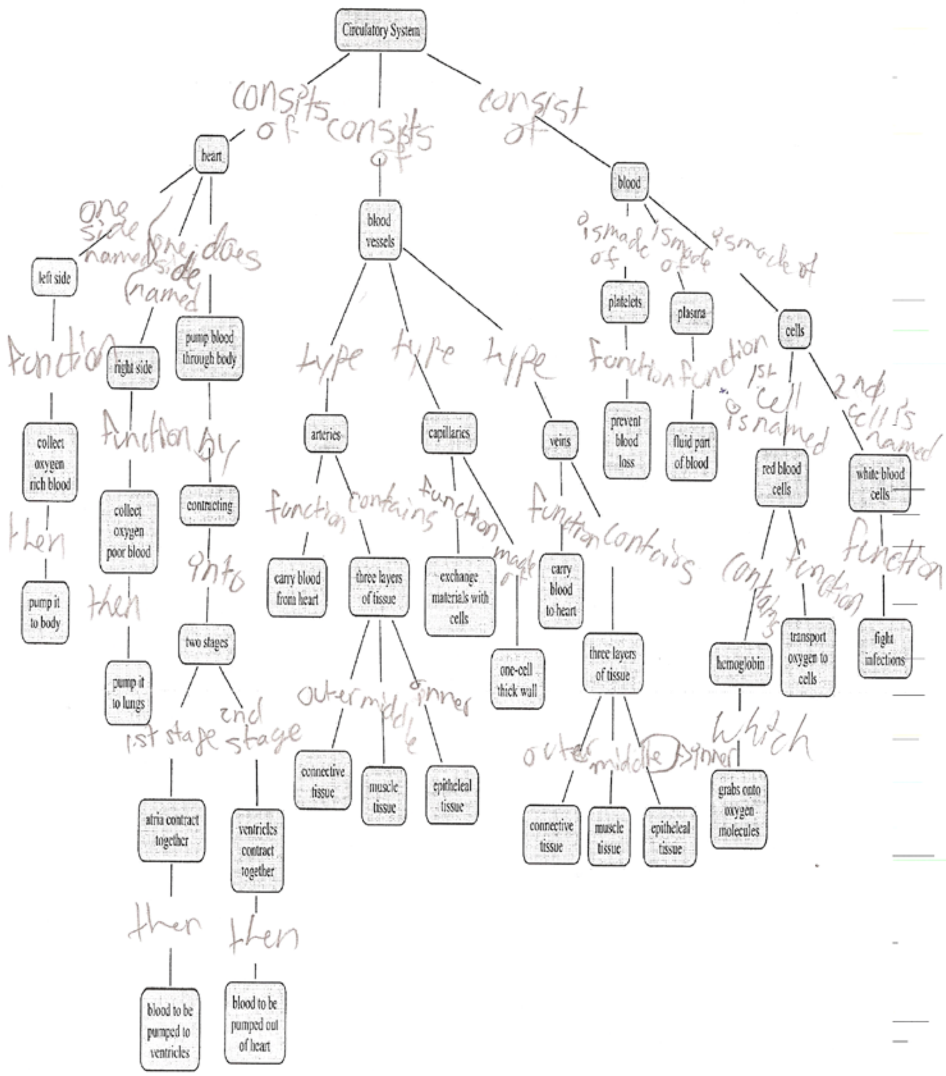
Proposition Identifying Concept Map ID #: 37

Directions: Fill in the linking words or phrases between the concepts to complete the circulatory system concept map.



Proposition Identifying Concept Map ID #: 38

Directions: Fill in the linking words or phrases between the concepts to complete the circulatory system concept map.



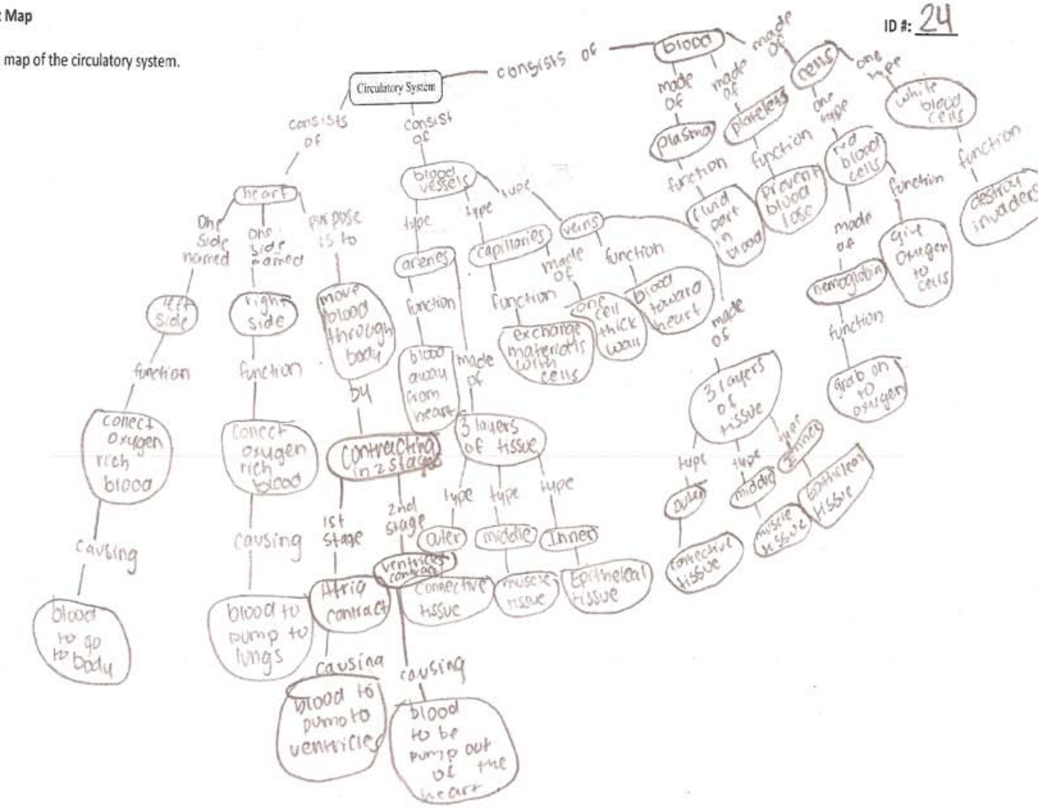
Appendix N

Examples of Student Generated Concept Maps

Student Generated Concept Map

ID #: 24

Directions: Create a concept map of the circulatory system.



Student Generated Concept Map

ID #: 5

Directions: Create a concept map of the circulatory system.