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Concept Mapping as a Tool for Enhancing Self-Paced Learning in a Distance Scenario

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by

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MA, University of Texas at San Antonio, 1991

BS, The Citadel, Charleston, SC, 1974

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

Educational Technology

Walden University

May 2015

Abstract

Researchers have determined that concept maps serve as effective tools in the traditional science classroom. The purpose of this experimental study was to investigate concept mapping as a tool for student knowledge acquisition in 10^{th} grade science for students in distance learning situations. Research questions were designed to investigate the influence of concept mapping on rate and quality of student knowledge acquisition and retention. This study was a pretest-posttest 2-group comparison study, constructivist in nature and based on the theory of cognitive learning. Participants included 36 students in the 10^{th} grade at an inner-city school in the United States. Control and treatment groups participated in completing pre and posttesting to establish standards for initial understanding and knowledge acquired. Pretest scores were used in a 2-tailed *t* test to establish equivalence between groups at the beginning of the study. ANOVA was used with test gains to determine differences between treatment and control groups. Cronbach's alpha was conducted to test for concept map interrater reliability. A 2-tailed *t* test for matched groups was used with concept map scores and treatment group test gains to determine any relationship. No statistically significant relationship between the use of concept maps and distance learning was found. Recommendations for future research include a wider age range for participants and investigations of academic areas such as reading, writing, mathematics, and language acquisition, native and foreign. Implications for positive social change include research with altered parameters to identify an existing tool that may be used by students in the traditional classroom as well as in distance-learning scenarios.

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Dedication

This dissertation is dedicated to my parents, John and Doris Richbourg. My father instilled in me the confidence and courage to be my own person, to always be true to myself and my family, and to never doubt that I can overcome any challenge with persistence, integrity, and intelligence. My mother, as a continuous supporter of my academic efforts, provided encouragement and the acknowledgement that my actions and attitude were always welcome, expected, and a source of pride for her. Together, my parents shared with me their love of learning and their insatiable curiosity about the world around them, motivating me to become a life-long learner.

This dissertation is also dedicated to my loving wife and children, who have supported me over the years this effort has taken. Without their unwavering confidence, encouragement, and love, this process of working up to and through the dissertation may have taken quite a bit longer or perhaps not even begun at all.

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Chapter 1: Introduction to the Study

One of the main expectations placed on classroom teachers is that they possess the ability to serve as subject matter experts with respect to a specific focus (math, science, language arts, and other core and elective courses). Another expectation is that teachers will act as facilitators in student development of higher order thinking skills and acquisition of new and useful information. With the introduction and growing presence of technology in education, researchers such as Clarke-Midura and Dede (2010) have observed that in many instances, these expectations are shifting from a balance of two main activities (those of subject matter expert and facilitator) to a more strongly favored role as facilitator. This is sometimes true of distance learning and scenarios similar to distance learning, in which educators may present less information while directing students in the use of technology in what could be perceived as self-paced, self-directed education (Wright & Wilson, 2007). Wright and Wilson (2007) noted that distance learning scenarios are becoming more common among academic institutions. The instructor is often not present and therefore unable to explain and clarify matters that may arise with the subject matter in real time. Although asynchronous communication is available in such cases, it is often not adequate. The question arises of what tools are available, or should be developed, to afford students the optimum opportunity to advance academically in this new, developing digital environment. Methods, techniques, and learning devices used in the traditional classroom are some of the first to be investigated in the new digital learning environment. These classroom learning aids include graphic organizers such as Venn diagrams, Wordle graphics, concept maps, and Cornell Notes.

Currently, there is a gap in available research and theory on the use of concept mapping by students participating in distance learning scenarios. The increasing presence of technology and STEM information has generated interest in the identification of information organizers that will facilitate learning and retention of STEM subject matter. Researchers previously determined that concept maps can serve as highly effective tools in the traditional science classroom (Asan, 2007; Cahng, Sung, & Chin, 2001; Cifuentas & Hsieh, 2004; McClure, Sonak, & Suen, 1999; Schaal, 2010; Tobin, Roth, & Zimmerman, 2001; Vanides, Yin, Tomita, & Ruiz-Primo, 2005). Concept mapping also provides a vehicle by which individually produced mental models can be externalized (Chang, 2007). Mental models allow people to "generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future system states" on an individual basis (Rouse & Morris, 1986, p. 360. Through this study, I sought to advance understanding of the use of concept maps in student-centered, digitally enhanced environments. More specifically, this study sought to determine the value of concept mapping in improving student knowledge acquisition and retention as a graphic organizer in a 10th grade science distance learning environment. Concept Mapping has been described as a technique that can increase student learning in the traditional classroom (Novak, 2007, 2008). Similarly, Clariana and his associates have been researching the use of concept maps in a digital environment, including a computer-based approach for scoring the quality of the resultant concept maps and their potential as classroom study aids (Clariana, Koul, & Clariana, 2008; Clariana & Taricani, 2010). *Concept map quality* refers to the amount, depth, and breadth of information and the number of connections made among disparate items included in concept maps. Clariana and associates (2008, 2010) indicated a relationship between the quality of the concept map and the total acquisition of information. Study subjects who took more time in the construction of their maps and included more detailed information retained more information for longer periods of time.

Included in this chapter is a brief introduction to the background of concept mapping followed by the purpose for the research, along with a presentation of the problem statement from which the research questions originated. The theoretical framework supporting the study is presented and discussed, along with the nature, scope, and significance of the study.

Background

Project 2061 (1998), a long-term initiative focused on improving American science literacy and education, concerns itself directly with the "growth of understanding in a variety of science literacy topics" (p. 14) and investigates the use of concept mapping in the traditional classroom. Concept maps allow students to conceptually link their understanding of diverse areas of science while providing teachers with insight on the development of student skills and understanding pertaining to specific science literacy goals (Project 2061, 1988). Novak and Gowin (1984) stated that concept maps are considered effective as teaching and learning tools that assist with the development of conceptual knowledge. The theoretical foundations of concept mapping incorporate the association between learning and memory. Concept maps assist learners in making connections between pieces of information, organizing and processing the information in short-term memory, and associating it with preexisting knowledge to become long-term memory (Novak & Cañas, 2008).

The current education system is responding to the mercurial and increasingly omnipresent nature of technology. Methodologies and tools to assist learning in technology-rich environments are regularly being proposed, constructed, and tried (Dede, 2000, 2007). As outlined by Novak (2006), the concept map has been a tool used in the traditional classroom since 1972, having evolved from the original hand-drawn diagram into the current digitally represented graphic. The concept map has been considered a tool that could increase student learning in the traditional classroom (Novak, 2007, 2008). Similarly, Clariana and his associates have been researching the use of concept maps in a digital environment, including a computer-based approach for scoring the quality of the resultant concept maps and their potential as classroom study aids (Clariana, Koul, & Clariana, 2008; Clariana & Taricani, 2010). Schaal (2010) has addressed biology instruction using concept mapping and noted positive changes in student cognition and motivation. Ruiz-Primo and Shavelson (1996), along with Tsai, Lin, and Yuan (2001), noted similar changes in students; however, all observations made thus far have been with traditional classroom populations.

Instructors sometimes do not possess the knowledge or skills to assist students in acquiring an understanding of science concepts (Tobin, Roth, & Zimmermann, 2001; Schneider & Krajcik, 2002; Settlage, 2004). Duderstadt (1997) considered the role of higher education in an information-based society and determined that the primary missions of the creation, preservation, integration, transmission, and application of knowledge are fairly static, with the particular realization of each of these roles evolving with technological developments as they appear in the educational arena. Duderstadt's research led him to the conclusion that higher education must continue to evolve rapidly to create and maintain a culture of learning in which educational opportunities become pervasive through information technology. Failure to maintain pace with these developments could result in catastrophic situations for postsecondary learning, potentially including "outsourcing, re-structuring, and (perhaps worst of all) divestiture" (Prestera & Moller, 2001).

With his research into education using immersive digital technology, Dede (2007) argued that this evolution of the educational system involves a combination of new technology and appropriate new methodology for its use. De Carvalho and Ferreira (2001) investigated varied knowledge management systems with the understanding that a major role of information and communication technology (ICT) is to accelerate the speed of knowledge creation, acquisition, and transfer. One system that was strongly considered as a highly suitable and effective learning tool, due to its rigor, simplicity, and potential, was knowledge mapping, also known as concept mapping, which places networks of cognitive relationships into simplified graphic forms. Schneider and Krajcik (2002) confirmed that most teachers (and consequently most students), even those who work regularly with technology, express a lack of familiarity with concept mapping. Novak (2007) described concept mapping is a tool used for organizing and representing knowledge, as well as assisting students in making distinctions between related and isolated facts. Novak (2007) further stated that there are two important features of concept maps that facilitate higher level creative thinking: the hierarchical structure present in a good map and the ability to recognize cross-links. With these features in place, evidence presented by Schaal (2010) indicated that concept mapping can allow students to gain an understanding of diverse areas of biology (or any area of science), including but not limited to the scientific method, cell structure and function, organic and inorganic compounds, and ecological succession. The understanding of these concepts is facilitated by the development of higher level thought processes (Novak & Gowin, 1984). Researchers King and Kitchener (1994) found that higher level thought processes requiring critical thinking and reflective judgment development are often found in task-oriented activities in the science classroom and lab.

Research conducted by Novak (2007) and Schaal (2010) indicated that the acquisition of science knowledge can be greatly facilitated by the use of concept maps. Concept mapping allows visual observation of relationships and connections between multiple areas and pieces of information (Schaal, 2010). Schaal (2010) noted that the ability to recognize connections between different pieces of information or aspects of a problem acts to facilitate problem-based learning. Problem-based learning (Savery & Duffy, 1995) assists in the development of higher order thinking skills, helping students to become independent, self-directed learners who respond appropriately to situations in a logical and reasonable manner. The use of learning tools in the STEM classroom such as concept mapping is an area in need of further attention and research (Novak, 2007). Although research and theory brought forward thus far suggest that concept mapping is an effective learning instrument in the traditional classroom, there is a lack of evidence concerning the use of concept mapping by students participating in distance learning scenarios. This study addresses the knowledge gap caused by this lack of evidence, with the intent of possibly supplying beneficial information concerning distance learning and the digital learning environment.

Problem Statement

This study addresses the gap in the literature pertaining to STEM classes and the use and effectiveness of concept maps in student-centered, self-paced digitally enhanced environments similar to distance-learning scenarios. Evidence and theories presented on the use and effectiveness of concept mapping thus far concern student response in the traditional setting. There is little to no meaningful evidence of the effectiveness of concept mapping in the digital, self-paced distance learning environment. With the growing preponderance of digital classrooms and number of distance learning students, concept mapping has yet to be determined as an effective instrument for learning outside of the traditional classroom.

Purpose of the Study

The intent of this study was to investigate the effectiveness of concept mapping as a tool for students in distance learning situations. The overarching purpose of this experimental quantitative study was to investigate concept mapping as a graphic organizer for student knowledge acquisition and short-term retention in 10^{th} grade science in a digital environment similar to a distance learning scenario, resulting in improved learning and test scores. The digital learning environment employed by this study included students preforming research individually with computers and the Internet, similar to distance learning. The major differences were that the work was to be conducted in a traditional classroom and that an instructor was available for consultation and assistance onsite when needed. A secondary purpose of this study was the investigation of a possible relationship between the amount of improvement between pre and posttest results and the quality of student-generated concept maps. This study focused on the effectiveness of concept mapping when used as an aid to self-paced learning in the science classroom, specifically when using computers in an environment similar to distance learning. The independent variables were the frequency and quality of concept mapping employed by students in their self-studies. The dependent variable was the resulting change in student understanding of select science concepts, as demonstrated by comparison between pre and posttest results of the two groups (for the first research question) and within two parts of the treatment group (for the second research question).

Research Questions

The two major research questions considered by this quantitative study are listed below:

1. What is the relationship between concept mapping and knowledge acquisition by students in a learning environment using a concept-mapping tool in a distance learning scenario to learn 10^{th} grade science?

   Hypothesis (H_{a1}): There will be a difference in learning gain as reflected by comparison of the mean gain scores for treatment and control groups.

Null hypothesis (H_{01}): There will be little or no difference in learning gain as reflected by comparison of the mean gain scores for treatment and control groups.

2. Is there a relationship between the quality of the concept map created by individual students and knowledge acquisition demonstrated by the differences in scores between pre and posttests?

   Hypothesis (H_{a2}): Gain scores of students of the treatment group who have constructed concept maps having higher quality scores will differ significantly from gain scores of students who have constructed lower quality concept maps.

   Null hypothesis (H_{02}): There will be no significant relationship between learning gains and the quality scores for constructed concept maps.

After the treatment group was divided and the two halves were considered as populations for investigation, the power of the groups could have been too low to be tested. In this instance, an exploratory analysis using descriptive techniques was anticipated, with results to be presented for consideration following the study.

Theoretical Framework

This study was based on the fundamental educational theory of cognitive learning. Cognitive learning theory, as developed by Ausubel (1968) and others (Wolpe, Piaget, & Lazarus, for example; Mahoney, 1977), proposes that an existing knowledge base is infused with new information. This merging of information is called "meaningful learning" and establishes a better understanding and longer retention of information by the learner. More recent theorists whose work was considered in the preparation of this study are Mayer and Moreno (1998) and Sweller (1988). Mayer and Moreno (1998) presented the cognitive theory of multimedia learning known as the “multimedia principle,” which states that more is learned from words and pictures than from words alone. Their theory introduces the concept that the brain selects and organizes sensory information (words, pictures, sounds) to produce logical mental constructs rather than collecting and holding sensory input as mutually exclusive elements. Emphasis is put on learning when new information is combined with prior knowledge. The amount of learning accomplished is determined by testing of content to demonstrate the successful transfer and retention of information. Mayer and Moreno’s work (1998) relates directly to this study in the use of concept maps that allow users to organize and display acquired information to demonstrate relationships between concepts.

Sweller (1988) based his cognitive load theory on the short-term memory findings of Miller (1956), one of the founders of the cognitive psychology field. Sweller (2005) described Cognitive load for multimedia learning and emphasized the need for sound design in the construction of lessons and associated materials. Sweller’s 2005 paper, “Implications of Cognitive Load Theory for Multimedia Learning,” outlined human cognitive architecture, along with the application of viable instructional design principles as determined by current information on brain and memory functions. Of particular interest is the third of Sweller’s three types of cognitive load, known as *germane load*. Germane load is devoted processing of cognitive schemas, including construction, and automation of those schemas. Further information concerning the thinking on major theoretical propositions and hypotheses is provided in Chapter 2 of this paper.

Theoretical and conceptual frameworks for learning are based on and derived from previous studies, conceptual analyses, and theories found in the research findings of Chang, Sung, and Chen (2001), who suggested that simple frameworks for learning content be provided to study subjects to facilitate the “construct-by-self” process. This can reduce the perceived cognitive load of participants while allowing the use of the time and energy in the construction of the framework to be used in mastering the complete content. These frameworks, such as Mindtools (Jonassen, Carr, & Yueh, 1998), are examples of scaffolding that serve to guide learning. Mindtools cannot be effectively employed as learning strategies unless the learner gives great consideration to the subject matter. Mindtools are actually semantic organizers that assist learners in analyzing and organizing information. Two of the best known semantic organizers in use currently are databases and concept mapping (Jonassen et al., 1998). Further information on similar frameworks is presented in Chapter 2. Novak (2010) referred to these frameworks as “expert skeletons” and stated that his research results indicate them to be useful metacognitive tools when used to facilitate meaningful learning. This understanding is further strengthened by observing research produced by Novak and Cañas (2008), who investigated theoretical foundations and origins (purposeful uses) of concept mapping, features that are essential when actually constructing and studying the resultant concept maps. A more contemporary theorist whose work is of particular interest in the development of this study is Anderson of Athabasca University. Anderson’s work with online learning (Anderson, 2008) and his theories on distance learning pedagogy (Anderson & Dron, 2010) present a more relevant model of cognitive learning in the distance learning scenario. The research findings of Eden (2004) and Park and Calvo (2008) were strongly considered when evaluating subject-produced maps. Eden (2004) investigated a range of possible analyses of concept maps that indicate emerging features of individual maps to be detected. Park and Calvo (2004) presented an automatic scoring framework for concept mapping using semantic web technologies. Special consideration was afforded to Clariana, Koul, and Salehi (2006) in establishing an effective method for computer scoring of the concept maps.

The Concept Mapping graphic in Figure 1 presents the graphic nature and connectivity of information as displayed on a concept map (Novak & Cañas, 2008). Information presented in this format, showing connections and relationships, is more easily understood and retained for longer periods (Novak & Cañas, 2008). In a concept map, knowledge is represented by concepts appearing in boxes or circles. Relationships between concepts are illustrated by connecting arrows labeled with linking phrases. Concepts in this instance are considered as regularities or records of events or objects represented by words or common symbols. When two or more concepts are connected by *linking phrases* (which may also be single words) and form a meaningful statement, they are known as *propositions* or *units of meaning*. Concepts are represented in a hierarchical organization ranging from general at the top to more specific appearing below. Because the hierarchy-like structure of these maps depends on the context in which the information is being considered, it is best to construct maps around focus questions.

Focus questions, queries for answering that pertain to an area under investigation, are used to direct the flow of information and assist in providing context within the map. Concept mapping also employs *crosslinks*, relationships or links between segments or domains that help in relationships between disparate segments of information. Crosslinks often represent creative leaps in the creation of new knowledge. More information concerning these areas is presented in Chapter 2 of this document.

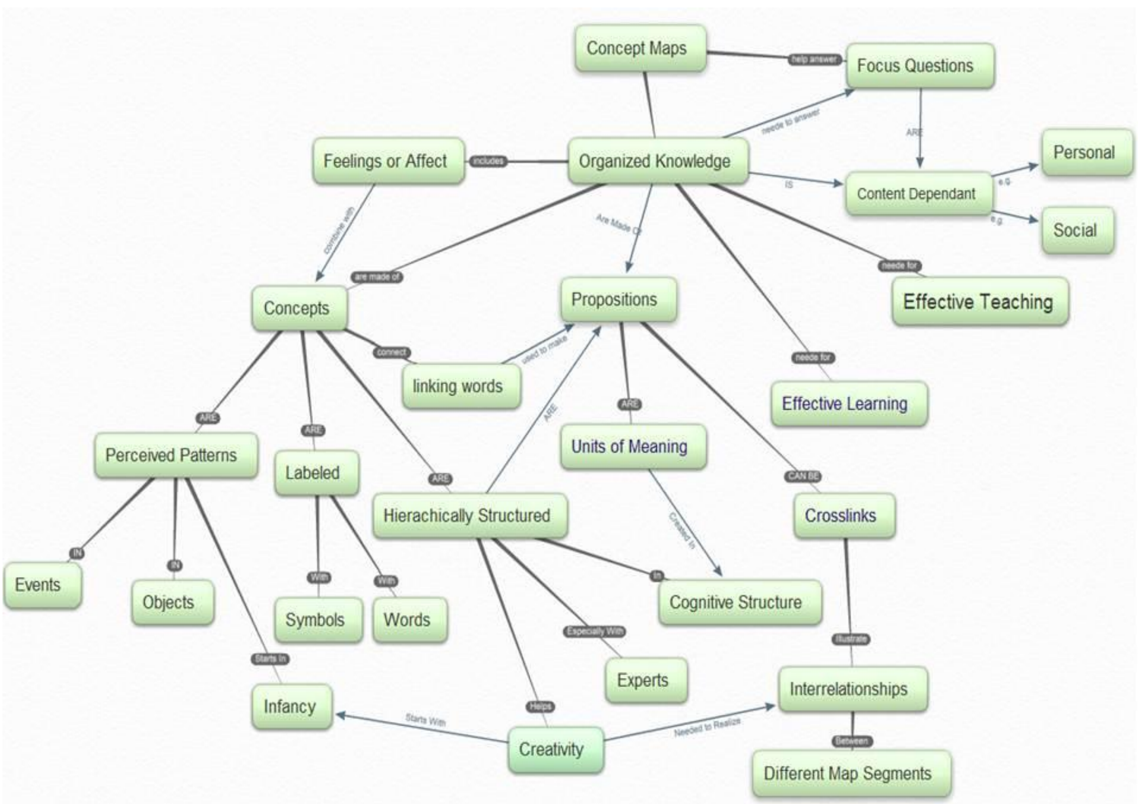

Figure 1. Explanation of concept mapping displayed as a concept map.

Nature of the Study

The experimental research design selected for this study was a comparison group design. This design affords researchers a comparison of two groups over time with controlled conditions in order to determine resultant differences. This design allows for two randomly chosen groups to be selected and exposed to a pretest, a treatment (for one group), and a posttest.

In this quantitative experimental study, I investigated the employment of student-generated concept maps in a meaningful learning scenario. The independent variables were the frequency and quality of concept mapping employed by students in their self-studies. The treatment introduced to one group was a 2-week block of instruction that included the making and use of concept maps along with time to practice making concept maps using material from the science content area. The differences noted in the scores for the pre and posttests of the two groups gave evidence of the effectiveness of the applied treatment while isolating that effect from other influences on learning gains. The *quality* of the completed concept maps referred to the frequency and validity of main concepts, links, and hierarchical levels (Koul, Clariana, & Salehi, 2005; Taricani & Clariana, 2006). The concept map scoring rubric used with this study is presented in Appendix F and reflects elements of both legibility and validity in the combined final score. The dependent variable was the resulting change in student understanding of select science concepts, as demonstrated by comparison between pre and posttest results of the two groups and within two parts of the treatment group. This type of study seemed to be the optimum choice, given that two groups were compared with only one group receiving the treatment, as it isolated the effect of the treatment from other factors affecting the dependent variable.

Two groups of 10^{th} grade students in a single-gender inner city public high school were identified to participate as test subjects, with an anticipated population of 48. Students agreeing to participate numbered 36. The two groups, the first having 15 members and the second having 21, had already been determined by convenience assignment to different home rooms. Listings for all classes at all grade levels were computer generated. Special scheduling requirements, class standing, and other factors were not considered in the home room assignment. To meet requirements for this study and ensure nonbiased groupings, students and proctors were assigned to control and treatment groups by chance. Groupings selected by this method represented truly randomized study populations. Figure 2 outlines the activities of both Control and Treatment groups as they progressed through the study.

Power calculations for the study, as illustrated in Tables 3 and 4 in Chapter 3, reflected low statistical power due to the small size of the study population. There appeared to be adequate power when dealing with the total population of 36 in RQ_1. Power estimates tend to grow weaker as the population becomes smaller, as in RQ_2. It appeared that it might be necessary to conduct a descriptive analysis of the findings in RQ_2 rather than run statistical tests of inadequate power. With further research into testing, it was determined that this was not the case.

