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Mindmapping: Its Effects on Student Achievement in High School Biology

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Mindmapping: Its Effects on Student Achievement in High School Biology

by

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DEDICATION

This dissertation is dedicated to my life partner, my best friend, my climbing buddy and my husband,

Gary,

and our goddaughter,

Hope.

"Hope" is the thing with feathers —
That perches in the soul—
And sings the tune without the words—
And never stops at all.

Emily Dickinson, Maggio, 1996, p. 320

Acknowledgements

When you get in a tight place and everything goes against you till it seems as though you could not hold on a minute longer, never give up then, for that is just the time and the place the tide will turn.

Harriet Beecher Stowe, Maggio, 1996, p. 514

So many times the summit appeared close at hand, only to reveal itself as a false summit with yet another peak on the horizon. And at the top of the next peak, yet another.

This climb has had a supporting cast of what at times seemed like thousands. I appreciate each and every one. To my dear friends who held the belay taut for so long, thank you Nancy, Mary Beth, Dan, Denise, Stefanie, Teresa, Cathy, Don, Dee, Frank, Margaret, Candy, Rick, and Michalinos from the bottom of my heart.

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Mindmapping: Its Effects on Student Achievement in High School Biology

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The primary goal of schools is to promote the highest degree of learning possible. Yet teachers spend the majority of their time engaged in lecturing while students spend the majority of their time passively present (Cawelti, 1997, Grinder, 1991; Jackson & Davis, 2000; Jenkins, 1996). Helping students develop proficiency in learning, which translates into using that expertise to construct knowledge in subject domains, is a crucial goal of education. Students need exposure to teaching and learning practices that prepare them for both the classroom and their places in the future workforce (Ettinger, 1998; Longley, Goodchild, Maguire, & Rhind, 2001; NRC, 1996; Texley & Wild, 1996).

The purpose of this study was to determine if achievement in high school science courses could be enhanced utilizing mindmapping. The subjects were primarily 9^{th} and 10^{th} graders (n = 147) at a suburban South Texas high school. A pretest-posttest control group design was selected to determine the effects of mindmapping on student achievement as measured by a teacher-developed, panel-validated instrument. Follow-up interviews were conducted with the teacher and a purposive sample of students (n = 7) to determine their perceptions of mindmapping and its effects on teaching and learning.

Mindmapping is a strategy for visually displaying large amounts of conceptual, hierarchical information in a concise, organized, and accessible format. Mindmaps arrange information similar to that found on the traditional topic outline into colorful spatial displays that offer the user a view of the “forest” as well as the “trees” (Hyerle, 1996; Wandersee, 1990b).

An independent samples t-test and a one-way analysis of covariance (ANCOVA) determined no significant difference in achievement between the groups. The experimental group improved in achievement at least as much as the control group.

Several factors may have played a role in the lack of statistically significant results. These factors include the instrument, the duration of the study, limited teacher training, and teacher constructed mindmaps to the exclusion of student constructed mindmaps.

Mindmapping has affective value as a teaching and learning strategy as indicated by the follow-up interview data. Further research is necessary to determine the extent of its effectiveness.

Table of Contents

List of Tables

List of Figures

M

CHAPTER 1: THE PROBLEM

Only as the theory's strengths—and limitations—become known
will the plausibility of the original postulation become evident.

Nor does science ever yield a completely correct and final answer.
There is progress and regress, fit and lack of fit,
but never the discovery of the Rosetta stone, the single key to a set of interlocking issues.

Howard Gardner, Frames of Mind, 1985, p. 59

Introduction

Many high school students spend 14-25% of every weekday in school (Boyer, 1983; Donovan, Bransford, & Pellegrino, 1999; Marzano, 2003), but only passively present. The opportunity to make sense of instructional material escapes them because they are not engaged. They spend days and years, passively listening to lecture-based curriculum with little opportunity for engagement or understanding (Grinder, 1991; Jackson & Davis, 2000; Jenkins, 1996). In his book *Effects of High School Restructuring: Ten Schools at Work*, Cawelti (1997) states a major criticism directed at high schools is that students are not motivated to take an active role in their own learning. Instead, they are passively present as the learning process passes them by. He goes on to write:

> If a high school were to focus on nothing else, helping teachers to engage students more actively in the learning process would probably have the biggest payoff of all the critical elements of the restructuring model. The other components of comprehensive restructuring are important mainly insofar as they contribute to making this possible (p. 17).