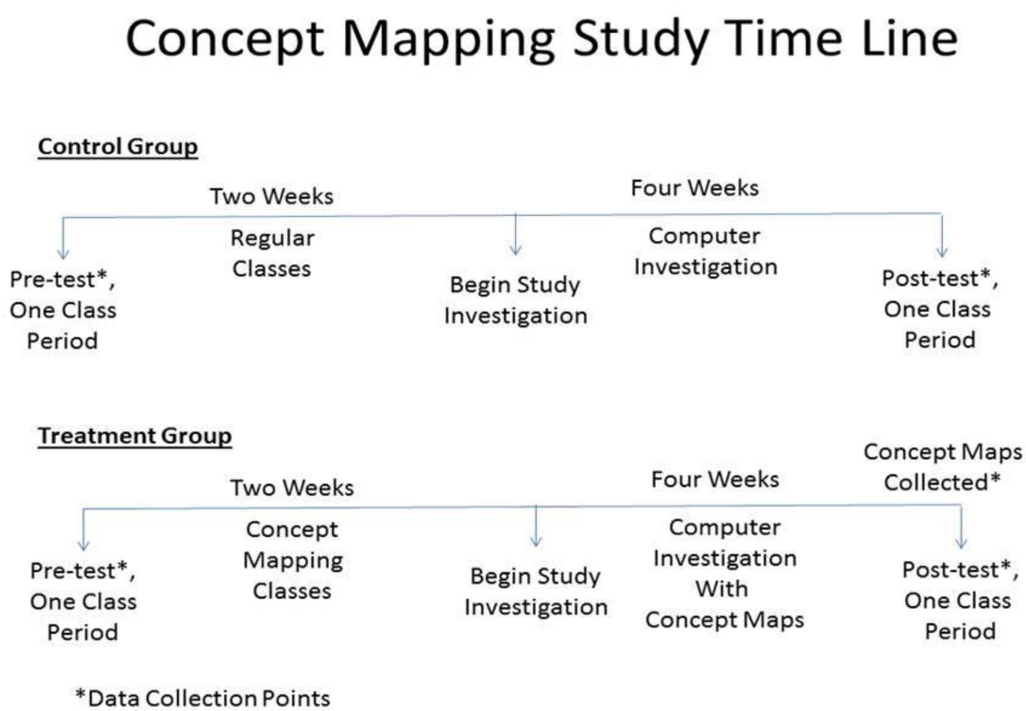

Figure 2. Concept mapping study timeline.

The single instrument used as the pre and posttest was constructed from questions selected by the school science instructors from the 2009 10th grade science state tests. Science instructors also created a listing of associated concepts that students were to research. Both study groups received the pretest at the same time, with home room teachers acting as proctors in the home room setting and grading the completed instruments. The treatment group then participated in 7.5 hours of training (45 minutes daily) over a 2-week period on the construction and use of computer-generated concept maps, facilitated by the school librarian in the school library. Strategies for constructing and using concept mapping presented to the treatment group included the procedures established and recommended as effective methods by previous research (Novak, 2010; Novak & Cañas, 2008; Novak & Gowin, 1984).

Sources of data for this study were as follows:

1. Student results from administered pretests for both control and treatment groups.
2. Student results from administered posttests for both control and treatment groups.
3. Concept maps scored with an appropriate concept map quality rubric.

Assumptions

This quantitative experimental study identified a number of factors that were considered true but not verified as such. These constituted assumptions, the first of which was that the population selected for the study was representative of the total population of this single-gender urban high school. As discussed in the nature of the study, the study population was initially separated into two groups, with the only determining factor being grade level. Two truly unique groups were determined by random selection as control and treatment populations. These randomly chosen groups were unique in that they had been selected by means that did not involve taking into consideration any shared or different characteristics for any participant. Any differences between the resulting groups were due to chance and not purposeful contrivance. Homogeneity for age, gender, abilities, ethnicities, and learning abilities of the study population was assumed in the convenience sample used. This first assumption was group equivalence between the control and treatment groups.

The second assumption was that study subjects in both the treatment and control groups participated in the study with no experience in using concept mapping as a graphic organizer. Some students might have had some exposure to concept maps in elementary classrooms, but as high school sophomores, this experience would have been far behind them. An understanding of teaching methods previously used in campus classroom instruction indicated that because the study site was an AVID (Advancement Via Individual Determination) campus, the only graphic organizer used regularly had been Cornell Notes. This factor allowed for differences in test performance to be attributed to concept mapping of information.

A third assumption was that the conceptual understanding of the specific information used in the study was reflected accurately by the pre and posttests. This assumption was strengthened by understanding that the questions for the instruments were taken directly from standardized tests that had previously been used with students statewide.

A final assumption was that the proctors involved in the study remained unbiased and provided identical learning experiences for students in both groups, allowing the construction and use of concept mapping by students in the treatment group to be the only experimental variable. Monitoring of this factor was my responsibility as the researcher and proved to be no obstacle in maintaining validity of the study. I checked all assumptions by regularly monitoring both groups, especially during the commitment of the student research portion of the study.

Scope, Delimitations, and Limitations

At the time the research was conducted, the school had a population of 390 students with a racial breakdown of 92% Hispanic, 5% African American, and 2%

Caucasian, with the remaining 1% split between students who claim Asian or Native American ancestry. This study began with a population of 36 10th grade female students in a single-gender, urban high school. The group was composed of 33 Hispanic students, two African American students, and one European American student. All 36 study participants came from families at or below the poverty line. These factors differed from the norms for ethnicity and income within the city, state, and country as of the last U.S. census of 2010 (U.S. Census Bureau, 2012).

Delimitations are those research features that are controlled by the researcher to narrow the scope of the study (Creswell, 2003). Data collection ran for approximately 6 weeks, from midOctober to late November 2014. Strategies for constructing and using concept maps were presented to the treatment group and included the procedure recommended by Novak and Gowin (1984). Selection of only one grade level (10th) was addressed in the study, with members of this grade level serving as both control and treatment groups. Pre and posttesting of both groups (control and treatment) provided levels of student understanding and improvement in information retention.

Study participants were students enrolled in a single-gender (female) inner-city school. The socioeconomic levels of study participants were low, with a majority of study subjects being Hispanic, White-Hispanic, or Mexican American. Data from participants of both the control and treatment groups were collected and analyzed during the execution of this study. The survey participants included students who were members of the 10th grade science classes currently enrolled in the single-gender school used in the research. Participation was limited to 10th grade students only in an effort to increase validity of the study outcome by maintaining homogeneous conditions (treatment, content, measures) within the subject population. Although the study had potential to positively affect students in any learning environment, for purposes of the study, only a specific group within a unique environment was considered.

Potential weaknesses to the validity of a study are known as *limitations* and are usually not under the control of the researcher (Creswell, 2003). The number of available study subjects was seen as the primary limitation in this instance. There were only two prep (homeroom) classes of 10^{th} grade students, with 25 and 23 members, respectively, for a total of 48 possible study subjects. Another limitation was the time constraint placed on students to complete their research. Students conducted their investigations during the 45-minute prep class. This was only half of the block schedule 90-minute classes that students were used to experiencing and may have proven to be a challenge in accomplishing tasks within the allotted timeframe.

This study was restricted to the use of concept maps by the treatment group, excluding all other graphic organizers. Concept maps were rarely used in the normal classroom setting, with Cornell Notes favored as the graphic organizer of choice by most instructors on campus. This preference was due to the current status of the campus as an AVID participant. The AVID program emphasizes the use of Cornell Notes as the graphic organizer of choice. All teachers and students receive training in the use of Cornell notes, with the expectation that the notes will be used in classrooms across the curriculum (Swanson, 2005; Watt, Yanez, & Cossio, 2002). Therefore, due to the novelty factor, more could potentially be learned about the implementation of concept mapping by students participating in the study. The incidence of other graphic organizers used by study participants in the control group was noted for future study. An attempt to minimize the Hawthorne effect (HE) was made by emphasizing to all participants that the information they collected would be used later in the curriculum and might be subject to testing by their instructors at a later time. Adair (1984) explained the HE as the change in behavior of test subjects from the norm caused by knowledge that they are participating in an experiment. Facilitators concentrated on knowledge acquisition and minimized the experimental nature of the exercise.

Definition of Constructs

Active monitoring is the practice of monitoring students in close proximity as they work in the classroom while being cognizant of student activities and prepared to respond to questions and concerns by individuals in a timely manner (Garofalo & Lester, 1985).

Concepts in this instance are considered regularities or records of events or objects represented by words or common symbols (Novak & Cañas, 2008).

Concept maps are graphic representations of conceptual ideas. These maps are often composed of different hierarchical structures and links depending on the conceptualization of knowledge relationships developed by individual students as these maps are constructed (Novak, 2010).

Concept map quality refers to the amount and depth of information and the number of connections made between disparate pieces of information located on the graphic organizer (Novak, 2010).

Distance learning is a means of (educational) instruction to individuals or small groups that are not physically located in a traditional classroom or in the area where the instruction is taking place (Dede, 2000).

Graphic organizers are instruments used within the learning environment to assist in the organization and relationship of separate items of information (Novak & Cañas, 2006). Examples of commonly used graphic organizers are Venn diagrams, concept maps, flow charts, KWHL (Know, Want, How, Learn) charts, and Cornell Notes.

Knowledge acquisition, also known as *learning*, refers to encountering, processing, understanding, and recall of information and is closely associated with memory, cognition, and perception of environment (Novak, 2010).

Learning environment refers to the physical or virtual setting in which learning takes place and incorporates factors that affect the five senses along with mental and emotional factors that help determine the outcome of the learning experience (Novak, 2010).

Single gender refers to the makeup of the study participants, who were enrolled as students in a public school that accepts only female students.

Urban or *inner-city students* is a term used to describe participants in this study from low-socioeconomic-status families who lived in the heart of a major metropolitan area and were predominantly culturally Hispanic American, African American, or first-generation immigrants from countries with learning styles and cultural backgrounds other than those normally found in the traditional classroom.

Significance of the Study

With respect to student achievement, this study presents information that permits a stronger understanding of the effects of concept mapping as a tool for learning in the digitally enhanced science classroom, with emphasis on individualized knowledge acquisition, as in a technology-enhanced learning environment. The potential for student benefit was in the acquisition of a tool that facilitates new learning metacognitively through organization, retention, and retrieval of information. Novak (2007) stated that concept mapping provides a tool for organizing and representing knowledge, skills that are becoming crucial to understanding and learning as technology becomes more omnipresent and the knowledge base increases. The use of digital concept maps as tools to assist with the development of higher level thinking skills in the science classroom could aid young women in becoming functional, contributing members of the technological community. Potential implications of this study include the provision of information pertaining to the value of concept maps as opposed to other graphic organizers (Venn diagrams, Cornell Notes) that may be employed.

Summary

Researchers (Dede, 2000; Lee & Choi, 2003) have noted that with the increase in technology use and information in school curricula has come the need for methods to organize information in formats that can be readily understood and used by students. There is no apparent confirmation in the literature that concept mapping will be an effective tool in the single-gender classroom in situations similar to asynchronous or distance learning scenarios. In Chapter 1, I have presented an introduction to the study, identified the research problem, and discussed the conceptual framework for the study. Chapter 2 contains a review of related literature in the form of an annotated bibliography with discussion. In Chapter 3, I present the methodology and procedures used to prepare the research. In Chapter 4 I discuss the findings of the study, and in Chapter 5 I present implications and recommendations for further research.

Chapter 2: Literature Review

In this chapter, evidence concerning the importance of graphic organizers, specifically concept maps, as assistive tools for future learning is discussed in a review of the literature including peer-reviewed articles. The information in this chapter addresses the current gap in available research and theory on the use of concept mapping by students participating in distance learning scenarios. This is a problem of some relevance, in that distance learning is becoming more widely used by educators as a teaching vehicle. New tools and methodologies must be developed to facilitate effective learning on the part of the student. An alternative to this requirement is the repurposing of currently available classroom tools (such as concept mapping) and methodologies to be more effective in the digital classroom setting. Background information presented in this section pertains to research on distance learning relevant to this study. This chapter contains information found in current literature concerning the theoretical basis of mental models and graphic organizers. The definition, potential uses, and construction and scoring of concept maps are discussed, along with their potential in the context of distance or web-based learning. Perspectives on current thinking on concept mapping are also presented.

Information Sources

In gathering the background information for this study, I used several databases almost exclusively through the Walden University library: Education Research Complete, EBSCO-hosted ERIC database, Education from Sage, and dissertations completed by earlier doctoral candidates. Google Scholar was also used to find articles concerning concept mapping. Search terms used to find information on concept mapping included (singly and in combination) *mental models, concept maps, concept mapping, distance learning science instruction,* and *traditional instruction*. The literature review was centered on peer-reviewed, professional articles and books published from the year 2000 to the present. The information accessed was not, however, limited to this recent period, extending as far back as 1968 (Ausubel). This extension of the timeline for acceptable sources was made due to the great paucity of published information concerning the use of concept maps in distance learning scenarios, justifying the need for a study dealing with the topic.

Theoretical Basis of Mental Models

Rouse and Morris (1986) considered *mental models* “the mechanisms whereby humans are able to generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future system states” (p. 351). The theory of mental models was selected as a major underpinning of this study, due in part to the nature of concept maps as visualizations of related concepts in graphic form (Chang, 2007). Researchers (Chang, 2007; Jones, Ross, Lynam, Perez, & Leitch, 2011; Zhang, Kaber, & Hsiang, 2008) have noted that mental models are unique to individuals, existing in the mind as internal cognitive representations of external reality and used to reason and make decisions affecting behavior and consequences in the world. These mental models are different for each individual and are based on personal experiences, perceptions, and resultant understandings of external reality. They also serve to filter new information, align new with previous information, and store acquired concepts and information appropriately. However, being unique to individuals means that the ability to portray the world accurately is limited, making mental models incomplete representations of reality and often inconsistent in that they are context-dependent, changing to match the conditions of each new situation. By this adaptive characteristic, mental models are viewed as continually evolving personal constructs changing over time with new learning (Jones et al., 2011).

Chang (2007) noted that although mental models have been given great importance in many fields, due to how and where they are formed and maintained they remain a complex topic that is very difficult to explore. This difficulty arises from the nature of mental models existing within the minds of individuals and therefore not readily available for appropriate or accurate observation or measurement. Determining methods to elicit mental models presents a major challenge for those interested in acquiring an understanding the internal world representations of individuals (Zhang et al., 2008). Zhang (2008) listed a variety of tools and techniques for meeting this challenge of realizing another's perceived reality, including but not limited to organizational research, education, risk communication, and human-computer interaction.

Zhang (2008) chose to work with the human-computer interaction phenomenon in research into mental models. Zhang's study was focused on identifying different mental models that could be identified as valid representatives of perceptual events in a multitasking scenario involving constant physical activity. Twelve male graduate students at North Carolina State University were immersed in a virtual learning environment (VLE), walking on a treadmill while being presented with eight different digital event features projected on a screen in front of them. Three types of mental model were hypothesized: First, events are categorized by participants according to their composition (causes, mechanisms, and outcomes); second, events are categorized using internal event tables that include combinations of causes, mechanisms, and outcomes; and third, events are categorized as separate and unique occurrence. Responses to changing situations and the descriptions of the participants' thought processes as they went through each simulation were noted. Findings included that study subjects rarely used the first model and tended to use the third model much more than the second. This indicates that study participants developed categorization functions that were able to match and assign virtual events to existing categories in their individual mental models.

As Zhang (2008) used a convenience sample of 12 male graduate students, the study results are not considered highly reliable. The participants of this study were a very specific group whose members had similar or congruent academic experiences and foci. The results obtained might have differed if the group population had been altered to include women, more individuals as test subjects, or other individuals besides those enrolled in graduate programs of study. Further, although this research contains evidence that individuals can incorporate and use new information within existing personal realities, it gives no information as to what might be contained in the preexisting information that is vital to the mental model (Zhang, 2008). To secure a more concrete example of a mental model (understanding of a specific topic, concept, or thing), a physical artifact must be constructed. This endeavor requires the tools and techniques inherent in education and organizational research.

Graphic Organizers

Graphic representations associated with documents are often referred to as *graphic organizers*. Graphic organizers are any type of visual depiction of information and include, but are not limited to, tables, charts, graphs, maps, semantic trees, mind tools, schematic diagrams, mind maps, Venn diagrams, Vee diagrams, flowcharts, blueprints, knowledge maps, some advance organizers, organizational wire diagrams, and concept diagrams (pictorial rather than written representations). Included among this very wide focus are concept maps, which show relationships between concepts or processes with the use of spatial position, connecting lines, and intersecting figures (Mayo, 2010; Nesbit & Adescope, 2006). The scope of this study included concept maps and their usefulness as tools in learning 10th grade science in a self-paced, distance learning scenario.

Concept maps were first conceived as physical artifacts emerging from Ausubel's (1968) theory of meaningful learning, which indicates that learners subsume new concepts within preexisting, subordinate structures (Nesbit & Adescope, 2006). These graphic organizers assist the learning process by preparing students to learn by activating prior knowledge and establishing relationships between new and preexisting concepts (Mayo, 2010).

As described by DiCecco and Gleason (2002), graphic organizers are "visual portrayals or illustrations that depict relationships among the key concepts taken from the learning" (p. 308). Relational knowledge is acquired by students when the relationships between concepts or ideas are understood (DiCecco & Gleason, 2002). Graphic organizers assist users in making connections between different ideas and concepts with regular success (Baxendell, 2003). This assertion comes from Baxendell's daily use of a variety of graphic organizers in his special education classroom over a period of five years. With regular use, graphic organizers have allowed special education students to communicate with teachers and peers, gain understanding of the subject matter appropriate for their grade levels, become less frustrated, gain self-confidence in themselves in the academic setting, and have a higher success rate when included into regular traditional classes (Baxendell, 2003). Graphic organizers have also been described as tools that facilitate the arranging of fundamental elements of ideas or concepts into patterns using labels known in this instance as *key words* (Egan, 1999). Cyrs (1997) asserted that these key words are the most important elements in communication because they often indicate the importance of the content of a message.

There are many different types of graphic organizer, all presenting information in a visual display that assists in the learning process (Baxendell, 2003). Graphic organizers allow users to visually arrange information on specific content to facilitate teaching and learning (Mayo, 2010). In his regular instruction of classes, Mayo (2010) used concept mapping, allowing students to generate these maps with their own original key concepts or concepts from a provided list. Student-generated maps were built using Cmap Tools only after students attended a 30-minute in-class training module followed by a 15- to 20-minute presentation period. This practice was encouraged by Mayo's classroom observations over several years of practice in combination with data gathered during his 2002 study using concept mapping as a tool for focusing on the human nervous system.

His observations and application over time confirmed that improvement of academic performance leading to classroom success with concept mapping can be obtained, but only with the required preliminary training on map construction prior to the task (Mayo, 2010).

One type of graphic organizer, the *Vee diagram* (not to be confused with Venn diagrams, introduced by Venn in 1880), was developed by Gowin in 1977 to assist in clarifying and reporting data in the science lab (Novak, 1990). Novak and Gowin (1984) described the Vee diagram as useful in gaining an understanding of the structure and process of knowledge construction. Novak and Gowin provided training with concept maps as a learning tool to seventh and eighth grade science students to ensure that the ideas of concepts, concept relation, and objects or events pertaining to them were introduced and understood. Once the students demonstrated facility with concept mapping, the Vee diagrams were introduced. Concept maps remain as an integral part of the Vee diagram in that they are equated as the lower left, or the thinking side of the Vee. Study results indicated that students were able to more readily understand and synthesize information when using the diagrams. Conclusions included that evidence indicated that the Vee diagram could be used for any grade level or age group. Further, Vee diagrams seem to provide valuable assistance in recognizing the relationships between concepts, along with a greater understanding of individual concepts. However, these benefits may only be attained if concept mapping is introduced prior to exposure to Vee diagraming. Further research on both of these points is needed to ascertain validity of the claim that Vee diagrams can be beneficial to all age groups and grade levels.

The *flow chart* is another type of graphic organizer that is used to depict planning and procedural knowledge. Flow charts are useful in identifying, defining and analyzing different processes. Flow charts can also be used to depict working plans for organizing varied concepts or topics (Mayo, 2010). *Venn diagrams* are made of overlapping circles containing sets and subsets of information representing different concepts, making possible the viewing of different characteristics or elements of a group that are shared by groups or unique to only one. Venn diagrams are very useful in organizing subject sets and showing relationships, similarities, and differences between concepts. They are, however, limited to the numbers and types of groups that can be compared in a single diagram (DiCecco & Gleason, 2002).

All of these graphic organizers, including concept maps, serve as metacognitive tools by assisting in the activation of prior knowledge, organization of the thought process, and encouraging understanding of relationships between information. They capitalize on visualization to assist users in making connections and seeing relationships between varied elements. In this manner, they facilitate the development of higher order thinking skills (DiCecco & Gleason, 2002). Conducting a study of 24 learning disabled middle school students and six educators in two urban Oregon schools, DiCecco and Gleason (2002) found that graphic organizers (including concept maps) assisted in the recall of relational knowledge. The researchers felt that this may have been at least partially a result of the treatment with graphic organizers being more explicitly aligned and intensive than treatments found in previous studies.

Defining Concept Maps

A *concept map* is a graphic representation that illustrates suggested relationships between concepts. This graphical tool is used by instructors, students, and business professionals to organize and structure information. Typical concept maps represent ideas and information enclosed in boxes or circles, which connect with labeled arrows in a downward-branching structure from more general to more specific information. Relationships between concepts are demonstrated with linking terms or phrases, such as *causes*, *requires*, or *contributes to,* and may be non-, uni- or bidirectional in nature. Connecting lines often have arrowheads, indicating direction of flow within the graphic. Concept maps are used to communicate complex ideas, assess understanding, ease the learning process by integrating prior and new knowledge, and generate new ideas and concepts. Concept maps relate information to the user in hierarchy-like manner, flowing from general to more specific. They differ from true hierarchical diagrams in that each parent concept may have more than one offshoot or offspring concept originating from and being connected to it and in this manner resemble more of a network of organized and related information.

The major difference between concept maps and other graphic organizers is that concept maps bestow their greatest benefit to students directly by their fabrication. They promote higher level thinking skills by forcing those who construct them to make judicious decisions concerning prioritization of selected concepts and organization of new and prior information (Kinchin, 2000b). This finding is corroborated by more recent studies, such as evidence presented by Liu, Lin, and Tsai (2009). Liu et al. (2009)

introduced concept mapping to 25 senior high school students from four schools located in Taiwan. All subjects were instructed on a one-on-one basis until they were proficient in the construction of concept maps. Students were then given a list of terms concerning correlation and were allowed to add their own terms to the construction of their individual concept maps. Students were also interviewed after the map construction by the researchers. Study results indicated that concept mapping assisted in detecting student misconceptions concerning statistical correlation. Once students were able to recognize misconceptions, they were also able to make corrections in some instances. Though the validity of this study is not strong, it does outline a potential area for further research, and it demonstrates that concept mapping may be used to encourage higher level thought processes.

Concept maps are also unique in that they illustrate varied types of connections between concepts, allowing for the formation of different causal connections (Novak & Gowin, 1984). Sometimes known as *Mind Maps* (Eppler, 2006), *Semantic Trees* (Park & Calvo, 2008), *Knowledge Maps* (Gordon, 2000), or *Mindtools* (Jonassen, Carr, & Yueh, 1998), concept maps are one type of representation of knowledge in graphic format and include concepts and the relationships between these concepts. *Concepts* in this instance are considered to be general ideas or understandings inferred from groups of influential occurrences, often resulting from the melding of new information with prior knowledge. Concept mapping was developed as an instructional tool by Novak and his Cornell University research team in the 1970s to assist students with science classes (Novak & Gowin, 1984). When using concept mapping, other knowledge types such as facts, procedures, sequences, or plans may be interchanged for concepts. Asan (2007) noted that these maps are spatial representations of concepts whose interrelationships are presumed to relate to the knowledge structures stored in the human brain. The theoretical framework supporting concept mapping is considered to be largely consistent with cognitive learning theory, cognitive psychology, and what currently passes for constructivist epistemology and instructional methodology (Asan, 2007).

Concept maps are instructional tools that allow both the learner and the teacher to understand the learner's prior knowledge and add new information and ideas to the learner's preexisting database (Novak & Gowin, 1984). Novak and Gowin (1984) also noted that this characteristic allows educators to evaluate the cognitive retention structure and assist in refining existing thinking and logical reasoning of their students. Concept maps are often used in educational scenarios by having students analyze a previously built map, or having students build original maps in response to a focusing question or statement. Often, these preconstructed concept maps are the product of concept map mining. The Concept Map Miner automatically constructs concept maps using students' compositions. Both methods, using original or previously constructed maps, have been found to result in increases in student learning in many instances. However, results are mixed, and the effectiveness of concept mapping in many instances, especially with concept map mining, remains undetermined (Villalon & Calvo, 2008).

There are two major types of concept map: the standard map as developed by Novak (Novak & Cañas, 2006) that progresses in a hierarchical-like manner, and the cyclic concept map introduced by Safayeni, Derbentseva, and Cañas (2005). The more familiar traditional maps present information from the more general to specific and are composed of concepts, links, and relationships that respond to a question as they develop and present relationships. In this manner, seemingly unrelated bits of information are often linked, resulting in a stronger understanding of the concept in question (Novak & Cañas, 2006).

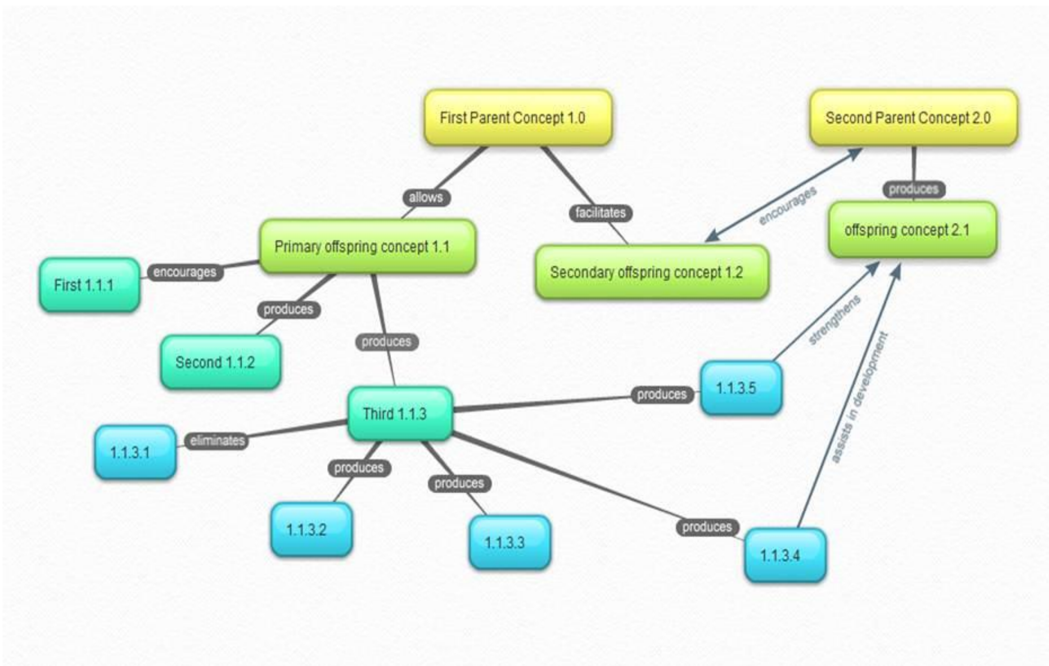

Figure 3. Traditional concept map made with https://bubbl.us website.

Cyclic concept maps are used to illustrate a connected system and are thought of as being dynamic, as opposed to the traditional maps which present connections between concepts or thinking that are more fixed. Cyclic maps demonstrate dynamic thinking because they present the working relationship of a system of interacting concepts while answering a quantifying question pertaining to the concept being investigated. This demonstration of working relationships often leads to more meaningful learning than the more traditional mapping. (Safayeni, Derbentseva, & Cañas, 2005).

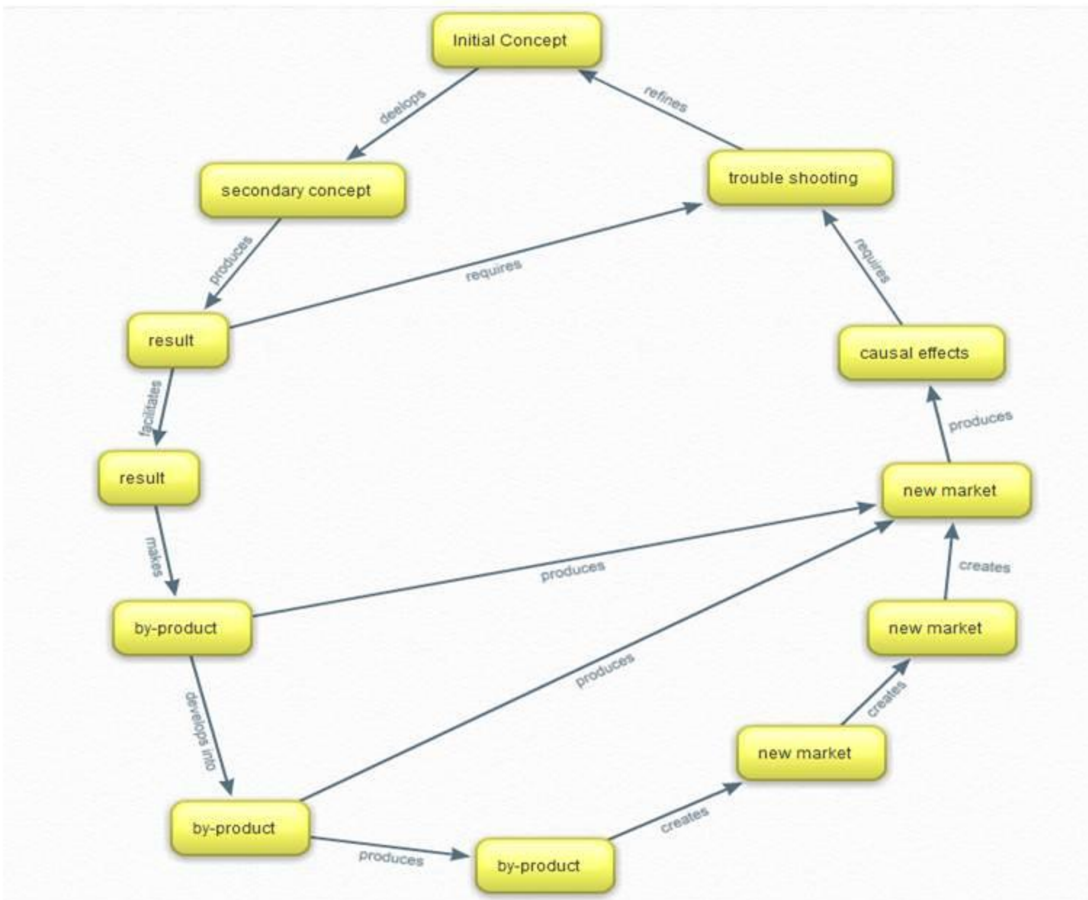

Figure 4. Cyclic concept map made using https://bubbl.us website.

Traditional concept maps are arranged with the most general concepts at the top of the map, becoming more detailed as the levels and connections move toward the bottom of the structure (Novak and Gowin, 1984). Novak and Gowin noted this modified hierarchical structure (modified in that each parent concept may have more than only one offspring concept) is based on Ausubel's theory that knowledge is also organized in hierarchical-like manner (Ausubel, 1968; Hebb, 2005). This multiple branching characteristic gives concept maps an appearance similar to organizational wire diagrams with connections between items and levels illustrating relationships. Concept maps, also known as mindmaps, display concepts in geometric shapes, usually circles and rectangles. These shapes containing concepts are then connected by lines and labeled with the relationships between the concepts (Kinchin & Cabot, 2007; Trochim & Trochim, 2006). Labels between concepts are referred to as linking words or linking phrases and describe the relationship between the connected concepts. Mind maps differ slightly from true concept maps in that they do not have the linking phrases illustrated between concepts (Novak & Cañas, 2006). Color on different levels and pertinent graphics may be used to enhance, elaborate, and emphasize points contained within the map and to act as further memory triggers (Miertschin & Willis, 2007). Individuals may also use an existing system, or devise their own system, for keeping the concepts organized. Such an original numbering system is illustrated in Figure 3.

Concept maps also display cross-links, which connect or relate different portions or domains of knowledge. Novak and Cañas (2008) defined cross-links as terms expressing creativity and cognitive function at the evaluation and synthesis levels, saying that these links often indicate logic leaps on the part of the map producer. Consequently, cross-links are highly indicative of understanding and creative thinking on the part of those constructing the maps (Novak & Cañas, 2008). These cross-links assist in connecting disparate concepts or pieces of information from one domain to the next, thus building associations between items that would not normally appear to be related (Novak & Cañas, 2006). Combinations of two pieces of information or concepts connected by linking words or phrases are referred to as propositions (Novak, 1990). Novak (2010) considered propositions as meaningful statements made of two or more concepts linked by words that form semantic units, also known as units of psychological meaning. Similarly, Ruiz-Primo, Schultz, and Shavelson (1997) defined propositions as the basic units used to judge the validity of conceptual relationships on a concept map.

Potential Uses for Concept Mapping

When working with graphic organizers, several instructional methods may be employed. This section gives a brief overview of some of those possible methods available to educators and other professionals. These methods include combinations of instructor and student centered along with individual and group learning. Concept maps were originally designed for individual learners; however they may also be used in collaborative learning with small groups. As described by Kinchen (2000a), concept maps have several noteworthy benefits. The construction of a concept map is an active intellectual process that promotes meaningful learning and metacognition. These tools are extremely versatile in that they can be understood and used by a wide range of individuals with varying characteristics and experiences while exhibiting usefulness across a varied spectrum of disparate topics. Students making concept maps in cooperative learning groups gain greater understanding of subject matter and concept relationships while experiencing positive gains in attitudes toward learning and achievement. Teachers may also use the student constructed maps to gain insight in the assessment of knowledge gains within specific domains (Kinchen, 2000b). This has become more prevalent within the past ten years, especially when efforts to digitally assess concept maps for multiple areas of instruction and learning have been more successful (Clariana & Koul, 2004; Clariana, Koul, & Salehi, 2006). Novak and Gowin (1984) cautioned users of concept maps that although they have many uses and positive attributes, concept maps become very unwieldy when 20 or more concepts are introduced. This limitation may be overcome in part by making the larger map into two or more smaller maps that can be related while being more explicit in their delivery of information (Novak & Gowin, 1984).

Individual concept mapping has many uses, including the promotion of conceptual understanding and as an assistive device in reflective instruction (Novak & Gowin, 1984). These constructions may also be used to gauge changes in an individual’s understanding of concepts (Littrell, 1999) and as tools to reduce student anxiety toward subject matter (Jegede, Alaiyemola, & Okebukola, 1990). Collaborative concept mapping has also proven to be a valuable learning tool in that it can serve as a vehicle to facilitate the establishment of common ground among learners while encouraging individual learning as knowledge is collectively gathered and assimilated (Cañas & Novak, 2000).

Novak (1991) noted that concept maps may be employed in any academic discipline, and are most productive when students are challenged by effective instructors who assist them in developing thinking skills. The inference here is that teachers and students have been trained in the use and construction of concept maps and encounter them in class on a regular basis. Students may work individually or in collaborative groups to construct structures from prepared forms or by originating their own maps. Any type of information may be used as a prompt, from a written article on a predetermined topic, notes taken during a class discussion, or information gathered from the Internet or other sources. In introductory lessons, students should be guided by instructors and encouraged to network among themselves in an effort toward understanding concepts and relationships prior to map construction (Novak & Gowin, 1984). Novak (1991) stated while constructing their concept maps, whether individually or in groups, students are organizing, conceptualizing, and presenting information as they understand it. By this process, students share their information from unique perspectives, often learning as much from each other as they do from the primary information sources while developing respect for the thoughts and contributions of others. The ability to develop and refine concepts within concept maps encourages higher-level thinking skills and greater cognition among students (Novak, 1991).

Instructors may also use concept maps as a revision tool to track student progress and comprehension. With this methodology, the teacher gives a short explanation to the class concerning the focus of the day's lesson while providing the major and minor concepts for each section of the lesson. Students are then instructed to construct within a time frame of less than five minutes a simple concept map that illustrates what will be learned during the class that day. Guastello, Beasley, and Sinatra (2000) conducted a study with 124 seventh grade students in an urban parochial school in the Brunswick section of Brooklyn, New York, to determine the effectiveness of concept mapping on science comprehension. They found that the method previously described was highly effective in involving more student participation and increasing student comprehension. Study results reflected an increase of approximately 120% for the treatment group posttest results as compared to those of the control group. Concept mapping with brainstorming is another strategy for the classroom. With this strategy, the instructor asks students, singly or in groups, to generate ideas or concepts associated with topics for class study. The resulting concepts are presented to the instructor or the class to elicit constructive criticism, adjusted, and organized by the students prior to investigation and final map construction (Guastello, Beasley, & Sinatra, 2000).

Guastello, Beasley, and Sinatra (2000) also conducted a study to determine the effects of concept mapping on low-achieving inner-city seventh graders and their concept comprehension in science. From a group of 147 Seventh grade students in a parochial school in the Brunswick section of Brooklyn, New York, 124 were identified as low performing on the Comprehensive Assessment Program (CAP). All participants in the study came from low socioeconomic circumstances and possessed reading levels and science achievement scores equivalent to the middle of the fifth grade. These 124 students were divided into two randomly selected groups of 62 identified as control and treatment groups. Each group was then given a pretest to determine knowledge prior to instruction. The control group was given a global overview of the main science lesson on the circulatory system in a traditional manner, without being encouraged to take notes or record any specifics. The treatment group was introduced to making concept maps and guided through the lesson and map construction by the teacher. At the end of the seventh day, students were given the maps they had created as study guides for the posttest. Both groups were then given a posttest to determine possible effects of the treatment. The entire study was conducted over a period of eight school days.

Study results indicated that the treatment group had experienced a more effective teaching experience with concept maps than members of the traditionally instructed control group. The pretest indicated that both groups scored similar results. The posttest indicated noticeable differences in scores, with the treatment group earning higher scores than the control group. These higher scores for the treatment group demonstrated an effect size of 5.98. This indicated that the treatment group experienced improved comprehension, as reflected by posttest scores, of approximately six standard deviations. These results seem to indicate that in this instance, concept mapping was an effective learning tool for enhancing science instruction presented to low achieving, lower socio-economic inner city seventh graders. Similar results could potentially be realized with other groups of varying social and geographic placement (Guastello, Beasley, & Sinatra, 2000).

Chang (2007) was able to externalize the mental models of students through the use of concept maps. Nine 13 year old seventh grade students from three different urban Taiwanese middle schools and five 15 year old ninth graders from one urban Taiwanese high school were chosen to participate in a study that investigated the concepts and misconceptions retained by students over time. In the case of the seventh graders, the time frame in question was 6 months, while the ninth grade students were approached and tested for concept retention two and one half years later. The concept learned and tested for retention over time was the homeostasis of blood sugar. Students were introduced to concept maps and given a short explanation of the graphic organizer prior to being instructed on the concept. Students were encouraged to use the concept mapping technique to describe their understanding of homeostasis of blood sugar during instruction. Study results indicated that seventh grade students retained more complete mental models of homeostasis of blood sugar than their ninth grade counterparts. This result was inconclusive as to cause, whether it was the shorter wait time between original learning and recollection, or if the differences in life experiences influenced memory retention of the mental model. Further, the study revealed that most students used prior experiences and real world behaviors to interpret and assimilate new concepts. Investigation of student concept maps revealed that, even though students may have a firm understanding of homeostasis, no students connected the concept directly to blood sugar, inferring that a strong association between homeostasis and blood sugar was lacking in the original exposure. The researcher concluded that concept maps can -be used as an effective presentation of internal mental models concerning complex and abstract concepts. This evidence could be made stronger by increasing the population and extending the geographic selection area to include more than one urban area in Taiwan. A stronger return may have been witnessed from the ninth grade participants had they had an opportunity to review the material regularly over the 2.5 year time frame. This last comment is supported with research by Ausubel (1968) and Novak (1991) whose research confirmed the idea that conceptually clear learning materials must be presented in a manner that relates to the learner's prior knowledge, indicating that concept maps can be used to identify a learner's existing knowledge prior to instruction (Chang, 2007).

In their quasiexperimental study of science concept learning among middle school students, Cifuentes and Hsieh (2004) found that test scores for students who had used pencil and paper to construct their visualizations improved, while those who had used computers to make their visualizations had scores that did not improve or were less than their study pretest scores. These findings indicated that students who did not possess a familiarity with computers, expressing mental concepts as visual products, or both, needed training in basic computer skills and computer-based visualization to successfully complete the construction of any digital organizational graphic. The lack of familiarity in the operation of the computer, the construction process of the concept map, or in some cases both circumstances, became a distraction to students, causing confusion and a lack of enthusiasm in completing the assigned task.

Based on these findings, Hsieh and Cifuentes (2006) created a computer-based study strategy to optimize learner computer visualization. Data collected in school settings employing the study strategy were quantitatively and qualitatively analyzed indicating that students who had received the training scored significantly higher on posttests than students who had not received the training. The researchers arrived at the conclusion that students were in need of training to use computer-based visualization effectively (Cifuentes & Hsieh, 2004). Though this conclusion seems to be a statement of common sense rather than a final finding made by researchers, it expresses the thought that training is necessary to achieve effectiveness with digital tools. This training of instructors in preparation for using new techniques and technologies is in itself problematic (Settlage, 2004). More seasoned, veteran teachers are often resistant to adopting and employing new teaching methodologies and technologies in their traditional settings which have worked since their inception (Samarawickrema & Stacey, 2007).

Novak and Cañas (2008) stated that, "The greatest challenge we may expect is to change the school situational factors in the direction of teacher as coach and learner from the prevailing model of teachers as disseminator of information." The current training infrastructure for educators will need considerable attention and reconfiguration before it is truly ready to fully address the concept of distance learning (Casey, 2008).

Clariana, Koul, and Clariana (2008) found that one form of computer-based visualization that enhances student organizational and conceptual abilities are concept maps, which are more quickly and easily created and revised than pencil-and-paper copies. Students possessing computer skills prior to their introduction to concept mapping are able to create and maintain (revise and correct) their products much more easily than those who have limited or circumscribed familiarity with technology. In a like manner, teachers trained and experienced with technologies involved with concept mapping are more readily able to monitor and evaluate students' understandings much more effectively (Clariana, Koul, & Clariana, 2008). The computer-based process of concept mapping alleviates much of the frustration experienced by students using pencil and paper (Hsieh & Cifuentes, 2006) while enabling students to visualize a topic entirely with other group members, thus fostering a more complete and shared understanding of the subject matter (Stoyanova & Kommers, 2002).

The differences between visual and verbal memory should also be taken into consideration when dealing with graphic organizers. An individuals' tendency to think verbally or visually is often the result of individual development and is difficult to predict without comprehensive testing (Rayner & Riding, 1997). Kirton (1976) assumed that these strategies related directly to traits of personality found in the individual that manifest early in life, such as, cognitive style. Klingner, Tversky, and Hanrahan, (2011) noted that visual presentation usually results higher performance when completing complicated tasks such as concept or schema learning and discerning patterns in data. Their study with twenty-four Stanford undergraduates suggests an advantage for visual over aural presentation, resulting in better immediate response with visual presentation. Greater cognitive load under aural presentation resulted in units of information retained in short-term memory. Klingner, Tversky, and Hanrahan (2011) also considered dual coding in the working memory being advantageous toward visual presentations. Dual coding theory is the work of Paivio (1971) and gives rise to the cognitive learning employing both verbal and visual representation. Dual mental representations seem to provide better cognitive understanding and memory than a single representation. This also allows retention of memories if one representation becomes corrupted. Visual presentation is more likely to result in two codes (visual and verbal) because individuals tend to name visual stimuli. The presence of two codes rather than just one could facilitate information processing as well as augmenting memory. Further, if memory is retained in the visual presentation format, the verbal format has more capability to process information (Klingner, Tversky, & Hanrahan, 2011). This dual coding facilitates the activities of many students using concept maps, in that the visual representation is often verbalized as the student attempts to learn the concept (Savery & Duffy, 1995).

Kinchin (2000a) and Novak and Gowin (1984) came to the conclusion through independent research that the potential strength of concept maps as a vehicle for teaching and learning is tremendous. With his comparative work of collaborative studies, Kinchin (2000a) noted that the planning of instructional sequences can be greatly aided by the coherent structure and illustration of vital links provided by concept mapping. The benefits of using concept maps in lesson preparation include increases in meaning, concept integration, and ownership of the material by the instructor, with a decrease in the possibility of the omission of key information. There is also an increase in the likelihood that the instructor can visualize multiple methods to construct meaning and more effectively acceptable to student perceptions. Kinchin (2000a) further stated that teachers who include concept maps in their lesson planning begin developing into ‘active innovators’ rather than the majority of educators who are more often the passive receivers of academic innovations. In this manner, educators assist in the development of the higher-level thinking skills and higher cognition of their students and themselves as well. Kinchin (2000a) was more introspective with his observations, stating that language is central to education and understanding among humans as a medium of information exchange. He equated language to concept mapping, stating that they possess the same educative value, also known as *felt significance*: that event that is experienced when the emotion of a new meaning is felt or realized by the learner. Though this is an interesting development, there has been no empirical evidence to demonstrate the accuracy of this belief. Further study to determine educative value attached to language and concept mapping is clearly indicated. Trifone (2006) used concept maps to motivate students in developing a more meaningful approach to learning biology. Four randomly selected, homogeneously grouped classes totaling 82 high-ability 10th-grade biology students participated in this eight month long study. Students were introduced to concept mapping in September using Inspiration™ Version 6 software. Students were then directed to construct concept maps for each subsequent science unit as it was introduced in the classroom. Teachers collected student maps and provided constructive criticism with feedback including the provision of questions to students designed to encourage more meaningful approaches to map construction. Feedback did not include corrections or filling in the excluded concepts. Maps were returned with feedback for student revisions and modifications. This process was continued throughout the school year, with concept maps being created for each unit presented in the classroom. Concept maps were scored by teachers using the system originated by Novak and Gowin (1984), similar to that found on table one of this chapter. Findings included that students who were classed as highly proficient map makers also scored very high grades on associated tests and quizzes. Results for lower proficiency mappers were parallel in that they scored lower on tests and quizzes, even when using their maps to study. A majority of lower proficiency mappers (75%) also noted that using concept mapping was very different from their understanding of what “studying” should be. Considering this point, perhaps the lower proficiency mappers were having prior experience preclude their effective use of mapping techniques as study aids (Trifone, 2006).