Research on effective teaching practices in Science Education reveals a strong correlation between keeping students' attention focused and academic achievement (Gabel, 1995). Focused attention provides the impetus for students to move from passivity into active engagement. This engagement brings learners into active participation in their own learning. "Engage" is the first phase in the BSCS (Biological Science Curriculum Study) "5E Instructional Model" that encourages curiosity, activates prior knowledge, and "hooks" the learner (Powell, Short, & Landes, 2002).

People learn when they are focused on, and actively engaged in, their own construction of knowledge. This engagement facilitates the building of connections between prior knowledge and new knowledge. These connections form meaningful patterns which can be stored and later retrieved (Donovan et al., 1999; Mayer, 1998).

Would students have a better understanding of material organized in a spatial format that included graphics, color, and key words in lieu of just isolated text? Would student achievement improve if students were focused and actively engaged in their own learning? Would a teaching and learning practice called mindmapping provide that format, focus, and active engagement?

Background

The U.S. Department of Education (n.d.) reports that American schools are not producing students with the excellence in science required for the United States to remain in a position of global economic leadership in the 21st Century. Reports from the 2000 National Assessment of Educational Progress (NAEP) science test showed that eighty-two percent of the twelfth graders in the United States performed below the proficient level.

Student achievement in Texas is assessed using the Texas Assessment of Knowledge and Skills (TAKS), a standardized test given to selected grade levels in selected subjects. Its task is to test core areas of the

Texas Essential Knowledge and Skills (TEKS), the state-mandated curriculum. Beginning in spring 2003, assessment in science for grades 5, 10, and Exit Level (starting at 11th grade) was initiated. In 2003, 42% of 10th graders and 47% of 11th graders passed the TAKS test in science compared to 71% of 10th graders and 78% of 11th graders who passed the TAKS test in social studies. In 2004, 51% of 10th graders and 63% of 11th graders passed the TAKS in science compared to 80% of 10th graders and 91% of 11th graders who passed in social studies (TEA, 2005).

It seems apparent more research and modification of science instructional practices need to occur to address high school achievement. Perhaps current practices are inconsistent with effective teaching and learning because they fail to address the needs of students. These practices may not engage students in sense-making and knowledge construction.

We cannot continue to work harder at traditional teaching methods and expect to achieve significantly different results. In order to enhance achievement for students in American schools, we must address the practice of teaching and learning. Continuing to do more of the same will not provide the desired result (Cawelti, 1994; Donovan et al., 1999; Stigler & Hiebert, 1999; Thomson, Carnate, Frost, Maxwell, Garcia-Barbosa, 1999; Zemelman, Daniels, & Hyde, 1993).

Science Education reform has been actively pursued for decades as various organizations have worked to further its causes. The National Science Foundation (NSF), American Institute of Biological Sciences (AIBS), American Association for the Advancement of Science (AAAS), National Science Teachers Association (NSTA), and National Research Council (NRC) have worked toward the ideals of improving science achievement and scientific literacy for all and promoting science curricula that move beyond the layered approach, and the inch-thick, mile-wide approach (AAAS, 1993; BSCS, 2005; Hurd, 1997; NRC, 1996; Texley & Wild, 1996).

Science Education leaders have worked diligently to create the vision and direction necessary to enable students of the 21st Century to take their places among world leaders. In order to make this vision a reality, might we need to bring forward that piece of teaching that addresses active learning and sense-making? Might we look at practices that promote organization of thinking and construction of new knowledge? Might we explore practices that promote understanding of core concepts applicable to the lives of all children?

The use of research-based methods for teaching and for measuring the results of that teaching waits to be explored. It is the charge of researchers and teachers to identify and research those practices that most effectively facilitate science teaching and learning, and thus achievement. The National Research Council, in *How People Learn: Bridging Research and Practice (1996)*, calls for collaborative research that moves away from the traditional isolation of researcher on the one side and the practice of teaching on the other side. It calls for an effort that combines the "strengths of the research community with the insights gained from the wisdom and challenges of classroom practice" (Donovan et al., 1999, p. 63).

This research study heeds the call for collaboration by combining the efforts of researcher and teacher in an endeavor to determine the effectiveness of mindmapping as a teaching and learning practice. The practice of mindmapping, using this particular graphic organizer, involves spatially organizing information using key words, symbols, sketches, and color. Mindmap construction facilitates student focus on and engagement with the material presented. It offers a framework for organizing ideas and concepts (Buzan, 1993, 1997; Hyerle, 1996; Margulies, 1991; Wycoff, 1991).