Moattari, Soleimani, Jamali Moghaddam, and Mehbodi (2013) conducted a quasiexperimental study with a convenience sample of 32- 4th year Iranian nursing students. After being randomly separated into two groups, Control and Treatment, the two groups were given a pretest and assigned comparable tasks. The control group began with normal clinical practices while the treatment group completed a 1-day workshop on clinical concept mapping. All participants were monitored for 10 weeks, after which they were given a posttest that measured the 17 dimensions of critical thinking in nursing. Evaluation of the posttest indicated that there was a significant difference between the cognitive critical thinking scores of the two groups. Although the Control group displayed improvement at the end of the ten week period, the Treatment group showed a greater degree of improvement in their understanding of clinical nursing and the use of critical thinking (mind habits). Treatment group participants also exhibited significant differences in 11 of the 17 dimensions of critical thinking. In their conclusion, these researchers noted the need for further studies to be conducted to verify their finding that concept mapping leads to development of critical thinking abilities in students (Moattari, Soleimani, Jamali Moghaddam, & Mehbodi, 2013).

Another successful study incorporating a quasi-experimental pretest–posttest–delayed posttest control group design was conducted by engaging 100 secondary chemistry students from three schools in Taraba State, Nigeria (Jack, 2014). This study was initiated in response to poor grades of chemistry students who were experiencing a combination of inadequate teaching and learning resources being fielded in a poor learning environment. The treatment group operated by constructing individual and collaborative concept maps while the control group used traditional summary, with both groups having anxiety as the moderating variable. Data collection instruments were the Chemistry Achievement Test for Students (CATS) and Chemistry Anxiety Scale (CAS). Three instructional periods of 45 minutes per week for 6 weeks were experienced by both groups between the pre and posttests. While conducting the study, it was noted that concept mapping acted as an effective instrument of paradigm shift in teaching abstract concepts in chemistry. The advantage to using concept maps appeared to be the consolidation of concrete and precise understanding of meanings and inter-relations of disparate concepts. Study findings included that when used as a teaching–learning strategy, concept mapping has a significant positive effect on learning in anxiety reduction (Jack, 2014). In very similar research, Adesola (2013) conducted a study using a pretest, posttest quasi and control group experimental design. Two secondary schools in Ogun State, Nigeria were identified as sources for 50 randomly selected students, 25 from each school, who served as participants for the study. The focus of this research was secondary school social studies and multiculturalism. Study findings included no real differences between gender or religion with regards to achievement or improvement when using concept maps. Findings also included a significant gain in test scores between pre and posttesting scores, indicating that meaningful learning and retention had taken place when concept mapping was incorporated into the instruction (Adesola, 2013)

In a qualitative study involving four graduate students, Gao, Thomson, and Shen (2013) examined the process of knowledge construction with students in an Educational Psychology course. Study participants, four American graduate students, used concept maps as primary data in a collaborative manner to establish initiate knowledge construction. Study findings indicated that the process of knowledge construction differed from one study participant to the next, seemingly based on individual domain expertise and learned concept map procedures. Further, language, used as a primary tool during the study, was identified as a source of tension by all participants during the collaborative learning activities. As observed by the researchers, the most effective knowledge construction took place when the group did not experience anxiety due to time constraints or peer pressure. This last observation is in contrast to findings by other researchers (Kotsopoulos, 2010; Andrejevic, 2005) who noted that tensions encountered during the collaborative learning that disrupted normalized learning patterns often created greater opportunities to develop and demonstrate critical thinking and problem solving skills while improving individual learning and participation. The researchers concluded that although collaborative concept mapping has the potential to facilitate knowledge construction, the activity of constructing concept maps does not in itself does not automatically ensure higher quality products or facilitate higher order thinking development (Gao, Thomson, and Shen, 2013).

Barchok, Too, and Ngeno (2013) used a Solomon-Four Group quasi-experimental research design in their study on the effect of Collaborative Concept Mapping (CCM) teaching strategy on Kenyan secondary school students' attitudes toward learning chemistry. A total of 166 out of a possible 4231 students from four secondary schools were randomly selected for the study. Participants identified as members of the treatment group were using the CCM teaching strategy for 8 weeks. During this same time, members of the control were taught using conventional teaching methods. The research instrument used as pre and posttest was pilot-tested for validity and reliability before being used in the study. In contrast to findings of other studies this research indicated that

CCM as a teaching strategy had no significant effect on students' knowledge acquisition (Barchok, Too, and Ngeno, 2013).

In light of the findings of these studies, it appears that concept mapping is much like any other educational tool. It is used across a wide swathe of the population with varying degrees of success and failure. Regardless of educational background, nationality, or culture, mixed results in research involving the use of concept maps for educational purposes continue to be generated. An intriguing concept for further research in this area is the differentiation of causation facilitating success or failure in the use of concept mapping.

Concept maps may effectively take on varying roles dependent upon the requirements of the user. Learners could use concept maps to make evident key concepts of propositions and relationships between concepts, while teachers might use them for organizing and evaluating. Curriculum planning is aided by having concept maps separate meaningful from trivial information and for choosing appropriate and meaningful examples. Concept maps help learners understand their responsibilities with their own education while clarifying the teacher's role and building an atmosphere of mutual understanding and respect between students and teachers in the classroom. As Kinchin (2000a) puts it, "Concept maps can foster cooperation between student and teacher (or child and school) in a battle in which the "monster" to be conquered is meaninglessness of information and victory is shared meaning".

Making Concept Maps

Novak and Gowin (1984) understood and related in their work that no single concept map can demonstrate the complete knowledge of a student a specific topic. They also noted that concept maps provide both the student and the instructor with a viable, current representation of the student's knowledge. Novak and Gowin (1984), along with other researchers (Winn & Snyder, 1996; Vanides, Yin, Tomita, & Ruiz-Primo, 2005) recommended that concept maps be constructed solely by the students using them, with everything in the student's own words. This recommendation was made after study results confirmed that students who made their own maps had ownership of their own work and were much more familiar with the concepts and relationships between concepts. The preconstructed forms having figures to be filled in by students should be avoided because they do not truly represent the cognitive process of each student. One objective of the process is to assist the learner in becoming a more flexible, original thinker. These same researchers go on to suggest that no more than 10 concepts pertinent to the subject domain be selected by either teacher or student for inclusion in each map. This reinforces the finding of Novak and Gowin (1984) that after 20 concepts, the construction becomes too unwieldy. Novak (2010) considered that the construction of concept maps focusing on knowledge of a specific domain is greatly affected by the context of the information involved and suggested that concept maps could be used to respond to a singular question, event, or phenomenon.

Anderson-Inman and Ditson (1999) suggest through their research that the ease of construction and maintenance of digital concept maps encourages the abilities of students to effectively gather and organize their conceptual ideas. Digital maps are easily created, independent of size restrictions, and can be quickly and easily revised, as compared to their hand-written counterparts that must often be completely re-done to incorporate additions, deletions, or simple changes. This ease of use makes students more prone to utilize digital organizers in study and research scenarios (Anderson-Inman & Ditson, 1999). Students possessing skill with computers are able to easily organize, modify, and maintain their individual constructions much more easily than working with analog (pencil and paper) materials (Royer & Royer, 2004). Lanzing (1998) surmised that the construction of digital concept maps facilitated within the structure dynamic linking, ease of storage, communication, analysis, and ease of adaptation and manipulation. These factors tend to make the digital experience much more positive in terms of visualization and accessibility, minimizing frustrations often experienced with pencil and paper constructions (Lanzing, 1998). The digital format also makes objective and quantifiable computer grading possible (Clariana, Koul, & Salehi, 2006).

The physical construction of concept maps in a digital environment allows students to relate, label, and describe perceived relationships between concepts to create an interrelated network of ideas and information (Jonassen, 2000; Jonassen, Carr, & Yueh, 1998). Tools most often used to accomplish the construction of such networks in a digital environment are Inspiration® (Brabec, Fisher, & Pitler, 2004; Royer & Royer, 2004), MindManger™ (Miertschin & Willis, 2007), CMap Tools (Cañas, Valerio, Lalinde-Pulido, Carvalho, & Arguedas, 2003), and Microsoft Visio (Miertschin & Willis, 2007) and Word (Luckowski, 2003). Also becoming more available and widely used are websites that enable the construction of graphic organizers free of charge. Several websites that are currently available are: Brainstorming Made Easy (Edelman and Amelyan, 2007) at https://bubbl.us/ ,Mindmup (Adzic, Vujnovic, & de Florinier, 2013) at http://www.mindmup.com/, Mindmeister (Hollauf & Vollmer, 2006) at http://www.mindmeister.com/, and Visual Thinking Evolution (Luna, Veiga, & Torrado, 2011) at http://www.wisemapping.com/. These applications, and others like them, allow students to construct concept maps without the tedious task of revising or correcting a paper copy written in pencil or pen. Ideas and concepts are easily displayed, recognized, and labeled to show relationships between concepts, with errors quickly and easily corrected (Anderson-Inman, 1996). Inspiration® is a popular graphic organizer for building true hierarchical structures (one offspring concept for each parent concept) that can be used in a limited fashion to make concept maps for identifying similarities and differences between concepts and elements of concepts. Higher-level thinking is encouraged by having students summarize text for the purpose of labeling their products (Brabec, Fisher, & Pitler, 2004). Royer and Royer (2004) investigated the difference between computer generated concept mapping using Inspiration® and map generation with pencil and paper. Findings included the creation of more complex maps by the group of 52 ninth and 10th grade biology students using Inspiration® as compared to the group using pencil and paper. This same study also revealed that when used properly, digital concept mapping promotes meaningful science learning (Royer & Royer, 2004). The difficulty in using Inspiration® appears when attempting to make associations between different elements of the hierarchical branching's. This characteristic of branching allows for successful analysis of relevant content, as long as it is linear in nature (occurring on the same branch). It does not permit the creation of arguments to support integrative statements by allowing comparisons of information from differing branches to be illustrated within the structure (Simone, Schmid, & McEwen, 2001).

Researchers (Miertschin & Willis, 2007) found that, although designed as an application for diagramming and computer assisted drafting, Microsoft Visio 2003 (Visio) could be easily adapted to concept mapping activities. In their study, Miertschin and Willis (2007) introduced the use of Visio to students working on an ongoing homework assignment, emphasizing the importance of knowledge and information visualization techniques along with the importance of effective knowledge management. In the semester-long project, students were introduced to 20 different concepts individually and in teams. Each week, students were assigned handouts or textbook chapters to review and resolve into related concepts, linking new concepts with those previously learned. Findings indicated an increased understanding among students of connections and relationships between domain concepts (Miertschin & Willis, 2007). The difficulties in using Visio are similar to those found in Inspiration®. Information units can only be related to concepts of origin or other information derived from them. Connections to other branches of the diagram cannot be made, meaning that relationships between existing elements must be illustrated in new branches that tend to complicate the final product. This makes the Inspiration® program a tool suitable for making true hierarchical illustrations but not truly suited for building concept maps that may include relationships with elements other than parent or offspring concepts. Further, connections cannot be labeled to specify the type of relationship between information units (Eppler, 2006). Visio should remain as a computer Assisted Drafting tool while being avoided as a consideration for concept mapping.

Miertschin and Willis (2007) also investigated MindManger™ concept mapping software, which is pen-enabled for the tablet pc (TPC) and gives users the choice of operating in pen-mode or converted into ASCII text by the handwriting recognition engine of the TPC operating system. MindManger™ mindmaps place the central concept in the center of the map, enclosed by a rectangle. Branches (as opposed to shapes) stemming from the central rectangle represent topics and sub-topics related to the central concept. Maps may be viewed in outline or presentation format. Map topics may be linked to data sources, such as documents, webpages, databases, or other maps. Maps remain dynamic when saved in the native MindManger™ format, and completed maps may be saved as images or web pages. One very useful feature is its integrated nature with Microsoft Office. Mindmaps may be exported to Word, PowerPoint, and Project, and map contents can be synchronized with an Outlook calendar or email (Miertschin & Willis, 2007). Presentations created by MindManger™ are similar to true concept maps. The possibilities for making comparisons and establishing relationships are present, but not entirely suited to the construction of concept maps. Each Mindmap made in this fashion focuses on a centrally placed concept that is not normally linked by characteristics to other ideas. These characteristics are often written out by the map author and may be difficult for some to understand. Further, the placement of the central concept makes linking to other concepts and ideas or showing cross-links a very difficult process.

Another widely used and versatile program for concept map construction is Cmap Tools, designed intentionally to support collaboration and sharing among peers, colleagues, students, and teachers by having the constructed concept maps serve as browsing interfaces for domains of knowledge. This sharing of information is accomplished by peer review and collaboration by annotations that can be added to areas of the concept map, and by Discussion Threads that can be added to linking phrases (Novak & Cañas, 2004). Cmap Tools allows the linking of a concept in a concept map to other information media anywhere on the Internet, including other concept maps, graphics, audio/video clips, text, Web pages, and other sources of information, thereby providing access to auxiliary information on the concept being investigated (Cañas, Valerio, Lalinde-Pulido, Carvalho, & Arguedas, 2003). The Cmap Tools program supports collaboration between users either synchronously (meaning two or more users editing the same concept map concurrently) or asynchronously through annotations, discussion threads, or using the Knowledge Soups (Cañas et al., 2003). The term *Knowledge Soup* describes the dynamically fluid nature of available information used for learning and communication (Sowa, 2006). This form of concept map construction seems ideal for the purposes of this study; however, it is not currently available in the school district.

Although designed primarily to be a word processing program, Microsoft Word (Word) may also be used to create mindmaps (Luckowski, 2003) (Trochim, 1989). In the absence of mind mapping or concept mapping applications, students who are equipped with a basic knowledge of Word may construct concept maps with very little difficulty. Instructions on the use of Word to construct a concept map are located in Figure 5, along with a resultant product.

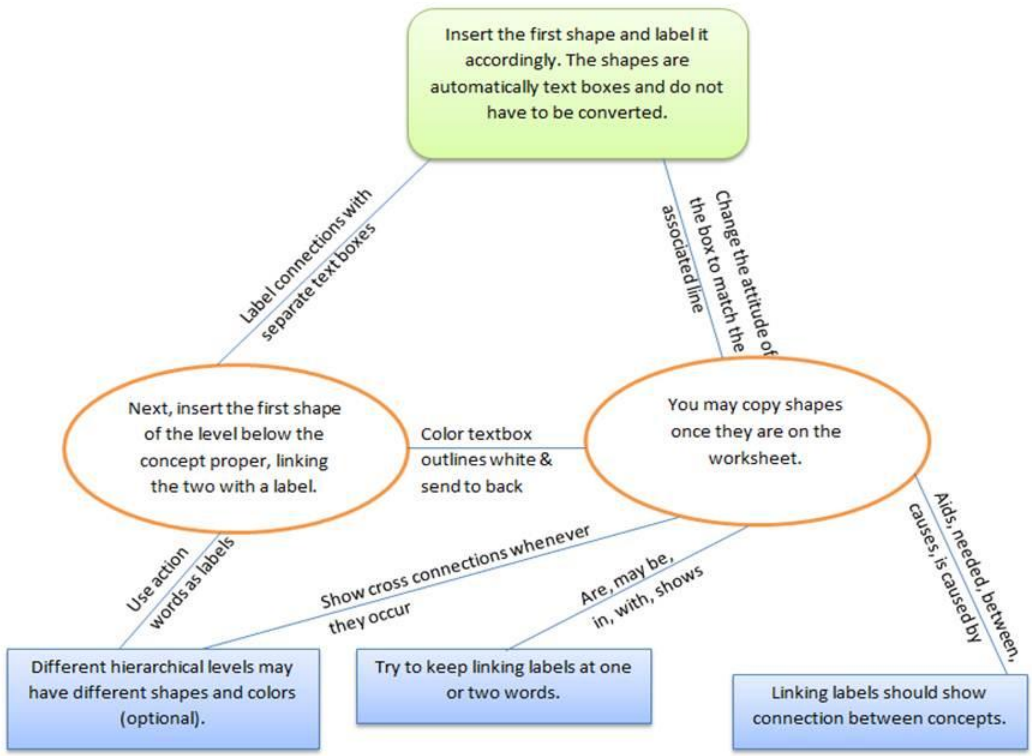

Figure 5. Using Microsoft Word to construct concept maps.

Due to the popularity of concept maps and their perceived effectiveness in the classroom, teachers and students may also go online and, after creating an account, construct concept maps free of charge. The availability of sites to assist in information organization becomes greater every day. Some of the more established and well known URLs where these sites can accessed include (but are not limited to): Brainstorming Made Easy (Edelman & Amelyan, 2007) at https://bubbl.us/ ,Mindmup (Adzic, Vujnovic,

& de Florinier, 2013) at http://www.mindmup.com/, Mindmeister (Hollauf & Vollmer, 2006) at http://www.mindmeister.com/, and Visual Thinking Evolution (Luna, Veiga, & Torrado, 2011) at http://www.wisemapping.com/.

Mindmup, at http://www.mindmup.com/, allows multiple offspring from parent concepts, avoiding the problem with hierarchical graphic displays, but will not allow free placement of nodes. Connections cannot be labeled, nor can connections be made from one level to the next, or to sibling elements. These factors make this free graphic production site less than optimal for concept map creation.

Mindmeister, at http://www.mindmeister.com/ allows multiple offspring from parent concepts to be created and allows free placement of offspring nodes. However, secondary offspring elements cannot be added to the original offspring, defaulting (attaching or originating from) to the original parent concept. Small clipart-like images can be added to nodes and connections can be made between offspring, but these connections could not be labeled. The site was also not free, as payment is required on a monthly basis to establish and maintain an account more permanent than the trial page.

Visual Thinking Evolution at http://www.wisemapping.com/ is a free site that presents itself as an appliance for education and business use. The owners of the site solicit donations from subscribers, though use of the entire site is without charge. Concept maps created with this site are similar in appearance to maps made with MindManger™, as investigated by Miertschin and Willis (2007). A concept may have multiple offspring elements that may in turn have multiple offspring. Nodes representing new concepts are not present, with information appearing on the connection between elements. This information may include relational information, information concerning the status of the offspring concept, or both. Although multiple offspring are possible with this system, offspring concepts may be connected only to their parent concept or to their own offspring (when acting as the parent concept). Connections from one offspring to the next, or from offspring concepts (that are not already connected) to the original parent concept are not possible.

Considering the options for concept map construction presented thus far, the Brainstorming Made Easy at https://bubbl.us/ demonstrates a great ease of use along with high quality of the final product. Users must create an account so that maps stored on the site can be recovered. Users may make up to three separate concept maps and store them in their accounts free of charge. If more storage or advanced attributes of the program are desired, the account can be charged a regular monthly fee. Separate maps may be removed from the site and stored in other locations, allowing multiple finished products to be maintained. There may be multiple parent concepts with multiple offspring that reflect relationships by connections to other concepts, such as offspring to non-sibling offspring or offspring to non-familial parent concept. This means that the main concept of the hierarchical-like diagram may give rise to sibling and offspring information items that can be cross-linked to any other item, regardless of status, with labeled links denoting relationships between the different elements. Links may be a simple line indicating connections, or a one or two headed arrow denoting direction of flow. Different levels may be color coded to indicate offspring, siblings and generational placement within the hierarchy. Working and final products may be stored on the web and on the individual hard drives of those using the program.

Novak and Gowin (1984) stated that when approached correctly, concept mapping can be a highly creative activity and may even assist in fostering creativity within students. These same researchers emphasize the fact that there is no one correct way to make a concept map. Differences, innovations, and creativity of each learner should be encouraged, with each student following a personal path to completion of their individual map reflecting their own prior knowledge, discoveries, and the links made between each. In this manner, Novak and Gowin (1984) surmised that new relationships and meanings not previously obvious may be recognized by students and teachers using concept maps.

Scoring Concept Maps

Concept maps are visual representations of acquired knowledge that display relationships between content terms by relative positioning of the terms and labeled lines that connect terms (Villalon & Calvo, 2008). Concept maps, along with other similar graphic organizers, appear to be the most effective method to measure the structural knowledge of content possessed by students (Jonassen, Beissner, & Yacci, 1993). Using this medium as an assessment tool accurately depends on consistency in how the map is constructed and how it is scored (Stoddart, Abrams, Gasper, & Canaday, 2000). To result in a valid evaluation, the concept map evaluative score and actual understanding by the student must be closely related. Even then, different scoring approaches may result in vastly different scores for the same individual maps or groups of maps (Novak & Gowin,

1984) were the first researchers to propose a manual scoring method for concept maps. Their thinking in this instance had evaluators considering propositions, levels of hierarchy, cross-links, and examples while considering the valid components occurring within the structure of the map. Once counted, the number of valid components was multiplied by a weighted factor for the category being evaluated and added to the scores of the other areas to produce a final score. As an example, table 1 lists the four major factors considered in the final concept map score. This table does not take into consideration the scoring of a criterion concept map. In such an instance, the student score would be divided by the set criterion score and expressed as a percentage. Students who score higher than the criterion would earn a score greater than 100%. The one weakness in this method was the establishment of valid components, which required the rater to have an extensive knowledge in the area in question.

Table 1

Concept Map Weighted Manual Scoring Example

	Concept map scoring model		
Characteristics	Raw score	Weighted factor	Final total
Valid relationships	14	1	14
Valid hierarchy	4	5	20
Valid cross links	2	10	20
Valid examples	4	1	4
		Final score	58

A similar method of manual map rating was devised by Lomask, Baron, Greig, and Harrison (1992). As with Novak and Gowin’s method, this alternative rating method stressed the importance of every component contained in the final structure. The major difference between the two is the method devised by Lomask et al. (1992), scoring concept maps by comparing them to an expert's map containing a finite number of terms and propositions. This comparison removes some of the ambiguity of prior knowledge on the part of the rater and the need for a subject matter expert as rater, while limiting the creativity and unique perspective of the individual (Koul, Clariana, & Salehi, 2005).

Researchers Kinchin, Hay, and Adams (2000) proposed an alternate scoring system based on their experiences with concept maps and biology content, in which the map score is dependent on the actual construction or organization of the final product. This scoring system considers knowledge as a more holistic variable instead of a variable comprised by the sum of its components. This methodology depends on the identification of progressive levels of comprehension on the part of raters by evaluating the overall structure (linear, spoke, net, etc…) of the complete map. The validity of these methods of manual rating is determined by the knowledge base of the rater. Unless the rater is a subject matter expert in the subject presented on the concept maps, the subsequent ratings may be inaccurate due to invalid connections or improper inclusion of concepts. Despite this obvious weakness, hand rating of concept maps is the most common rating system. This may be due to it being the first dependable rating system devised for concept maps, a product of observation in the validity of other methods, or simply the fact that other digital methods are not compatible with existing computer operating systems, or that the applications themselves are too costly or not developed well enough to be practical for many potential users.

Stoddart et al. (2000) found that different scoring methods affect observed correlations between concept map scores and scores obtained from other test formats such as essays or multiple-choice tests. Scoring methods used with concept maps that focus on the importance of major content items or propositions showed a high correlation to traditional multiple-choice tests. This high correlation is due to the common characteristic shared by both the scoring method and the test format: both focus on numbers of ideas, principles, or concepts expressed within the map (Stoddart et al., 2000). Although a concept map may exhibit several levels or kinds of information, no single scoring method can account for all facets of domain knowledge appearing in a concept map (Koul, Clariana, & Salehi, 2005).

McClure, Sonak, and Suen (1999) stated that raters are often overwhelmed by complex scoring rubrics. They determined that as the cognitive complexity of the scoring task increases, the reliability of concept map scores became proportionally decreased. This one discovery infers that only the simplest of scoring rubrics can be successfully and consistently used for classroom assessments employing the casual use of concept maps (McClure, Sonak, & Suen, 1999). This again calls into consideration the validity of hand scoring and the expertise of the rater in the selected subject matter.

Concept maps are often hand-scored by raters using rubrics designed to quantify content, meaning, and structural arrangement. Researchers (Ruiz-Primo & Shavelson, 1996) have noted that scoring approaches with the highest criterion-related validity and reliability compare specific features in student-constructed concept maps to those in expert referent maps. Taricani and Clariana (2006) stated that, due to the varied nature of information included and individual characteristics of different concept maps, raters must be (or must develop into) subject-matter experts in areas covered by the each map. For this one reason, hand scoring of concept maps is a tedious task that demands great time and experience from the rater prior to being consistently successful with the task (Taricani and Clariana, 2006). However, to recognize the unique and often innovative and original nature and responses of individuals constructing the maps, a scoring method must be considered that allows for these factors. The concept maps being constructed are (ideally) a melding of prior knowledge and new information creating what could be considered a synergistic learning situation with a product that can be expressed as an original idea or concept. Criterion scoring may be used to set a specific standard, but often does not account for the idiosyncratic nature of each individual student and may serve to stifle student development. In other words, the validity of the scoring method may be high within a focused area, but little or no consideration is granted to the student who may be following an independent or novel course with original ideas and additions to established concepts.

Recently, computer-based software has been used to evaluate concept maps. The first of these is the ALA-Mapper, which is a low-cost, easily operated and interpreted program that can be used to determine science content knowledge of students (Koul, Clariana, & Salehi, 2005). Clariana and Koul (2004) also investigated another software product known as the ALA-Reader can be used to translate text summaries into concept maps for proposition analysis, which can then be scored by the ALA-Mapper. In order to operate the ALA-Reader software, the user must generate a list of key terms with their synonyms and metonyms (totaling not more than 30 terms), which will be used by the software to locate co-occurrences in each sentence of the target essay. These co-occurrences are then converted into propositions and aggregated across all sentences into a proximity array. In this manner, the ALA-Reader software converts essays into concept map like structures for proposition analysis. The resulting concept maps as translated from written text gave students and instructors a varied perspective of their writings, especially when correct, incorrect and missing propositions were highlighted in the text (Clariana, & Koul, 2004). Clariana and Koul (2004) determined that essay scores on the ALA-Reader are more closely aligned with concept map scores because the resulting maps are visual representations of the written essays. The validity and accuracy of this grading method is a direct function of the key terms and their relation to the text as produced by students, meaning that the evaluation of the product is only as good as the material focusing concept map construction (GIGO: Garbage In, Garbage Out).

Pathfinder networks (*PFNets*) are a well-established method often used for automatically scoring open-ended concept maps (Jonassen, Beissner, & Yacci, 1993). *PFNets* reflect concepts as nodes and relationships as unlabeled connecting lines joining nodes. *PFNets* closely resemble true concept maps, but possess no linking terms between nodes. Links, linking terms, concepts, and complexity (determined by the overall layout of the physical map) are information components that can be automatically collected by the program (Yin, Vanides, Ruiz-Primo, Ayala, & Shavelson, 2004). Scoring open-ended concept maps is considerably more difficult than evaluating closed-ended concept mapping tasks in which the subject is provided with listings of predefined concepts and linking terms. However, Taricani and Clariana (2006) prefer scoring of open-ended concept maps, specifically because the open-ended maps allow individuals to use any concepts and linking terms present within their maps. For this reason, Taricani and Clariana (2006) consider the open-ended concept map to be the best method to ascertain students' knowledge structures being used at the time. In later research, Clariana and Taricani (2010) determined that open-ended map scores are connected by numbers of terms or items, links, and item location within the map during its creation. They found that adding to the complexity of the map in the form of increasing the number of terms decreased the predictive ability of the maps, making them a less reliable measure for student knowledge. Clariana, Koul, and Salehi (2005) originated a method for scoring open-ended concept maps that appears to be unique among scoring approaches because it considers link lines rather than the validity or correctness of the proposition. Further, their unique method expresses hierarchical and coordinate concept relations by using the relative spatial locations of concepts. Clariana et al. had test subjects read specific articles on the human circulatory of not more than 2400 words. They then constructed concept maps as summaries of the articles. The resulting concept maps were subjected to analysis by *ALA-Mapper* software tools to measure distance data, geometric distances between key terms in the concept maps, and compile link data (counting link lines connecting terms). The raw distance and link data were converted into *PFNets.* The concept maps and text summaries were also evaluated by five pairs of raters, resulting in five pairs of expert's *PFNets.* The machine created *PFNets* and those created by the human raters using rubrics were than compared to obtain a range of similarity scores. The researchers established that “automatically derived concept map scores can provide a relatively low-cost, easy to use, and easy to interpret measure of students’ science content knowledge” (Clariana et al., 2005). However, validity of scoring results remains a matter of the material applied as a standard comparison agent. In some cases this includes a list of concepts that should be included, while other standards include comparison to preconstructed maps displaying congruent concepts establishing a standard for an expected final product. Once again, this scoring method does not take into account the individuality of original student thinking and may serve to stifle the characteristic that should be nurtured and allowed to develop, that of higher-level thought.

Regardless of the type of scoring, human or computer-based, the total numbers of valid links and necessary connections (as compared to expert maps) contained within the resulting products are key factors in quantitative scoring methods (Kinchin, 2000). The scores produced by raters using a quantitative rubric vary less than scores obtained by using a qualitative rubric. This difference in rubric guided scores is a function of the procedural and philosophical differences evident in the qualitative (holistic) and quantitative (analytic) rubrics employed (Kinchin, Hay, & Adams, 2000). This difference in scoring rubrics constitutes a significant variable when considering concept map assisted learning. Other variables to consider are the software design and the familiarity, capabilities, and innovative abilities of both the concept map creators and evaluators (Koul, Clariana, & Salehi, 2005).

For the purposes of this study, concept maps were constructed using the bubbl.us web site. This site is available on the Internet and is free for use after setting up an account. An alternate construction application, should the Internet not be available, is Microsoft Word. Although it is a more difficult application to work with, it is readily available to participants and should prove useful as a substitute. The considered scoring method was hand scoring as presented by Novak and Gowin (1984), sans criterion scoring. This seems to be the most reasonable of the scoring methods with respect to student capabilities and availability within the district. Scoring of concept maps was be accomplished by the school librarian, with assistance from members of the school science department members. Further information concerning this facet of the study will be presented in chapter three.

Distance or Web-Based Learning and Concept Maps

Distance learning has been reflecting an egalitarian approach to education for the last three hundred years, first with mail-order vocational courses and more recently delivered with technology over the Internet. Moller, Robison, and Huett (2012) emphasize the need for innovation adoption, including new or altered instructional delivery by educators, to meet the developing requirements of students in terms of cognitive processing with networking, learning, and problem solving. The common elements between services provided at its inception and the present are the asynchronous nature of the instruction and the lack of a traditional student-teacher “face-to-face” working relationship (Casey, 2008). Garrison and Shale (1987) characterize distance education as having non-contiguous group members who use technology to facilitate communication in support of the educational process between instructor and student. Casey (2008) noted that the factors making distance learning popular in the United States today include the rapid advancement of technology, the great geographic and socio-economic distances involved, and the individual thirst for knowledge, with the understanding that this knowledge may result in personal advancement and improvement. Khalifa and Lam (2002) report that these factors may be partially responsible for the improvement in attitude and achievement evidenced by students as they become more comfortable with the learner-controlled web-based instruction of distance learning. Khalifa and Lam (2002) also noted that there are three predominant types of web-based instruction currently employed in education: Computer-Mediated Communication (CMC), Hypertext/Hypermedia, and Computer-Based Training (CBT). CMC is defined as the use of computers, possibly in an asynchronous manner, for collaboration of spatially separated individuals in achieving a common goal. Hypermedia, derived from hypertext, is a method for organizing and displaying different forms of information (text, sound, graphics, animations, etc…) in a non-linear, non-sequential fashion. CBT takes the form of real-time activities with the learner interacting with the computer to fulfill requirements posed by questionnaires, tests, or tutorials that may or may not be interactive (Khalifa & Lam, 2002).

Questions to be asked about concept mapping in conjunction with distance learning are numerous, since the combination of the two concepts is still relatively new. Concept mapping has been and continues to be used in the traditional classroom with instructor supervision. Can it also be an asset to student learning in a distance-learning scenario? Can concept mapping also be used in a self-paced, self-directed student centered situation in which teacher involvement is minimized? These questions gain importance as distance learning and the need for students to develop higher-level thinking skills earlier (to meet the challenge of our increasing knowledge base) become more prevalent.

Distance learning (Internet) technologies are becoming integral components of education, facilitating the learning process in many contexts, both formal and informal (Hill, Song, & West, 2009). Indeed, what has been sufficient in terms of instructional learning environments up until the last twenty years or so may no longer be adequate to meet the needs of the technology-savvy learners of the 21st century. Distance education in the United States has flourished for three main reasons: the great geographic and socioeconomic distances between individuals and institutions, the growing realization that education is a necessary factor in our current society, and the rapid advancement seen across the board in all fields of technology (Casey, 2008). Hill, Song, and West (2009) advocate the establishment of web-based learning environments as a more promising venue offering opportunities for relevant technology-oriented learning. This promise can only be realized with the commitment of all shareholders in leaving the traditional learning scenario for a different, alternate learning experience. This is a factor that has not been fully embraced by the learning community, even though it is gaining popularity (Hill, Song, & West, 2009). Moller, Robison, and Huett (2012) state that distance learning has become “an irresistible force in mainstream education and training”, while explaining that we as a nation grown into a generation of distance learning in which technology-enabled learning environments are widely facilitated.

With the understanding of the benefits of distance education adoption, the realization of significant changes for the conceptualization, funding, and design and delivery of instruction will impact all members of the education industry, from learners to policymakers (Moore & Kearsley, 2011). Although a many educational institutions are now embracing distance learning as a factor for consideration and implementation, Samarawickrema and Stacey (2007) found stable adoption of the technology can only be managed through a holistic approach to staff development, considering performance management and recognition of individual development. This implies that institutions and instructors must adapt and develop technology based attributes for staff development and maintenance of technology skills prior to having students respond to a technology-rich learning environment (Samarawickrema & Stacey, 2007). Researchers Cifuentes and Hsieh (2004) found in one controlled study that computers could serve as distracting agents to learners using them. This study involved the visualization of information as a learning tool. Visualization is any process or tool (including concept mapping) that, according to Jonassen, Carr, and Yueh (1998), "…helps humans to represent and convey those mental images, usually not in the same form they are generated mentally, but as rough approximations of those mental images".

Concept mapping has been a learning tool used in many traditional classrooms since its introduction in the 1970s. In numerous studies (as reported in this chapter thus far) it has been instructor supervised with varying degrees of success. D'Antoni, Zipp, Olson, and Cahill (2010) used concept maps to assist medical students in their courses. Twenty-five medical students were given a 30 minute introduction to concept mapping and told to use the tool in their preparation for daily exercises and tests. Initially there was no discernible change, however, over the next several weeks, as students became more familiar with concept map construction, their understanding of material improved, as reflected by their grades, along with their performance during practical training sessions. One note concerning this instance mentioned that despite the short training and limited guidance in the use of concept maps, these students experienced success with the learning tool. The inference pertaining to the success with concept mapping was that these are very dedicated students who are self-starters, motivated to success, and in possession of finely honed higher-level thinking skills (D'Antoni et al., 2010). Although impressive and somewhat thought provoking, this combination of factors has not been proven empirically to be the basis for success with concept mapping in this instance. What has been proven is that in most cases reported thus far, the correct use of concept maps requires adequate training and guided practice to be truly effective as a learning tool (Novak & Gowin, 1984).

The evidence concerning the use of concept mapping in a distance-learning scenario is very scarce. With adequate training and guidance prior to the event, concept mapping should prove to be effective when coupled with distance learning; however this remains to be determined. Also rare is the use of concept maps as a tool in a self-paced scenario with minimal instructor guidance or intervention. This topic appears to lack adequate investigation, reflecting a lack of empirical evidence establishing or rejecting concept mapping as a valid tool for distance learning. Traditionally, instructors guide the use of concept maps in the classroom very closely, hoping to maximize the academic return by participating students. The only noted exception encountered in the literature review was the study conducted by D'Antoni et al. Thus, there is also a real paucity of information concerning the usefulness of concept mapping in a self-paced scenario with limited instructor involvement after the initial introduction of the tool. There is a need for further research into both areas, distance learning and self-paced student centered use, concerning the construction and application of concept maps.

Current Thinking

Novak and Cañas (2008) report some insight into the theoretical framework of learning and the use of concept maps. Early concept acquisition is primarily a discovery learning process in which individuals observe patterns and regular occurrences and equate them with events or objects identified with language or symbols by older individuals. This type of learning takes place up to the age of three, when new learning becomes more heavily dependent on language. This new learning is termed reception learning and is perpetuated by inquiry to clarify relationships between old knowledge and concepts and the newer information being encountered. This type of learning is greatly mediated by “hands-on” activities with objects used as learning props to provide concrete experiences (Novak & Cañas, 2008).

Ausubel (1968) made a great distinction between rote learning (memorization through repetition) and meaningful learning (acquiring information that is relative to the individual). He emphasized that meaningful learning is dependent on three conditions:

1. Information to be learned must be presented with language relatable to prior knowledge and must be conceptually understandable.

2. Relevant prior knowledge must be present.

3. The learner must take ownership of the learning and make it meaningful.

Novak and Cañas (2008) further noted that the creation of new knowledge is a constructive process involving the combining of prior and new knowledge to revise or form new concepts. Individuals constructing concept maps are involved in the creative process and can be severely challenged if the majority of their learning has been by rote. Rote learning assists minimally in developing knowledge structures and cannot be the foundation for higher-level thought processing, creative thinking, or problem solving. In fact, this meaningful learning process is used by scientists, mathematicians, and discipline experts when constructing new knowledge and concepts. Novak forwarded the argument that, “new knowledge creation is nothing more than a relatively high level of meaningful learning accomplished by individuals who have a well-organized knowledge structure in the particular area of knowledge, and also a strong emotional commitment to persist in finding new meanings”. There is currently a growing understanding and agreement among epistemologists and philosophers that the creation of new knowledge is constructive in nature, developing new meanings and methods to share these meanings and methods with others (Novak & Cañas, 2008).

Kinchin (2011), along with Novak and Cañas (2008), qualified concept maps as just one of an array of graphic learning devices that each has their own strong and weak points. For example, a Venn diagram allows the viewing of different characteristics or elements of a group while allowing the user to see which characteristics are shared by groups and which are unique. Venn diagrams are very useful in showing relationships;

however they are limited to the numbers and types of groups that can be compared in a single diagram (DiCecco & Gleason, 2002). Similarly, Mindmaps are extremely helpful in note taking, but their radiating shape and unlabeled links limit their expressive impact (Eppler, 2006). D'Antoni, Zipp, Olson, and Cahill (2010) used mind maps in a study with 131 medical students and determined that there was no significant difference in pre and posttest results between the control and treatment groups. This may have been the result of the participants lacking adequate training in the use of mind maps, having been given a 30-minute introduction prior to the study. Also, mind mapping as a learning strategy yields similar results in short-term, domain-based knowledge when compared to standard note-taking (D'Antoni et al., 2010). Concept mapping facilitates the learning process by enabling the reflective development of ideas by allowing the user to see varying concepts and how these concepts are related with the use of labelled links (Novak & Cañas, 2008). For this single characteristic, Novak and Cañas (2008) presumed that it is the mapping process itself that is the most important element in supporting effective learning. Novak and Cañas (2008) claimed that the mapping process is "one of the most powerful tools to help students think about their own learning".

Despite these assertions, current thinking concerning the use of concept maps as tools for higher learning is mixed. Novak (2010) supported concept mapping, giving the example of the secondary school in Costa Rica that began using concept mapping in all grades and subject areas. The first year showed a decline in overall grades. However, within 4 years of its inception, the concept mapping program produced results reflecting a 100% passing rate for state exams by all students, as compared to previous rates of 60%

or below. This situation presents a special case, in that teaching patterns and student learning patterns went through substantial changes during the first year. These changes included instruction in the construction and use of concept maps by both teachers and students. Further, after becoming invested in the process of meaningful learning associated with the concept mapping program, student gains were more than knowledge, as reflected on state exam scores. Students also reported they were more confident in their own abilities and experienced less stress in the academic setting (Novak, 2010). It should be noted that this situation involved total immersion of the learning community with their use of concept mapping. Every classroom, including every teacher and every student, participated in the program. The final results of this study indicate that concept mapping can make a great difference under the correct circumstances.

Novak's findings are similar to those of Hwang, Shi, and Chu, (2011), who developed a concept mapping approach that could be used to formulate collaborative mind tools, specifically mind maps, to facilitate context-aware ubiquitous learning. Their experimental findings indicated that without effective learning strategies or training with the Mindtools (concept maps), student performance could prove to be disappointing. Student learning with the collaborative Mindtool was significantly better than learning accomplished with other methods, with significant improvements in self-efficacy with computer skills and learning abilities and student attitudes toward learning being noted. Hwang, Shi, and Chu (2011) also recognized limitations in addition to the need for training by all participants. Quality of final products will be limited to the capabilities of the available technology and may not be compatible between devices. Also, the success rate of the program may be due in part to the Hawthorne Effect, in which a new technology is focused upon and used almost exclusively because it is new. A final comment concerning grading of the concept maps by teachers indicated that without an automatic scoring function with an easily understood operating procedure, the burden of evaluating the final products of students could be substantial (Hwang, Shi, & Chu, 2011).

Kinchin (2011) noted that one of the major obstacles to the adoption and productive use of concept maps lies with the instructors. Teachers often see learning as an “instructivist” (learning is information transfer) activity rather than “constructivist” (students formulate their own meanings and associations between new and preexisting knowledge). Teachers also often see working with concept maps as an add-on activity rather than a core activity to facilitate the manipulation and synthesis of information. Kinchin (2011) further implies that concept mapping can, with a constructivist approach, can assist in the development of student abilities to process and transform knowledge structures within any given domain, eventually making them experts within those domains being manipulated, however this assertion has yet to be verified with empirical evidence.

In addition to encouraging higher-level thinking, concept maps can be used for evaluation, curriculum planning, and the capturing and archiving of expert knowledge. The use of concept maps for learning evaluation is a new concept that is only now being seriously scrutinized by some academic organizations. Using concept maps instead of traditional testing instruments may prove an interesting exercise in the flexibility of the tool and the commitment and acceptance of the instructors involved in such an endeavor.

To ensure that concept mapping is included in daily instruction and evaluation, the movement to change testing in the classroom should be a top-down program, starting with the state that makes standardized tests and moving down through the ranks to the classrooms where the testing takes place.

A newer use for concept maps that is becoming more prevalent is using them to capture and retain the "tacit" knowledge of subject matter experts. Tacit knowledge is acquired over years and involves experiences dealing with encountering, considering, and responding. It is knowledge that often cannot be easily articulated by the owners, who often mention the need to "get a feeling for what's going on". The value of this particular use for concept maps has not yet been established, however it does appear to have promise, understanding that valuable experiential information is lost whenever leaves a position, leaves the workforce, or passes away (Novak & Cañas, 2008).

The two major research questions considered by this quantitative study were:

1. What is the relationship between concept mapping and knowledge acquisition by students in a learning environment utilizing a concept mapping tool in a distance learning scenario to learn 10th grade science?
2. Is there a relationship between the quality of the concept map created by individual students and knowledge acquisition demonstrated by the differences in scores between pre and posttests?

This first question investigated by this study set the learner in a reception learning situation, using inquiry to clarify relationships between old knowledge and concepts and the newer information being encountered. The learning itself was a "hands-on", constructive process as subjects connect prior knowledge with new concepts while using digital tools to create concept maps. This was is in line with current thinking concerning effective learning as described by Novak and Cañas (2008). The intent of the study was also to investigate whether the learning being accomplished is meaningful in terms presented by Ausubel (1968). Although the three conditions for meaningful learning were present, the degree to which meaningful learning is accomplished remains to be seen.

The second question presented for investigation with this study endeavored to establish a connection between the quality of the maps produced by study subjects and the differences in pre and post test scores. The thinking here was that participants with more complete and correct maps should reflect greater differences between the two test scores than participants whose maps were of lesser quality. This was dependent, at least in part, on the quality of the scoring conducted by the designated subject matter expert. The correlation between thorough investigation of the subject matter and the degree of meaningful learning was a standard in the reception learning scenario. More information concerning the results of both questions is presented in chapter four of this document.

Considerations

Graphic organizers, specifically concept maps, are visual representations illustrating relationships between ideas, concepts, or separate pieces of information. These graphic organizers reflect hierarchical, sequential, and causal relationships between concepts, thus facilitating an understanding of often abstract ideas with visual representations. To be completely successful with the implementation of concept mapping as a graphic organizer in the classroom, students and instructors must be trained in the construction and use of these tools in conjunction with the technology to be jointly incorporated. The primary focus of this study is the use of concept maps in a distance learning scenario to facilitate the learning of 10th grade science.

Despite being widely used and investigated for almost 50 years, much remains in question concerning the efficiency and usefulness of graphic organizers as tools for distance learning. Their merits and potential to improve individual and group learning in such a setting remain unknown. While some researchers (Stoddart, Abrams, Gasper, & Canaday, 2000) found that computers with visualization improved individual learning, others (Cifuentes & Hsieh, 2004) claimed these same elements detracted from learning. Concept maps can be used to promote active learning and develop conceptual understanding of content by processing and relating information rather than having students memorizing definitions and lines of text, thus emphasizing the implementation process crucial to graphic organizer usage (Novak, 2007; 2010). Novak (2010) also stated that meaningful learning "underlies the constructive integration of thinking, feeling, and acting leading to empowerment for commitment and responsibility."