In this study, students followed mindmaps constructed by the teacher as she presented interactive lectures in their biology classes. As they followed the teacher's lecture and mapping, the students copied her map. This map-making facilitated organizing and making sense of the presented material. In the process, students were focused and actively involved with the lesson as well as their thinking about the presented material. Figure 1.1 displays the mindmap format used in the study. See Appendix A for specific mindmaps used in the study.

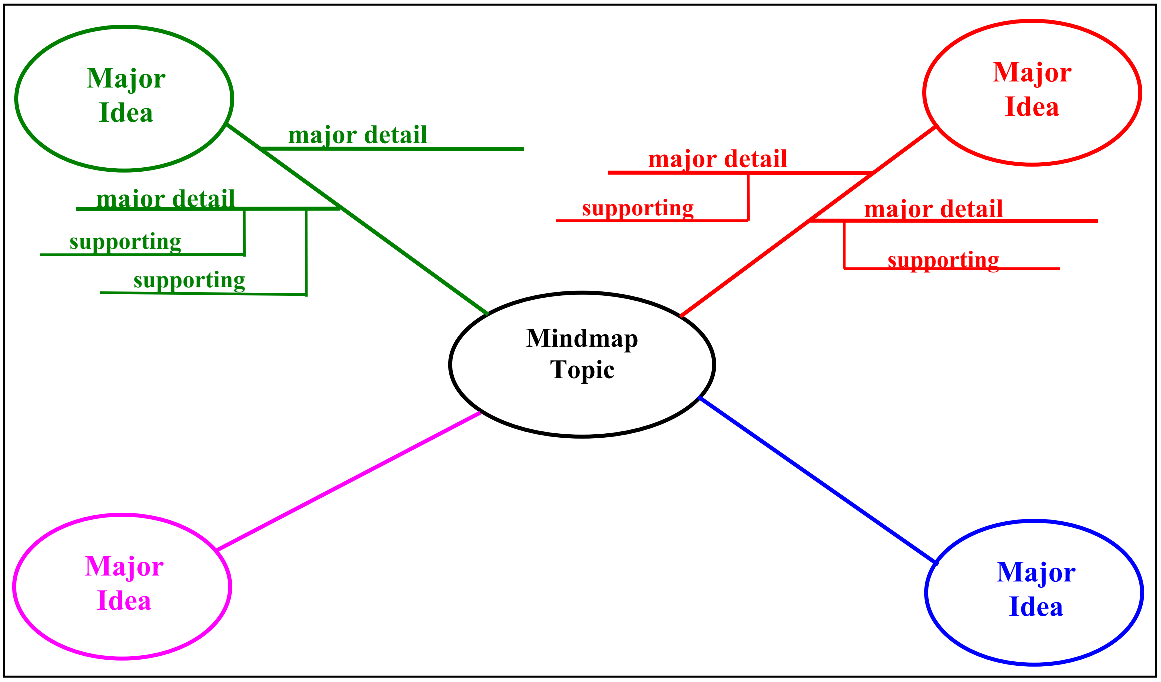


Figure 1.1. Format for mindmaps used in this study.

"Tony Buzan is the originator of Mind Maps®, the President of The Brain Foundation, Founder of the Brain Trust and the Brain Clubs, and the creator of the concept of Mental Literacy" (Buzan, 1993, p. 7). He has authored 14 books. Four of them have been published in fifty countries and translated into twenty languages. *Use Both Sides of Your Mind* has exceeded sales worldwide of one million copies. It is used at the Open University for students. It is used as an introductory text for training at corporations such as IBM, General Motors, EDS, Fluor Daniel, and Digital Equipment. Yet very little research addressing its use was found.

Buzan created a type of graphic organizer called a mindmap as a note-taking tool in the 1970's in Great Britain. He developed the mindmap to help him make sense of information he encountered in his university courses. Mindmapping allowed him to take notes without the rigid, linear structure of a topic outline. The spatial format of the mindmap allowed him to add to his map without the confusion encountered when he tried to add to a topic outline. To further his understanding and memory, he used graphics and color to illustrate key points.

Buzan has excelled in his career by translating his personal study tool, the mindmap, into a universally functional memory aid. He encourages the personalization of mindmaps as a way for students to make cognitive links with the content presented in school. In order to do this students must interact constructively with the information as they add key words, sketches, symbols, and other details to aid them in making connections between their prior knowledge and the content being studied. These connections are what facilitate understanding (Buzan, 1993, 1996; Fogarty & Bellanca, 1995; Margulies, 1991).