The past twenty years have seen numerous studies documenting the benefits of concept mapping within the traditional classroom environment. These studies help to solidify the understanding that, in many instances, concept maps can be very effective tools to assist with student understanding (King & Kitchener, 1994; Littrell, 1999). They may be influential in helping to develop and encourage higher-level thought processes (Cicognani, 2000; Jonassen, Carr, & Yueh, 1998; King & Kitchener, 1994; Miertschin & Willis, 2007) and improving attitudes toward the disciplines reflected in the concept maps (Littrell, 1999), while allowing instructors to have a more definitive view of student understanding (Lanzing, 1998). They may also serve to improve student text learning (Chang, Sung, & Chen, 2001, 2002). Chularut and DeBacker (2004) noted that the regular use of concept maps may well have a positive influence not only on student achievement. Although originally developed to assist individual learners, collaborative use of concept maps emphasizes brainstorming among group members leading to visualization of new ideas and synthesis of unique concepts (Cicognani, 2000; Simone, Schmid, & McEwen, 2001; Novak, 2010). Freeman and Jessup (2004) hypothesize that the beneficial effect of concept mapping is dependent upon (among other things) individual involvement and enabling shared understanding. Novak and Gowin (1984) observed that concept mapping could be beneficial in the improvement of marketing and management practices in the workplace. They also noted that concept maps seemed facilitate the higher-level thinking and learning processes in academic settings, especially with explicit and tacit knowledge (Novak & Gowin, 1984). Research indicates that concept maps are easily adopted and used, appropriate for communication, and are seen as having positive effects on the user (Freeman & Jessup, 2004). Despite the wide use of Concept Maps in educational and work settings, there remain many unresolved theoretical issues concerning their use. Concept maps have been used in numerous traditional academic settings (Asan, 2007) (Clayton, 2006) (Kinchin, 2011) (Miertschin & Willis, 2007) (Ruiz-Primo, 2000) (Schneider & Krajcik, 2002). In these settings, they have been primarily instructor driven, with students responding to regular direction in the classroom. With the incorporation of the computer and Internet in classrooms on a more frequent basis, much of the instruction has included many of the elements of online learning (Cicognani, 2000) Hill, J. R., Song, L., and West, R. E. (2009). Distance learning, in which students and instructors are often geographically removed from one another, is becoming more prevalent in current education, reaching a large segment of the population that possibly have not been included due to physical distance and boundaries (Moore & Kearsley, 2011; Garrison & Shale, 1987). The use of concept maps to enrich distance learning is also becoming more frequent among learning scenarios, however the vast majority of these tend to remain instructor driven (Samarawickrema & Stacey, 2007) (Tsai, Lin, & Yuan, 2001). One unresolved theoretical issue that has not been adequately investigated is the distance learning scenario with the self-directed student. This self-directed distance learning scenario was examined during the course of this study. This was accomplished by first comparing pretest scores of the control and treatment groups. Other statistical comparisons included a comparison of pre and posttest scores between and within the control and treatment groups. The information gathered from these comparisons should give some indication as to the effectiveness of the concept maps as a learning tool in the self-directed distance learning scenario. Another comparison included a possible link to the change between pre and posttest scores and the quality of concept maps created by individuals in the treatment group. Another area of concern with this study is the actual grading of the resultant concept maps. Most of the scoring methods discussed earlier are not accessible or available to our campus. In light of this factor, the hand scoring method as described by Novak and Gowin (1984) was incorporated. This precluded difficulties with obtaining and using computerized grading systems and possibly added an additional degree of validity to the results.

A final area for consideration was the training period and material of the treatment group in the use of concept maps. Kinchin (2011) noted in his research that instruction can become a major obstacle to the successful adoption and productive use of concept maps by students. This includes the period of familiarization and the instructional methodology. Two weeks were set aside for students to familiarize with the tool prior to beginning the 4 week study. The concept mapping instructor delivered instruction emphasizing the "constructivist" approach, in which students formulate their own meanings and associations between new and preexisting knowledge (Kinchin, 2011). The instructional time frame and the type of instruction appeared adequate to allow students to become proficient with the construction and use of their concept maps.

Conclusions

The focus of this experimental study was the investigation of the effectiveness of concept maps in a student-centered distance learning scenario. The understanding is that concept maps are only one of a large group of graphic organizers that are available to enhance and facilitate learning and the development of higher order thinking skills using "constructivist" methodology in which students formulate their own meanings and associations between new and preexisting knowledge (Kinchin, 2011; DiCecco & Gleason, 2002). It is strongly presumed that concept mapping facilitates the learning process by enabling the reflective development of ideas, allowing the user to see varying concepts and how these concepts are related with the use of labelled links

(Novak & Cañas, 2008). Concept mapping has facilitated meaningful learning, with most examples being presented in the traditional classroom (Novak & Cañas, 2008). Some situations have occurred involving minimal instruction and teacher guidance (D'Antoni et al., 2010), but the importance of adequate training prior to concept map construction has been established. Further, the commitment reflected by participants has a tremendous amount of influence on the success of any new program, as seen by gains made after the total immersion of an entire school in Costa Rico into the use of concept maps (Novak, 2010). Distance education has flourished and is a growing reality in the academic arena (Casey, 2008; Samarawickrema & Stacey, 2007). The question of the effectiveness of concept mapping coupled with distance learning remains. The factor of minimal instructor guidance is also in question, with most examples found in the literature search being instructor driven. Finally, no conclusive evidence has been reported concerning the quality of resultant concept maps and improvements in concept understanding, as reflected by differences in pre and posttest results.

Concept mapping may prove to be viable as a learning strategy that can assist students in visualizing the content and relationships necessary for an understanding of 10th grade science. The quantitative approach seemed the best form of research to address this issue. Chapter three addresses the research design of this experimental study investigating the potential of concept maps as a learning tool for students in distance learning scenarios in detail.

Chapter 3: Methodology

The purpose of this experimental quantitative study was to test the effectiveness of concept mapping when used as a study device for 10th grade science students in a distance learning scenario. Chang, Sung, and Chen (2001) defined *concept mapping* as domain knowledge represented visually and connected with labeled lines that represent relationships between concepts. Novak and Cañas (2008) noted that, although traditional classrooms and learning scenarios are still the most common educational mode, distance learning situations are becoming more frequent. The efficiency (amount and speed for acquisition and accuracy) of learning for students in situations where the instructor is geographically distant or absent is becoming more relevant (Casey, 2008). This chapter presents information on research design and rationale, along with methodology and concerns pertaining to validity.

Research Questions and Hypotheses

The two major research questions considered by this quantitative study are listed below:

1. What is the relationship between concept mapping and knowledge acquisition by students in a learning environment using a concept mapping tool in a distance learning scenario to learn 10th grade science?

   Hypothesis (H_{a1}): The learning reflected by the comparison of the mean difference of the treatment group's learning will be different when compared to the mean difference in the learning of the control group.

Null hypothesis (H_{01}): There will be little or no difference in learning gain as reflected by comparison of the mean gain scores for treatment and control groups.

2. Is there a relationship between the quality of the concept map created by individual students and knowledge acquisition demonstrated by the differences in scores between pre and posttests?

Hypothesis (H_{a2}): Gain scores of students of the treatment group who have constructed a concept map having higher quality scores will differ significantly from gain scores of students who have constructed lower quality concept maps.

Null hypothesis (H_{02}): There will be no significant relationship in learning gains related to the quality scores of constructed concept maps.

Research Method

This experimental quantitative study was designed to investigate the use of concept maps by students learning 10^{th} grade science in a distance learning scenario in terms of learning gains realized. This study was designed to identify differences in pre-post learning gains by comparing test scores of two groups, one using concept maps (treatment group) to assist with research, and one conducting research without using concept maps (control group). The study was also designed to determine any relationship of increases in test scores for the treatment group with respect to the quality of concept maps constructed by students.

Results in any quantitative study involve the existence of possible statistical relationships between independent and dependent variables. The independent variables of this study were the frequency and quality of concept mapping employed by students in their self-studies. The dependent variable was the resulting change in student understanding of select science concepts, as demonstrated by comparison between pre and posttest results of the two groups and within two parts of the treatment group. This was an experimental pretest, posttest, two-group comparison study that was constructivist in nature, in that each participant was to come to a personal interpretation of the concepts being investigated. This approach was appropriate for the study in that it was aligned with the research questions, reduced constructs to specific variables, and used measurement as observation (Creswell, 2003). This design allowed for initial and terminal comparisons prior to and after treatment between two randomly assigned groups. The design also isolated the effects of the treatments, allowing inferences to be made about those effects. The data collected from this study had the potential to assist in identifying an effective graphic organizing tool for distance learning. I also investigated a possible correlation between the quality of concept maps constructed and increases between pre and posttest scores.

Research Design and Protocol

This quantitative experimental study was designed to compare students who learned 10th grade science while assisted by concept maps in a distance learning scenario with students who did not. Other individuals and groups not experiencing the 10th grade science curriculum were not considered for participation in the study. Due to the small size of the available study sample (48 students), having 100% participation was extremely important to the study outcome. As presented on Table 2, the research effort began with contacting parents and guardians to secure informed consent. The letter presented in Appendix B contains a complete description of the study in anticipation of parental agreement and consent for student participation. This effort resulted in nonconsent by some parents and guardians. These parents were contacted separately in the hope of resolving any issues preventing positive consent. Students who did not participate in the study remained with their homeroom teachers during the 45-minute prep period and used the time as a study hall. Although this might have introduced a sampling bias, it assisted in establishing a stronger group for the final statistical comparison concerning concept map quality and gain in posttest scoring.

Participants were randomly assigned to two different groups, one the control and the other the treatment group, prior to the start of the study. The random assignment (by chance) of participants to two groups assisted in achieving probabilistic equivalence between the groups. Each student was assigned a number, 1 through 48, and these numbers were used to generate a table of random numbers using a random number generator for lists at http://www.random.org. The resulting table of numbers was used to assign students to different groups, with every other number being assigned to the treatment group. Students who had numbers that were not chosen for the treatment group were assigned to the control group. A similar process was used to select proctors for both groups. These randomly selected groups remained with the randomly determined proctor for the duration of the study.

Table 2

Study Protocol: Sequence of Events

Step #	Description
1	Permission obtained from local school to conduct concept map research with students.
2	Pre and posttest assembled from items identified by school science department personnel. Appropriate rubrics constructed addressing concept map quality and treatment fidelity.
3	Consent from parents obtained with signed permission letter prior to group assignment.
4	Random number generator used to establish control and treatment groups: random assignment.
5	Proctors administered pretest to control and treatment groups and scored tests, with each proctor cross-checking scores for tests from both groups, resulting in two (agreeing) scores per document. Proctors then shared with researcher the same day of grading.
6	Two-week (7.5 hours total) concept map training period for treatment group presented by the school librarian. Instruction included history and rationale of concept map construction, types of concept maps, and practice creating concept maps for science concepts. Treatment group proctor monitored instruction.
7	Four-week (15 hours total) self-study conducted by students simulating a distance-learning scenario.
8	Proctors administered posttest to control and treatment groups and scored tests, with each proctor cross-checking scores for tests from both groups, resulting in two (agreeing) scores per document. Proctors then shared with researcher the same day of grading.
9	Both proctors and librarian practiced scoring concept maps prior to scoring actual products of the study. Both proctors and librarian scored concept maps, cross-checked scores between raters, and shared with researcher the same day of grading.
10	Researcher maintained all tests, answer documents, and product concept maps under lock and key.
11	Researcher entered collected data into an Excel spreadsheet for use with SPSS to complete statistical tests. Each test was run multiple times to ensure accuracy of data input.
12	Missing data and participant attrition handled by assigning the average group score.

Although not absolutely needed, the pretest was included in the study as a measure to demonstrate individual starting levels, equality of groups, and ensure a high degree of internal validity. Both groups completed the pretest, after which the control group continued with normal classes during the homeroom period with their assigned proctor. Proctors graded and returned the multiple choice pretest documents to the researcher. The treatment group received a 2-week block of instruction from the school librarian in the making and uses of concept maps. Training included 10 - 45 minute sessions over the 2-week period for a total of 7.5 hours of instruction. Training was designed by the school librarian, whose job description includes special training of teachers and students. The scope of training included a brief background on concept maps, purposes and methods for their construction and various uses, flexibility and rationale when relating concepts, and practice opportunities to optimize skills in creating valid maps that reflect inter-conceptual relationships. Training introduced the basic construction of concept maps, while emphasizing the higher-level thought processes necessary for the cognitive task of concept mapping. Students were introduced to Brainstorming Made Easy (Edelman & Amelyan, 2007) at https://bubbl.us/ to facilitate construction of their concept maps online.

After this 2-week period, both groups began their research of a provided list of chemistry topics previously selected by their chemistry instructor. Each group occupied a computer lab and treated the requirement as a distance learning scenario, with minimal guidance being contributed by the class proctor. Labs considered for this purpose had comparable assets available for student use. These separate labs were the primary areas where student digital investigations were conducted by both groups for 45 minutes daily for an additional 4-week period totaling 15 hours of student self-paced research. The 2-week time frame for training and familiarization with concept maps, along with the 4-week investigation by both groups, was established to maintain interest in the tool while allowing for a reasonable amount of time for students to conduct their self-paced digital inquiries. Listings of previously selected concepts to be investigated were given to participants. Control and treatment group study subjects were allowed to search the Internet to define and learn concepts, with the understanding that the researched items would be tested items in regular science classes later.

Students were advised that they were to work on the selected material during their prep periods only. Proctors were also instructed to be aware of tools and techniques used in the classroom, ensuring that concept mapping is used only by the treatment group. Treatment subjects were expected and encouraged by the class proctor to use concept maps exclusively. Control subjects were monitored by the class proctor who allowed, but did not encourage, the use of any graphic organizers. Use of graphic organizational tools by the control group was noted and included in the final discussion. Upon conclusion of the 4 week investigation period, the treatment group provided the proctor with the resultant concept maps constructed online at Brainstorming Made Easy (Edelman & Amelyan, 2007) at https://bubbl.us/. These concept maps were shared with the school librarian who, along with the two instructors who served as proctors, graded them in accordance with the protocol in table 1 of chapter two of this document (Novak & Gowin, 1984). All three concept map evaluators received instruction using parallel scoring samples and were considered as ready for scoring student concept maps when they achieve a level of agreement with scores that were within three to four points of each other. Graded maps were then returned to the researcher for statistical analysis. Both control and treatment groups completed a posttest at the end of the student research period. These multiple choice tests were graded by class proctors and returned to the researcher for analysis. During the execution of this study, the researcher had no contact with students singly or in groups, was not aware of which students were in the control and treatment groups, and did not exercise authority over them in any way. Participants considered that they had exited the study once they turned in to their respective proctors a completed posttest and samples of their student created study guides (concept maps). At the conclusion of the study, participants in both groups were debriefed by the researcher once the results were verified. The concept mapping technique was then made available by the researcher to all students enrolled at the school.

Setting and Sample

The site of this research was an urban public high school with approximately 390 students enrolled in grades six through twelve. At the time of the study, the overall student population consisted of 5% African American, 92% Hispanic American, 2% Caucasian, and 1% who claimed Asian or Native American ancestry. Students were bussed from their home school areas in various school districts all over the county, with about 7% of all students being considered “neighborhood” students. The school was classified as Title 1 based on 77% of the students qualifying for free or reduced lunch.

The convenience sample used for this study consisted of 36 10th grade students, with the average age 15.5 years.

This study population was a convenience sample, including all of the members of one particular grade level. An area of concern was that this small population would not be adequate to properly conduct the planned study and yield a meaningful product due to lack of statistical power. Statistical power refers to the likelihood that the null hypothesis will be rejected and that a statistically significant difference does exist and will be recognized. With statistical testing, the power should approach 0.8 or greater, meaning that there is an 80% (or greater) chance that a statistically significant difference will exist and be found.

Tables Three and Four illustrate the power associated with varying elements within the study. The combinations that result in greater powers for both study populations of 36 and 18 involve a Delta Mu of 0.3 with an Alpha Error of 0.05 or greater and a standard deviation of 0.6. This combination also yields higher effect sizes. Anticipated effect size for this study is between 0.1 and 0.3, which is considered low when compared to recent research conducted on effect sizes. Uttal, Meadow, Tipton, Hand, Alden, Warren, and Newcombe (2013) investigated 217 different studies that contained a total of 1,038 effect sizes and found that the average effect size for these studies was 0.47.

Table 3

Statistical Power Table for Two-Tailed Test, Population = 36

Value	Variation of values table: Two-tailed test (36)											
Delta Mu (*r* value)	0.1	0.2	0.3	0.1	0.2	0.3	0.1	0.2	0.3	0.1	0.2	0.3
Std. dev. (sigma)	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.0	0.6	0.8	1.0
Effect size	0.17	0.33	0.5	0.13	0.25	0.38	0.1	0.2	0.3	0.5	0.38	0.3
Alpha error	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.075	0.075	0.075
Sample size	36	36	36	36	36	36	36	36	36	36	36	36
Power	0.17	0.52	0.85	0.12	0.33	0.61	0.09	0.23	0.44	0.89	0.68	0.51

Table Four illustrates the main problem with a small population in terms of power. There was the possibility of inadequate power to properly test RQ_2 and no way to reasonably increase the population number to acquire greater power. The only real element that may allow a statistical testing is the appearance of a very large resultant effect size. Failing this outcome, the RQ_2 analysis was to be descriptive only with no accompanying causal inferences. Information for both Tables 3 and 4 was gathered from the DSS Research Calculator site (https://www.dssresearch.com/KnowledgeCenter/toolkitcalculators/statisticalpowercalculators.aspx) and The Interactive Statistical Calculation Pages (http://statpages.org/).

Table 4

Statistical Power Table for Two-Tailed Test, Population = 18

Value	Variation of values table: Two-tailed test (18)											
Delta Mu (*r* value)	0.1	0.2	0.3	0.1	0.2	0.3	0.1	0.2	0.3	0.1	0.2	0.3
Std. dev. (sigma)	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.0	0.6	0.8	1.0
Effect size	0.17	0.33	0.5	0.13	0.25	0.38	0.1	0.2	0.3	0.5	0.38	0.3
Alpha error	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.075	0.075	0.075
Sample size	18	18	18	18	18	18	18	18	18	18	18	18
Power	0.11	0.29	0.56	0.08	0.19	0.33	0.07	0.14	0.25	0.63	0.43	0.31

Treatment and Control Protocols

The 10th grade participants were randomly assigned by class lists and chance selection, as described in chapter one, to one of two groups, experimental or control (Creswell, 2003). This was accomplished by using the list randomizer at http://www.random.org. Participant selection, including the two class proctors being assigned a group to monitor, was made with the use of this random number generator. Group proctors were the regular homeroom teachers who team-teach often, meaning that they could monitor and guide (as needed) their groups while maintaining a similar teaching style and learning environment. The proctors, a history instructor for the control group and language arts/foreign language (Chinese) instructor for the treatment group, understood that questions concerning the subject matter being researched (chemistry) may be directed to the chemistry instructor for clarification if an understanding on the part of the student is not reached through continuing research. Proctors facilitated clarification by contacting the chemistry instructor between research sessions and providing information to students during subsequent sessions as needed. This practice was kept to a minimum to maintain the feeling of a self-paced, distance learning scenario for study participants.

The proctor for the treatment group sat in on the concept mapping training as it was conducted by the school librarian to ensure an understanding and working knowledge that can be applied when monitoring students during the study. Both groups, with proctors, were assigned to computer labs with similar capabilities to conduct student research during the study. Proctors also administered pre and posttests before and after the student research phase of the study. All research sessions were actively monitored by the respective proctors and students were advised against sharing information with participants not in their control or treatment group. Instructions to group members included not sharing information concerning the study outside of the study area. These actions were put into place to preclude treatment contamination.

Instrumentation and Materials

A chemistry multiple choice pretest/posttest (same test) consisting of 20 questions selected to emphasize conceptual understanding of the material and relationships between concepts was utilized. Included items pertaining to compounds, reactions, and chemicals were used as an assessment tool to gauge student improvement. The multiple choice pretest/posttest was in alignment with state test for chemistry. Test items were selected from the 2009 science test. Validity for the instrument was assured because it was aligned with the curriculum presented to all 10th grade students in the state at the time. This factor also ensures that the test was appropriate for use with this study.

Three members of the school science department considered the current 10th grade curriculum and selected questions for inclusion from the 2009 instrument that were parallel with current presented curriculum. Items identified by this group were incorporated in the construction of the instrument used in this study as both the pre and posttest. The posttest was also used to signify participant exit from the study. There was no follow-up requirement for participants after the posttest. The concept mapping tool and instruction on its use were made available to all students after the conclusion of the study.

The pre and posttest instrument originated from state-sanctioned standardized tests and use closed-ended questions (multiple choice), ensuring that the resultant data were sound and appropriate for interpretation using statistical means. Questions comprising the pre and posttest instruments were selected from a past state standardized test for 10th grade science. Topics for research to be conducted during the study were determined by members of the school science department. Items selected in both instances, pre and posttest and research topics, were identified as being parallel with the current science curriculum. Items were also selected for possible relationships between separate concepts.

Rubrics

Two rubrics were actively used during the execution of this study: one for treatment fidelity and another for concept map quality. Treatment fidelity is a collection of strategies and practices put in place to enhance the accuracy and consistency of a study and ensure that the each component of the study is executed as planned. Treatment fidelity consists of two main elements: treatment differentiation and treatment integrity. The rubric for treatment fidelity consisted of five types of fidelity:

1. Fidelity of implementation checks to ensure that an adequate amount of treatment is received by participants.
2. Provider training establishes that individuals working with the treatment and study participants are adequately trained to facilitate the study.
3. Treatment implementation includes monitoring of the activity while minimizing treatment contamination,
4. Treatment receipt checks for the understanding of the purpose and implementation of the treatment by study participants.
5. Treatment enactment investigates the success in implementing the treatment and the level of understanding attained by participants.

The rubric for concept map quality was determined by legibility or ease of reading and the validity of four main elements found in the maps. The elements of validity are the same as those listed on the concept scoring model listed at Table 1. A numerical evaluation was assigned to noted characteristics of the participant-produced maps. The concept map rubric includes:

1. Relationship validity ensuring that relationships illustrated between concepts and elements of concept are plausible.
2. Hierarchical validity investigates correct placement of elements with respect to one another within the concept map.
3. Cross-links validity checks for proper labeling of links between concepts and elements of concepts.
4. Example validity ensures that any examples given to enhance understanding are appropriate and accurate.

Both rubrics were completed prior to the execution of this study. Examples of both are included as Appendix C: Concept Mapping Scoring Rubric. The proctor for the treatment group attended all training sessions on the construction of concept maps. This facilitated a level of understanding needed to monitor students as they make their individual maps during the self-paced research phase of the study. Prior to scoring participant concept maps, both proctors and the school librarian trained using the concept map scoring rubric and examples of completed concept maps until they attain an agreement rate within three or four points of individual scores.

Validity

Internal validity involves itself with the normal processes of the study and is threatened when these processes are altered. Creswell (2003) discussed maturity of the study as such a possible threat. Since the length of the study is just over 6 weeks, the risk of maturation was low and internal validity should have been maintained. Several threats to internal validity have been recognized. Treatment contamination was approached by instructing both control and treatment group participants to refrain from speaking to one another concerning elements of the study, especially the topic of concept mapping. The threat of sufficient length of study was answered by extending the original three week study (3.75 hours of training over one week with 7.5 hours of research over 2 weeks) to 6 weeks (7.5 hours of training over one week with 15 hours of research over 2 weeks) This allowed participants a greater chance to adequately learn and practice with concept mapping prior to the self-study and research portions of the study. The longer blocks of time also served to minimize the familiarity phenomenon some may experience with the pretest being applied as the posttest. Dropout or missing data were handled by applying the group mean as replacement data.

External validity refers to the accuracy of the tested sample as being true representatives of the group being described. These external threats to validity manifest when the study results of a small test group are applied to larger populations (Creswell, 2003). This study is representative of 10th grade science students in an urban setting, which may constitute a risk to validity. This risk is recognized because all 10th grade students in this urban area were not accurately represented. This is particularly true when considering the factor of gender, as all study participants are enrolled in a learning academy specifically for young women.

Content validity (Creswell, 2003) was established because the test items measure the content areas on compounds, reactions, and chemicals according to the state science curriculum for 10th Grade students and the state content standards. The multiple choice test has previously been employed by high schools across the state and subsequently recommended as an assessment tool for science, including chemistry. After being used as an assessment instrument, the test was made available online to teachers as a teaching tool. Items used in the pre and posttest were carefully selected by members of the school science department to ensure that students would need an understanding of the concepts involved to correctly answer test questions. A list of concepts for student use was also prepared to focus student efforts in their self-study research. The pre and posttest and the focus topic list were constructed to reflect concepts that were either currently being presented or are due to be presented within the next several months. This step was taken in an effort to lend relevance to the study for participants and preclude the appearance of a misdistribution (ceiling or floor effect) of pre and posttest data.

Statistical conclusion validity is considered during the analysis of data collected during the study. This type of validity results from the use of appropriate testing of data with the correct statistical instruments and procedures (Creswell, 2003). The validity of the statistical conclusion was assured by the selection of the appropriate statistical tests being applied to the study data. Characteristics of statistical tests were reviewed and compared to data and study requirements. Tests were identified that would best handle the available data and result in responses that were appropriate to the study questions and hypothesis.

Preparation of the Data

Data was prepared for use with SPSS by creating data sets. This included assigning a letter-number identifier for each piece of data generated by a participant. For instance, the score for study participant three of the control group for the pretest may read, “CTL1#03”. The posttest score for participant eleven of the treatment group could be represented as, “TMT2#11”. Finally, the score for the concept map produced by student 19 could be represented by, “CMAP#19”. Although there was no missing data, preparation was made to account for it by replacing the pound sign with the letter “M”, as in “CTL1M03”, meaning that the pretest score for participant three of the control group is not available (the calculated group mean was to be input for the missing data).This answers the SPSS requirement for less than eight characters in an identifier while allowing the information to be easily identified. Data were cleaned by checking them against the data source prior to entering the data set into SPSS. All data have been maintained in SPSS format, using Microsoft Excel as source files.

Data Analysis

Initial Analysis

This study involved a pretest/posttest control group design with randomly assigned students in control and treatment groups. Study assumptions include the dependent variable having score ranges for pretest and posttest from 0 to 100, thus precluding any possible significant outliers (data that is somehow inconsistent with the rest of the data set), and that the independent variable consists of data collected from the control and treatment groups. Assumptions concerning outliers, distributions of the differences, and sphericity can be checked using the Statistical Package for the Social Sciences (IBM SPSS Statistics 22.0, released August 2013) program after ensuring that collected data meets assumptions for dependent and independent variables. Data was collected and imported into SPSS to conduct simple, one-way ANOVA (parametric) testing between the control and treatment groups for pretest and posttest score means. Although random assignment was used to construct groups, small differences not associated with the treatment can make demonstrating the resulting differences as functions of the experimental treatment a difficult task. Individual differences causing variations in resultant data may be statistically adjusted by applying an ANCOVA with covariates (if any).

Inferential Analysis for RQ1

A Student's *t*-Test was indicated instead of the ANOVA if assumptions with the data are met. Assumptions at this point include the control and treatment groups being equivalent at the beginning of the study. This means that although study participants are different individuals who have been randomly sorted into two different groups, their academic capabilities in completing the pretest will be roughly the same. This was evaluated by applying a *t*-Test for equivalence to the pretest scores of both groups. After checking the distributions, a *t*-Test was run to determine differences in the two groups' pretest results. The alpha implies that a statistically significant difference between means would be found (even if there was none) about 5% of the time.

H_{a1}: The learning reflected by the comparison of mean difference of the treatment group's learning will vary when compared to mean difference in learning of the control group.

The assumption with this hypothesis is that the treatment group will have a group mean differing from the group mean of the control group. An ANOVA was conducted to test for the degree of change (if any) between the groups.

H_{a2}: Gain scores of students of the treatment group who have constructed a concept map having higher quality scores will differ significantly from gain scores of students who have constructed lower quality concept maps.

Analysis for RQ2

After the posttest was complete, the treatment group was divided into two sets: those having higher map scores and those having lower map scores, with the median of the group being the break point. After checking for assumptions, the two sub-sets then had an ANOVA run on their posttest vs. map scores to determine significance (if any) of higher map scores being an indicator of greater posttest scores. At this point, due to the small size of the groups being tested (nine in each group as determined by the total group median for concept map scores), the necessity of decreasing the ANOVA standard deviation used or increasing the significance to a value as 0.10 (but no greater) to ensure an acceptable return was considered. If the conduct of a reliable ANOVA was not possible, changes in the data were to be reported descriptively. Raw data for the statistical tests involving the pre and posttests were to be taken from the numerical scoring of each item. Raw data for the quality of concept maps was obtained as a numerical score form the scoring rubric included in Appendix C of this document.

Data Reporting

Reporting of study results was presented in three different formats: tables, graphs, and written information. Raw data collected from participants were presented on tables in preparation for use with SPSS. Statistical test results were presented as tables or graphs (as appropriate). Results were discussed and explained as they are presented.

Participants' Rights

Approval to undertake this study was obtained from the school board and local school administrators. All academic material used in this study, including pre and posttests and focus sheets used by students for self-paced research, was consistent with the established curriculum. The content and use of these materials was approved by district and school administrators for this study, along with the investigation of concept mapping as a possible learning tool for students. Confidentiality of study participants was enforced through the omission of names and other identifying information on study data. Data are stored on paper documents under lock and key and electronically on CD, accessible through password clearance only. All data were stored in a secure, locked facility during and after the data collection process, accessible only for data analysis of the study. All data will be destroyed 5 years after the study. Informed consent for all stakeholders and participants is covered in the Ethical Considerations section.

Researcher’s Role

In this quantitative study, the role of researcher was objective, observing the proceedings, collecting and processing data, and preparing an accurate and thorough report of the study. This included monitoring proctor and participant activities with attention to detail and confidentiality. At the completion of the study, final findings were shared with all participants and included the intended use of those findings as well as intentions concerning the future disposition of the collected data. Approval by the Walden Institutional Review Board (IRB Approval Number 10-03-14-0135041) has been added into this document as Appendix A. The district board for Institutional and

Community Based Research, along with local school administrators, granted permission for this study to take place.

Ethical Considerations

Individuals who granted consent for participation in the study included parents or guardians of students and the individuals themselves. As an example, if the parents gave their permission for their child to participate in the research, the child also had to agree to participate without coercion. This agreement to participate was considered to be provisional in that continued participation was dependent on the research being conducted within a negotiated framework that was congruent with the subject's expectations (Flewitt, 2005). Further, at any time during the research, if a study subject decided that participation in the study was something that was no longer desired, their participation ended without question. All students were made aware that the concept mapping tool and instruction on its use would be available to all students after the conclusion of the study. This served to preclude any anxiety felt by students assigned to the control rather than the treatment group.

Confidentiality of collected data was also a matter of great concern. To protect the confidentiality of participants and preserve individual anonymity, no identifying information (including names, addresses, birthdates, email addresses, etc…) was associated with any study participant product. Prior to the study, each study subject was assigned a numerical identity that was to be used to identify data with participants. All data collected during the study are considered confidential and will be kept under lock and key to preserve participant's privacy and anonymity. Collected data were used for study related purposes only. Upon completion of the study, all stakeholders were invited to view the research have the opportunity to discuss study findings without identifying any individual or group of participants. Other ethical concerns involved participants not sharing information between the groups (control and treatment), performing the work in the prescribed work environment, and students doing their own work without "borrowing" information from classmates.

Summary

The purpose of this experimental quantitative study was to test the effect of concept mapping when used as a study device for 10^{th} grade science students in a distance learning scenario. A secondary purpose of this study was to determine whether there was a connection between the quality of student-constructed concept maps and amount of improvement between pre and posttests. Thirty-six 10^{th} grade students were randomly assigned to treatment and control groups and participated in a 4 week, self-paced study in a scenario similar to a distance learning scenario. A pretest/posttest design with treatment and control groups to investigate the effects of concept mapping (independent variable) on improvements of student scores (dependent variable) was incorporated in the study. Data were collected and analyzed using ANOVA or Student's *t*-Test. Chapter 4 includes a description of the study analysis and study results. In Chapter 5, I describe the overall study, summarizing findings and discussing the implications for social change along with recommendations and possible needs for future study.

Chapter 4: Presentation and Analysis of Data

The purpose of this experimental quantitative study was to test the effectiveness of concept mapping when used as a study device for 10^{th} grade science students in a distance learning scenario. The questions this study addressed were as follows:

1. What is the relationship between concept mapping and knowledge acquisition by students in a learning environment using a concept mapping tool in a distance learning scenario to learn 10^{th} grade science?
2. Is there a relationship between the quality of the concept map created by individual students and knowledge acquisition demonstrated by the differences in scores between pre and posttests?

In this chapter, I review information concerning the study participant demographics, restate the research questions and hypotheses, review the data collection process, and present and discuss findings of the study.

Study Sample

This research took place in an urban public high school. The sample population involved with this study was representative of the school and surrounding neighborhood in terms of ethnic and cultural diversity. The one difference between the population at large (i.e., the population of the surrounding neighborhood) and the sample population was that all participants of the study were female. From a class of 48 10^{th} grade students, 36 elected to participate in the 6-week study and were randomly assigned to two groups consisting of 18 students each: treatment and control.

Descriptive Statistics

Listed in Table 5 are the descriptive statistics for participants' demographics. The percentages of study participants presented in Table 5 are roughly representative of the total school population as presented in Chapter 3: 92% Hispanic American, 5% African American, 2% Caucasian, and 1% who claimed Asian or Native American ancestry. The study sample contained one grade level (10^{th} grade) with students ranging in age from 15 to 17 years, with an average age of 15.5 years. One hundred percent of the participants were female students, due to the nature of the school, with ages ranging from 14 to 16 years. The participants' ethnicity was reported as follows: 33 (91.67%) Hispanic American, two (5.56%) African American, and one (2.78%) European American.

Table 5

Descriptive Statistics for All Study Participant Demographics

Variable	Number	Percent
Gender		
Female	36	100%
Ethnicity		
Hispanic American	33	91.67%
African American	2	5.56%
European American	1	2.78%

Descriptive statistics for demographics of control and treatment group participants are listed in Table 6. All 18 (100%) participants in the control group were Hispanic American. The treatment group was composed of 15 (83.33%) Hispanic American participants, two (11.11%) African American participants, and one (5.56%) European American participant.

As illustrated in Table 6, each of the two groups (control and treatment) was composed of 18 10th grade female students. The only difference in the composition of these two randomly selected groups was the racial/cultural makeup, with the control group being totally Hispanic American and the treatment group having a majority of Hispanic American with African American and European American members. This difference was not considered to be important to the conduct of this study, nor to the interpretation of the results of the study.

Table 6

Descriptive Statistics for Study Participant Demographics by Group

Control group Variable	Number	Percent	Treatment group Variable	Number	Percent
Gender			Gender		
Female	18	100%	Female	18	100%
Ethnicity			Ethnicity		
Hispanic American	18	100%	Hispanic American	15	83.33%
African American	0	0	African American	2	11.11%
European American	0	0	European American	1	5.56%

Data Collection

The Institutional Review Board (IRB) confirmed that this study met Walden University's ethical standards on October 3, 2014 (IRB approval number: 10-03-14-0135041). Permission from the District Office for Research was also obtained prior to beginning the study. Shortly thereafter, coordination was made with the school, and the study was introduced to the potential participants, members of the current 10th grade class. A letter of explanation (Appendix B: Parent Consent Form) was sent home to parents of potential participants that included a signature sheet acknowledging willingness for participation on the part of the student and permission from the parent. Thirty-six members of the 10th grade class (totaling 48 students) agreed to participate in the 6-week study. Treatment and control group assignments for study participants were randomly made, and the pretest was administered. Immediately after the pretest, the 2 week period of concept map familiarization and training for the treatment group was initiated. This included formal classes (45 minutes a day for 10 days) on concept map construction from the school librarian.

Fidelity of implementation for the treatment group included instruction as delivered by the school librarian on the construction and use of concept maps. This fidelity of implementation was further strengthened by the 18 study participants each completing a concept map during the study as expected. This instruction paralleled instruction for graphic organizers (specifically Cornell Notes) that students received during their first weeks of enrollment in the school. The control group used this same time as an extended study hall class, using the school standard (Cornell Notes) to facilitate their study sessions. Following this training, the 4 week independent study for both groups was carried out. Both groups were given a list of science concepts related to chemistry and were told to use graphic organizers indicated (Concept Maps for the treatment group, Cornell Notes or another preferred graphic organizer for the control group) to complete their independent online research. The independent-study portion of this research lasted 4 weeks, with five 45-minute sessions per week, totaling twenty 45-minute sessions. The study was concluded by participants completing the posttest just before the annual Thanksgiving break. Grading of all posttests and participant-generated concept maps was completed after the break and shared with me as the researcher in early December. Examples were presented to the evaluators for grading, and results were discussed and compared. Instruction and practice with grading concept maps continued until individual ratings for practice concept maps were within three or four points of each other. Once this level was reached and consistently obtained, the actual concept maps produced by study participants were rated. Eighteen concept maps, one for each participant in the treatment group, were then rated by the school librarian and both group proctors, with averages from the three resulting score sheets (Appendix C: Concept Map Scoring Rubric) being used in this evaluation. Information provided by the proctors was checked and confirmed prior to its use.

The study executed as planned with few distractions and no serious events that disrupted the actual flow of the study. Due to the nature of the time used during the school day, there were several instances when individual students were called away from the study to participate in other school-oriented activities. On at least two instances, the entire grade level was called away for a school-wide presentation during the time scheduled for the study. These days were made up by lengthening the time of the study to ensure the nominal number of research hours for the participants. Because additional days were included in the study, the time to prepare and submit scores to the researcher by the group proctors was not adequate. This information was prepared and submitted to the researcher almost 2 weeks after the posttest was administered, due to the Thanksgiving holiday break. Information was then confirmed by the researcher and prepared for statistical evaluation. During the confirmation process, it was noted that there was no incomplete data to account for. All 36 participants beginning the study had completed the study without attrition occurring, with all pre and posttests accounted for.

Results

Examination of the information collected during the study began with compiling and preparing the data, as presented on Table 7. Thirty-six participants, 18 subjects each in control and treatment groups, began and finished the study without any loss of study participants. This sample size was the same as that calculated in the proposal. The instrument used for the pre and posttest contained a set of questions on the concepts taught, taken from the 2009 state test for science with a focus on basic chemistry. Improvement in student understanding of science concepts was measured in differences between pre and posttest scores. The data reflected some similarities between groups in that the beginning and ending ranges for both sets of data (pre and posttest). Further, both groups showed the same number of individuals (14) between the two tests with increased scores. Distribution graphs for scores of each group in the pre and posttests are presented in Figure 6. The groups initially displayed distributions that were considered as acceptable, without displaying affects that could be considered “Floor” (AKA Basement) or “Ceiling” groupings of participant scores illustrates the distribution of scores for each group between pre and posttest.

Table 7

Concept Mapping Study Raw Data Compilation

Control group	Pretest	Posttest	Difference	Treatment group	Pretest	Posttest	Difference	Concept map
1	50	75	25	1	65	70	5	41
4	75	65	-10	3	60	85	25	42
5	70	85	15	4	60	85	25	83
6	70	90	20	5	65	85	20	74
8	95	90	-5	6	85	90	8	42
9	60	75	15	8	60	80	50	77
10	50	70	20	10	55	50	-5	60
11	85	85	0	11	50	75	25	43
13	80	80	0	12	85	80	-5	34
14	80	90	10	13	50	60	10	44
15	85	90	5	14	75	85	10	51
16	55	70	15	15	60	75	15	54
17	70	85	15	16	65	70	5	85
19	70	80	10	17	70	90	20	68
20	80	90	10	19	60	85	25	76
21	50	60	10	20	75	70	-5	30
22	50	55	5	21	75	85	10	30
23	65	70	5	23	75	70	-5	42
High	95	90	25	High	85	90	5	85
Low	50	55	-10	Low	50	50	0	41
Mean	68.89	78.06	9.17	Mean	66.11	77.22	11.11	54.22
Median	70	80	10	Median	65	80	15	47.5
Mode	50	90	15	Mode	60	85	25	42

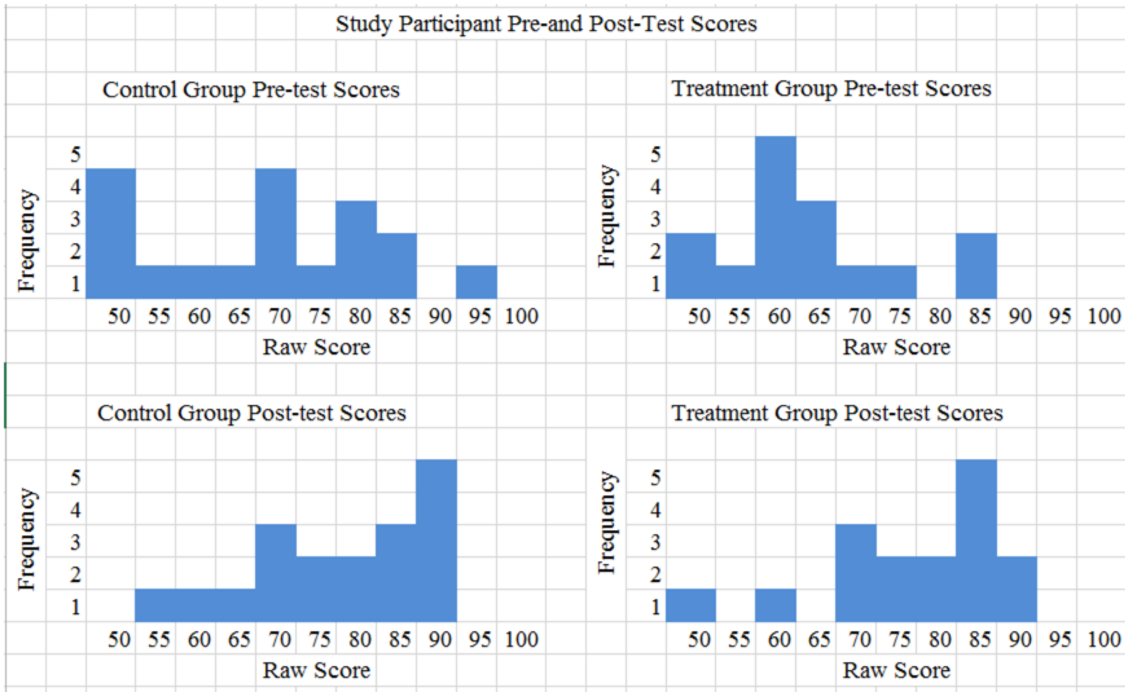

Figure 6. Study participant pre and posttest scores.

The information as presented in Figure 7 is illustrated in Figure 8 as a point graph that includes the frequency of score gain for each group. The mean and median for assumptions with the data were met, meaning that that although study participants are different individuals who have been randomly sorted into two different groups, their Student's *t*-Test was used instead of an ANOVA to establish equivalence in the two groups by comparing pretest results.

With an acceptance level of 0.05 for the p value, values >0.05 indicate equivalence between groups while values <0.05 denote two non-equivalent groups. When run, the 2-tailed *t*-Test presented a p value of 0.50519 (p=0.50519>0.05), indicating that the two randomized groups were equivalent at the beginning of the study (see Table 8).

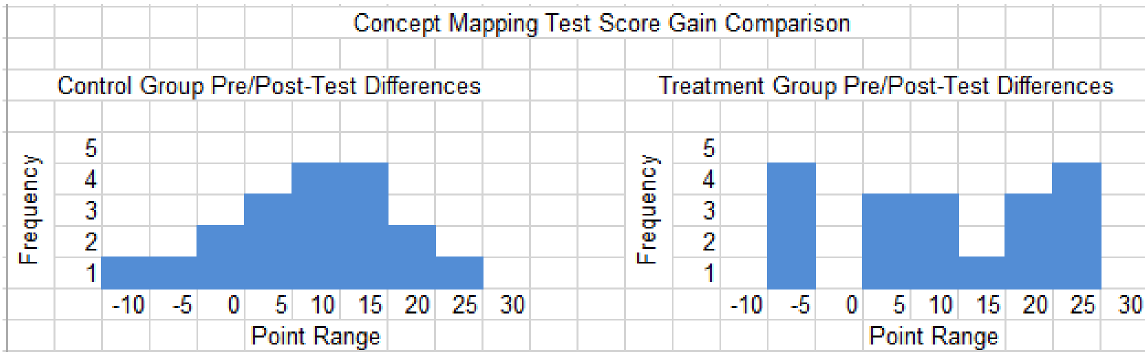

Figure 7. Study group pre and posttest score differences.

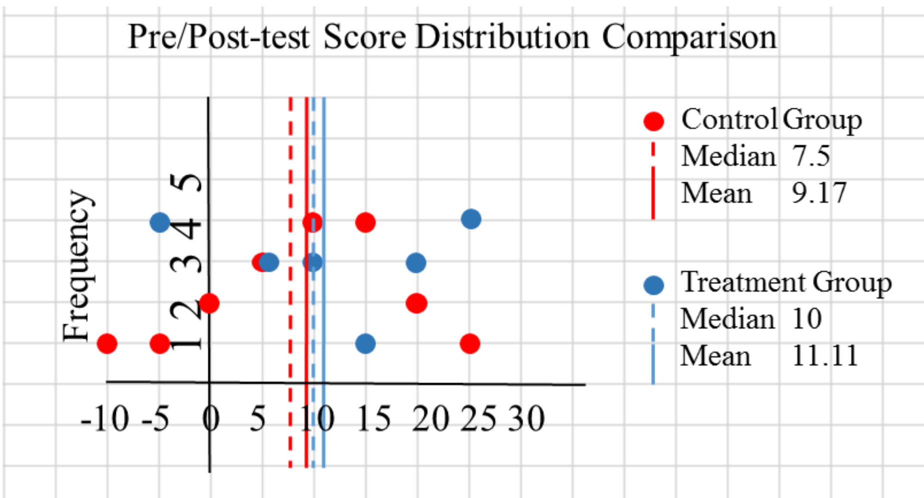

Figure 8. Study group pre and posttest score distribution comparison.

Table 8

Two-Tailed t-Test for Equivalence of Two Groups

Pretest results	Mean	Std. deviation	Std. error
Control group	68.8888	13.99113	3.29774
Treatment group	66.1111	10.50988	2.4772
t-value		0.67348	
p-value		0.50519	

Research Question 1

In exploring the first research question (What is the relationship between concept mapping and knowledge acquisition by students in a learning environment utilizing a concept mapping tool in a distance learning scenario to learn 10^{th} grade science?), an analysis of variance was completed on the pre and posttest scores of both control and treatment groups. This was a standard one-way weighted means analysis of variance (ANOVA) conducted to test for variance among the independent groups of data with the variance dependent on a single factor. In this instance, the single factor was the use of concept mapping to enhance student learning. This type of test is referred to as "one-way" because it analyses data generated by experimentation involving only one independent variable between data sets. With an anticipated standard deviation between 0.6 and 0.8, the standard deviation per group (Control, 11.13: Treatment, 10.74) encountered in both groups was much higher. The anticipated power of 0.11 was also not as expected, with power values for the Control and Treatment groups at 0.818. In situations when there are only two sets of data, an appropriate type of *t*-Test (as used earlier to establish equivalence) will normally provide an adequate statistical analysis.

However, the one-way ANOVA determines the significance of relationships between quantitative "response variables" and a proposed explanatory "factors". Considering that an ANOVA can be more useful than a two-sample *t*-Test as it has a lesser chance of committing a type I error, a one way ANOVA including pre and posttests of each group was also conducted. Results for the data of this study, as presented on Table 9, reported F= 0.054, p=0.818. With p = 0.818> 0.05, the null hypothesis that there will be no change between groups is not rejected.

Table 9

One-Way ANOVA Data Sheet

		Control	Treatment	Total	
	N	18	18	36	
	$\sum X$	1405	1390	27.95	
	Mean	78.06	77.22	77.64	
	$\sum X^2$	111775	109300	221075	
	Variance	1123.94	115.36	165.74	
	Std. dev.	11.13	10.74	10.94	
	Std. err.	2.62	2.53	1.96	
			ANOVA summary		
	SS	*df*	MS	*F*	*P*
Between	6.35	1	6.35	0.054	0.818
Within	4029.04	34	118.504		
Total	4035.5	35			

Research Question 2

With respect to investigating research question two (Is there a relationship between the quality of the concept map created by individual students and knowledge acquisition demonstrated by the differences in scores between pre and posttests?), each of the 18 concept maps constructed by study participants were evaluated for complexity, relevance, relationships between information, and appearance, including logical presentation and visual appeal as evaluated with the Concept Mapping Scoring Rubric located at Appendix C and discussed in chapter three. Instruction for the evaluation of concept maps was shared with the two proctors and the school librarian over the course of three 45 minute class periods. Examples were presented to the evaluators for grading and results were discussed and compared. Instruction and practice continued until proctor agreement on sample concept maps was within three or four points between raters was reached. Concept maps were then rated by the school librarian and both group proctors. Once the raw data was provided to the researcher, a Cronbach's Alpha was conducted to test for inter-rater reliability. A phenomenon to be aware of with this test is that as the number of items included for testing increases, Cronbach's alpha also tends to increase without any increase in internal consistency. In an effort to preclude a less accurate measure as a product, the treatment group was divided into two groups of nine participants each, having higher and lower concept map scores. The resulting reliability coefficient of 0.75 for both high and low groups indicated a level of acceptable to good reliability between rater products. The three concept map scores for each participant were then averaged and used as final scores in this evaluation.

The concept maps of 18 treatment group participants were considered for this portion of the study. As illustrated in Table 7, concept map average scores ranged from 30 to 85 points. The small population of the upper half of the treatment group proved too small for reliable results from traditional statistical testing. Therefore the raw data were observed and compared in an effort to discern any advantages to using concept maps.

As previously determined in chapter three (see Table 4.), the possibility of having inadequate power to satisfactorily test RQ_2 with no way to reasonably increase the population number to acquire greater power was considered. This lack of computed power was not unexpected. With a sample size of 18, a standard deviation of 0.6, and an Alpha Error value of 0.05, the Power value was 0.56 with an r value of 0.3 (Table 4).

The only real element that could allow adequate statistical testing was the appearance of a very large resultant effect size. To facilitate this analysis, Table 7 should be considered. In reviewing the information contained in these two tables (tables 4 and 7), it should be remembered that the same instrument was used for the pre and posttest, making comparisons between group test gains reasonable. Table 7 illustrates all treatment group participants with individual pre and posttest scores, gains between the tests, and concept map scores. When considering the testing method to be used for the relationship between the final test scores and concept map scores, the very small sample was addressed. Parametric testing was considered as a response to the small sample size when deciding on an appropriate testing method for RQ2. Siegel (1956) noted that, due to underlying strong assumptions, traditional parametric tests, such as the *t*-Test, should not be considered when working with extremely small samples. These assumptions include a normally distributed population and equal variance between populations. However, later research by De Winter (2013) on parametric testing showed “no fundamental objection to using a regular *t*-Test with extremely small sample sizes.” De Winter further reported that the *t*-Test can be applied to very small populations ($N \leq 5$) while accepting a very large effect size. The low population *t*-Test, specifically the Student’s *t*-Test, may also be used with unequal variances, unequal population sizes, or skewed distributions. In these instances, researchers should be wary of the high false positive rates on non-normal data or unequal sample sizes and variances are combined. Some testing not recommended for small populations are rank transformations and the Welch test (De Winter, 2013).

To facilitate the investigation of the second research question, a matched group two tailed Student's *t*-Test was employed by comparing scores that showed the greatest gain with maps having the highest final score. Because the group having the greatest gain between pre and posttest was different than the group having the highest concept map scores, two separate tests were run and are illustrated with Table 10. Information in Table 10 reflects the greatest gains between pre and posttests as related to Concept Map scores (on the left) as compared to Concept Map scores as compared to tests gains (on the right). Since the information between test gain and concept map score for each participant is matched, one student's *t*-Test was necessary. Testing results, as reflected by the p value presented in the analysis, indicate that there is no significant relationship in learning gains related to the quality scores assigned to concept maps. In this instance, the null hypothesis cannot be rejected.

Table 10

Test Gain vs. Concept Map Score

Two-tailed *t* test for matched groups

Greatest gain vs. map score			Greatest map score vs. gain		
Participant	Greatest Gain	Map score	Participant	Highest Map score	Gain
T4	25	83	T16	85	5
T19	25	76	T4	83	25
T11	25	43	T8	77	20
T3	25	42	T19	76	25
T8	20	77	T5	74	20
T5	20	74	T17	68	20
T17	20	68	T10	60	-5
T15	15	54	T15	54	15
T14	10	51	T14	51	10
T13	10	44	T13	44	10
T21	10	30	T11	43	25
T16	5	85	T3	42	25
T6	5	42	T6	42	5
T1	5	41	T23	42	-5
T10	-5	60	T1	41	5
T23	-5	42	T12	34	-5
T12	-5	34	T21	30	10
T20	-5	30	T20	30	-5

Statistical measures

	Gain	Map score
Mean	11.1111	54.2222
Std. dev.	11.3183	18.5172
Std. error	2.66776	4.3645
t value	0.41649	-0.751
p value	3.179	

Summary

Two research questions concerning the effectiveness of concept maps in improving student test scores were explored and statistically answered with this study. The first question asked about the relationship between concept mapping and knowledge acquisition by students in a learning environment utilizing a concept mapping tool in a distance learning scenario to learn 10th grade science. A 2-tailed *t*-Test was initially run to confirm that the control and treatment groups were equivalent. A one-way ANOVA was then conducted to determine differentiation among the groups. Results of the ANOVA indicated that the null hypothesis for research question one (There will be little or no difference in learning gain as reflected by comparison of the mean gain scores for treatment and control groups) should be accepted.

The second research question, asking if there is a relationship between the quality of the concept map created by individual students and knowledge acquisition demonstrated by the differences in scores between pre and posttests, was considered by employing a two-tailed *t*-Test for matched groups. Although posttest scores were higher in many cases, they were not consistently high in the either group. The statistical testing inferred that there was no significant relationship between the quality of the concept map created and the gain between pre and posttest scores. With this evidence, the null hypothesis for the second research question, stating that there is no significant relationship in learning gains related to the quality scores constructed concept maps, should not be rejected.

Chapter 5 includes a summary of the study along with conclusions presented this chapter. I discuss the data, implications for future research, and social impact.

Chapter 5: Conclusion and Recommendations

Concept mapping has been used as a valuable tool in differing education scenarios to promote student learning. Concept maps allow students to identify relationships between concepts and disparate bits of information and assist in establishing meaningful learning by connecting previous knowledge with ongoing knowledge acquisition. When employed with science curriculum, concept maps serve as a graphic organizer for students to clarify and relate concepts. They also promote higher level thinking in students and allow instructors insight into the thought processes and understanding held by their students.

In this chapter I present an overview of the study, with findings and discussions related to the research questions. Implications and recommendations for continued future research are also presented for consideration.

Study Summary

The main purpose of this experimental quantitative study was the investigation of concept mapping as a graphic organizer for student learning of 10th grade science in a digital environment similar to a distance learning scenario, resulting in improved learning and test scores. A secondary purpose of this study was the investigation of a possible relationship between the amount of improvement between pretest and posttest results and the quality of student-generated concept maps. This study focused on the effectiveness of concept mapping when used as an aid to self-paced learning in the science classroom, specifically when using computers in an environment similar to distance learning. The independent variables were the frequency and quality of concept mapping employed by students in their self-studies. The dependent variable was the resulting change in student understanding of select science concepts, as demonstrated by comparison between pre and posttest results of the two groups and within two parts of the treatment group. The questions addressed in the study were as follows:

1. What is the relationship between concept mapping and knowledge acquisition by students in a learning environment using a concept mapping tool in a distance learning scenario to learn 10th grade science?
2. Is there a relationship between the quality of the concept map created by individual students and knowledge acquisition demonstrated by the differences in scores between pre and posttests?

To investigate these questions, a treatment vs. control group with random assignment design, also known as a randomized control trial (RCT) design, was used. This affords researchers a comparison of two groups over time with controlled conditions in an effort to determine resultant differences. This design allows for two randomly assigned groups to be selected and exposed to a pretest, a treatment (for one group), and a posttest. Equivalence of two groups (control and treatment) was established with a t Test comparing pretest scores of both groups.

Posttest results were also compared with a one-way ANOVA that found no significant relationships between the pre and posttest scores of the control and treatment group participants. With respect to these test findings, the null hypothesis for RQ1 was not rejected, with the recognition that there was little or no difference in learning gain as reflected by comparison of the mean gain scores for treatment and control groups. Gains between the pre and posttests of the treatment group were also compared to concept map scores with a *t*-Test in an effort to establish the relationship between the two scores. Statistical testing in the form of a student's *t*-Test indicated that there was no significant relationship between pre and posttest gains and concept map scores. This finding indicated that the null hypothesis for RQ2, which stated that there would be no significant relationship in learning gains related to the quality scores of constructed concept maps, should not be rejected.

Interpretation of the Findings

The final data collected and evaluated during the study were not as initially predicted. The expected results of improvement in test scores associated with concept map scores were not consistent among members of the treatment group, nor was this pattern present in the majority of treatment group participants. These findings differ from those of similar studies, as with the study by Guastello et al. (2000), who worked with inner-city middle school students in learning science with concept maps over an 8-day period. They found that concept mapping was an effective learning tool for enhancing science instruction and increasing student participation and grades of low achieving, lower socioeconomic status inner-city students. Chang (2007) also found that concept maps can be used as an effective presentation of internal mental models concerning complex and abstract concepts.

It is possible that the study participants were experiencing a phenomenon similar to that found in another study (Trifone, 2006) in which lower proficiency mappers may have had prior experience precluding their effective use of mapping techniques. Study participants may have been uncomfortable with deviating from the usual current standard for studying (i.e., by using concept maps instead of Cornell Notes) and as a result may have retained less information over the self-study period. Participants had used Cornell Notes as their sole graphic study aid since beginning the sixth grade. As 10th grade students, they may have experienced hesitation to switch to another, potentially less productive study tool, which may have inhibited the effective use of the concept map during the self-study portion of the research study.

The short period of familiarization and use of concept mapping during the study may have contributed to this same element of unfamiliarity with the graphic organizer. Though this may have been the case with this study group, other studies have resulted in different findings. For instance, D'Antoni, Zipp, Olson, and Cahill (2010) introduced concept maps to a group of 25 medical students over a 30-minute presentation. Success in the form of increased understanding and synthesis by students using concept maps appeared, to the authors, to be a combination of individual drive and realization of goals. Initially, there was no discernible change; however, over the next several weeks, as students became more familiar with concept map construction, their understanding of material improved, as reflected by their grades, along with their performance during practical training sessions (D'Antoni et al., 2010).

Another example of increased learning over time is that presented by Novak (2010) involving a secondary school in Costa Rica that began using concept mapping in all grades and subject areas. In the first year, there was a decline in overall grades. However, within 4 years of its inception, the concept mapping program produced results reflecting a 100% passing rate for state exams by all students, as compared to previous rates of 60% or below. This seems to confirm the need for extended exposure to the practice of concept mapping prior to experiencing any significant increase in learning.

The restricted time for investigation of the required science concepts may have contributed to the lack of conceptual understanding gathered and developed by participants and reflected in posttest results. This may have involved a combination of understanding over time and a sense of relevance to current academic requirements. It is possible that the participants acquired and retained the required concepts but were not given the opportunity to display this understanding because the posttest instrument was not appropriate, as seen in the unexpected recidivism between some pre and posttest scores of the treatment group.

The element of committed participation seemed to be lacking in the characteristics of study participants. It might have been realized by participants had the study been extended and if the results had been important (relevant) to the participants in the form of class outcome. As previously stated, individual drive and goals are often elements of relevance for the individual. As this effort was not associated with the academic performance recorded in individual permanent records, students may not have participated as fully as anticipated.

Final thoughts on the results of this investigation seem to be parallel with findings of other researchers (D'Antoni et al., 2010; Novak, 2010; Trifone, 2006). Research participants must have adequate exposure to the graphic organizer for it to be an effective tool in aiding academic effort. Further, the practiced use of the graphic organizer must be relevant to the immediate situation of the individual, as in resulting in an improvement in academic standing. Without an extended period of training and use of the tool and motivation on the part of the participant, the findings of this study appear to be similar to other studies lacking these same attributes.

Limitations of the Study

The available number for 10th grade students for this study (48) was further limited by 12 students declining participation. The resulting small sizes of the control and treatment groups served as a potential weakness to the provision of valuable, significant information, leading to an overall loss of statistical power. Another possible set of limitations with this small group could have included age (15 to 17 years), gender (female) and culture (Hispanic). Although all of these elements were present within the study group, they were not considered as elements that may have influenced the final result of the research.

Another potential limitation was the time frame in which the research was conducted on a daily basis. Although having the research occur on a daily basis is considered an issue of treatment fidelity, the 45-minute class period may not have been adequate for student purposes during the study. This 45-minute class also served as a time for additional instruction and school-wide presentations. The study time was extended by several days in an effort to compensate for some of the days that the study was not able to proceed as planned.

Since the pre and posttest was the same instrument that consisted of excerpts from a standardized achievement test with the background and data to establish its reliability and validity, concern over the appropriateness of the instrument was not considered as a limitation. However, the inability to control student improvement on the posttest due to exposure with the same instrument as a pretest could be considered as a limitation. This phenomenon was compensated for with the 6-week time between exposures to the instrument and seems to have been successful, as several (5) participants scored lower on the posttest than the pretest.

Recommendations

The purpose of this study was to investigate the impact of concept mapping on science (specifically chemistry) in a self-paced, distance learning scenario. Recommendations resulting from this study suggest a need for future research to improve and strengthen the relationship between concept mapping and academic learning, specifically in science. Future studies of this nature dealing with concept maps should include both genders over a longer period of time and begin with participants of a younger age in an effort to preclude interference resulting from prior learning or familiarization with other graphic organizers . These future studies may also consider including other academic areas such as reading, writing, mathematics, and language acquisition, both native and foreign (Brabec, Fisher, and Pitler, 2004) (Cañas and Novak, 2000). These studies must consider evaluating and investigating strategies for the teaching of concept maps and their basic uses (DiCecco and Gleason, 2002).

Implications

Concept mapping has been investigated by numerous researchers since its inception as a graphic memory and learning an instructional strategy to improve knowledge acquisition. Concept mapping may be used by any area of academic endeavor at any developmental level (Cañas and Novak, 2000). However, the inclusion of concept mapping should be an element that is considered and committed over time, giving the individuals who could potentially benefit from their use the time necessary to adequately prepare for their successful use. Without this familiarization time, the expected beneficial results of concept map use may not be evident. It is a distinct possibility that this time element makes concept maps only appropriate for use in large, long-term projects, while shorter, smaller projects may benefit more from other graphic organizers.

Used properly, concept mapping may have importance as an effective element of social change. The development of higher level critical thinking has become a cultural necessity with the increase of technology on every level of society. Regardless of an individual's future goals, effective higher level thinking and communication skills are crucial elements needed for success in the work place or academic environs. Some research indicates that the use of concept maps fosters the development of higher level thinking and problem solving by presenting relationships between concepts in a manner that can be readily understood by learners (Ifenthaler, 2010). Although further research is indicated, the inclusion of concept maps has the potential of positively influencing social change in currently developing areas.

Conclusion

Presently, there is a very real paucity of information concerning the usefulness of concept mapping in a self-paced scenario with limited instructor involvement after the initial introduction of the tool. There is a need for further research into both areas, distance learning and self-paced student centered use, concerning the construction and application of concept maps. The use of concept maps as an active instructional tool for assisting in student learning necessitates the extraction of terms and ideas from verbal or written content, organizing the information into graphic diagrams illustrating relationships between components (Novak & Cañas, 2008). As our culture develops with technology, and technology advances with new knowledge and applications, so must the tools wielded by educators and administrators alter to meet the requirements of change. The intent of this research was to present a significant understanding of a tool (concept maps) that could potentially assist students with learning and development of higher level thinking skills. More detailed research with a larger portion of the population is needed to confirm Concept Mapping as such a valuable fool for education.

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Appendix A: Original IRB Approval Letter

IRB Materials Approved - John Richbourg   Inbox x

IRB <IRB@waldenu.edu>   Oct 3
to me, Les

Dear Mr. Richbourg,

This email is to notify you that the Institutional Review Board (IRB) confirms that your study entitled, "Concept Mapping as a Tool for Enhancing Self-Paced Tenth Grade Science in a Distance Learning Scenario," meets Walden University's ethical standards. Our records indicate that you will be analyzing data provided to you by the Young Women's Leadership Academy as collected under its oversight. Since this study will serve as a Walden doctoral capstone, the Walden IRB will oversee your capstone data analysis and results reporting. The IRB approval number for this study is 10-03-14-0135041.

This confirmation is contingent upon your adherence to the exact procedures described in the final version of the documents that have been submitted to IRB@waldenu.edu as of this date. This includes maintaining your current status with the university and the oversight relationship is only valid while you are an actively enrolled student at Walden University. If you need to take a leave of absence or are otherwise unable to remain actively enrolled, this is suspended.

If you need to make any changes to your research staff or procedures, you must obtain IRB approval by submitting the IRB Request for Change in Procedures Form. You will receive confirmation with a status update of the request within 1 week of submitting the change request form and are not permitted to implement changes prior to receiving approval. Please note that Walden University does not accept responsibility or liability for research activities conducted without the IRB's approval, and the University will not accept or grant credit for student work that fails to comply with the policies and procedures related to ethical standards in research.

When you submitted your IRB materials, you made a commitment to communicate both discrete adverse events and general problems to the IRB within 1 week of their occurrence/realization. Failure to do so may result in invalidation of data, loss of academic credit, and/or loss of legal protections otherwise available to the researcher.

Both the Adverse Event Reporting form and Request for Change in Procedures form can be obtained at the IRB section of the Walden web site:
http://researchcenter.waldenu.edu/Application-and-General-Materials.htm

Researchers are expected to keep detailed records of their research activities (i.e., participant log sheets, completed consent forms, etc.) for the same period of time they retain the original data. If, in the future, you require copies of the originally submitted IRB materials, you may request them from Institutional Review Board.

Both students and faculty are invited to provide feedback on this IRB experience at the link below:

http://www.surveymonkey.com/s.aspx?sm=qHBJzkJMUx43pZegKlmdiQ_3d_3d

Sincerely,
Libby Munson
Research Ethics Support Specialist
Office of Research Ethics and Compliance
Email: irb@waldenu.edu
Fax: 626-605-0472
Phone: 612-312-1341
Office address for Walden University:
100 Washington Avenue South
Suite 900
Minneapolis, MN 55401

Appendix B: Parent Consent Form

PARENT PERMISSION LETTER

September 25, 2014

Dear Parent or Guardian,

This semester I am conducting a research study entitled "Learning Science with Concept Maps" with 10th grade students. I am interested in examining the possible value of using an information organizational tool to learn science in a self-study situation. One of the main objectives for me in this research is to provide our students with another tool to assist them in their academics. With the permission of the school board and our school principal, I am requesting that you allow your student to participate.

Participants in the study will be asked to take a pretest to establish a start point for the study. Afterwards, some students will be asked to take classes with the school librarian on constructing and using concept maps. All participants will conduct research to gather information on concepts chosen by their science teachers. After several weeks, students will participate in a posttest activity to determine how much they have learned by conducting their research using concept maps. The total time to participate in the study will be approximately 6 weeks. Students who participate will complete the study during the daily AVID Prep period. (There will be no loss of academic class time.) The hope with the timing of the study activities and material investigated is that all of this will help in preparation for the XXXX test later this year.

There are no foreseeable risks to participating in the study. No names will be used in filling out the study's forms so all responses will be anonymous. No one at the school will have access to any of the information collected except for myself. All student materials will be kept in a secure area off of campus and will only be used for research purposes.

Participation in the study is entirely voluntary and there will be no penalty for not participating. All students for whom we have parent consent will be asked if they wish to participate and only those who agree will take part in the study. Moreover, participants will be free to stop taking part in the study at any time.

Should you have any questions concerning the study, please contact me at the school by phone at XXXXXXXX. Thank you for helping your daughter to improve her academic abilities.

Please give your permission by signing the enclosed consent form and having your daughter return it to her AVID teacher tomorrow. Please keep this letter for your records.

Sincerely,

John A. Richbourg Jr.

Consent to Participate

I have read the attached informed consent letter and agree to have my student participate in the study entitled **"**Learning Science with Concept Maps**."**

____
Student's Name

____
Parent's or Guardian's Name (please print)

____
Parent's or Guardian's Signature Date

Appendix C: Concept Mapping Scoring Rubric

Participant Number:______________________ Concept Map Score:____________________

Table One: Appearance/Legibility

Item Scored	Excellent (4 pts)	Good (3 pts)	Fair (2 pts)	Poor or Absent (0-1 pts)	Raw Score
Title	Meaningful title present, student number present	Title not entirely appropriate, student number present	Title misleading, student number present	Minimal/No title present or no student number	
Task or Goal Statement	Objective clearly stated	Objective somewhat vague	Stated objective inaccurate	Objective not stated	
Number of Concepts Related	Five or more	Four	Two to three	One	
Number of Valid Connections	30 or more	25 or more	15 or More	14 or less	
Number of Valid Directions	All Connections Labeled	At Least 75% of Connections Labeled	At Least 50% of Connections Labeled	Less than 50% of Connections Labeled	
Visual Appeal	Makes effective use of colors to illustrate relationships	Makes effective use of one color shading to illustrate relationships	Makes use of neither gray nor color to illustrate relationships	Maps are not visually appealing or difficult to note relationships	
Logical Arrangement	Clear effort to cluster related elements	Some effort to cluster related elements	Little effort to cluster related elements	No effort to cluster related elements	
Concept Numbering Schema Used	All parent concepts and offspring numbered correctly	At least 75% of parent concepts and offspring numbered correctly	At least 50% of parent concepts and offspring numbered correctly	Less than 50% of parent concepts and offspring numbered correctly	
				Total Points =	

Table Two: Accuracy/Validity

Item Scored	Raw Score	Weighted Factor	Total
Valid Relationships		X1	
Valid Hierarchy		X5	
Valid Cross-links		X10	
Valid Examples		X1	
		Total Points =	

Final Score = Table One Score________ + Table Two Score_______ = Final Score________