Visual tools or graphic organizers have been used to show recall and retention of science knowledge (Spiegel, 1994), cause and effect relationships, comparisons, answers to problems or questions, and chronological sequences (Readance, Bean, & Baldwin, 1985). However, relatively few graphic organizers have been studied sufficiently to support their use as effective teaching and learning tools (Rice, 1994; Trowbridge & Wandersee, 1998).

In 1977, Joseph Novak developed the concept map, a graphic organizer, to summarize interview data (Novak, 1998). He has researched and used concept mapping for decades to visually display conceptual understanding (Novak, 1990, 1991; Novak & Gowin, 1984). In recognition of the contributions of concept mapping to Science Education, The National Association for Research in Science Teaching (NARST) published a special issue devoted to concept mapping (Novak & Wandersee, 1990).

There is little research devoted to mindmapping as it pertains to teaching and learning in the classroom setting. However, some professional business consultants use mindmapping when they train executives and employees of corporations. Mindmapping is used because it is a fast and efficient method of taking notes, and helps organize and visualize one's thinking processes (Buzan, 1997; Lewis, 1997; Margulies, 1991; Senge, 1990; Wycoff, 1991, 1995).

Some research has shown that mindmapping may be effective in a corporate environment. Williams (1998) studied mindmapping as a note-taking strategy with employees in a large high-tech firm (n = 120) during a two-day training course. Her study determined, through a pretest/posttest control group design, that mindmapping, when used in training learners how to learn, was an effective learning strategy. It was, however, not significantly effective, possibly due to the novelty of the strategy and the limited duration of the study.

Mehegan (1996) conducted a study on the effectiveness of mindmapping versus traditional note-taking with adults in corporate training courses (n = <20 in both groups). The same instructor, using the same content, over a two-day period, conducted the courses. Prior to the course, the experimental group received a 1.5-hour training session on mindmapping, while the control received a 1.5-hour session on learning styles (visual, verbal or kinesthetic). Immediately following the two-day course and 30 days later, posttests failed to reveal a significant difference between the groups. The mindmapping group however, did score higher on both posttests though not significantly. In addition, the mindmapping group gave the course higher ratings on all evaluation criteria.

Conner (2003), addressing mindmapping in a classroom setting, conducted a qualitative study to report the experiences and opinions of ESL teachers (n = 3), and an ESL student (n = 1), who used mindmapping to teach, and learn, a second language. Participants in Conner's study, recruited via e-mail, received a questionnaire requesting information on his/her experience with mindmapping. Responses were positive to mindmapping used as a memory aid, and as an organizational and visual tool.

Parisian (1997), addressing mindmapping in a science classroom setting, used mindmapping as one strategy in the cognitive learning techniques section of his study of 9th grade earth science students (n = 97). Of the five classes in this study, three classes were in the Regents (gifted) program while the other two were in the non-Regents program. During a 7-day period, students were taught the learning techniques of mindmapping, chunking, converting words into small pictures (icons), and a phonetic mnemonic system whereby visual icons (content) were linked to the memory system through humorous associations. Following the treatment, students were given a Likert scale questionnaire to determine the level of their enjoyment of the cognitive science learning techniques listed above. Parisian reported that 41% of the Regents students (those typically successful using traditional educational techniques) enjoyed using mindmaps. In comparison, 54% of the general students (those typically less successful with traditional techniques) enjoyed using mindmaps. Parisian speculated that perhaps the mindmaps, which are rich in pictures, color, and spatial orientation, tap the spatial intelligence (one not normally tapped with traditional linear teaching techniques), and this might account for the larger percentage of enjoyment found by the general classes. Overall, 57% felt they would benefit from additional practice with the techniques used in the study. The researcher suggested the need for a longer, more structured treatment in a consistent environment. In such an environment, students may demonstrate an increased appreciation for mindmaps and a greater willingness to practice techniques (mindmapping, chunking, and mnemonics) in order to master their use.

Goodnough and Woods (2002) conducted a qualitative study with sixth grade science students (n=16) as part of an on-line curriculum unit. The perceptions of the students and the teacher were the focus of the study. Qualitative data were collected over a 10-month period. The study included teaching students the practice of mindmapping, having them follow the teacher's map, and finally creating individual and group mindmaps. Students enjoyed the mindmaps considering them fun, interesting, motivating, and easy to understand. They thought mindmaps had a variety of purposes in learning science and reported that mindmapping helped their learning. They also indicated a preference for individual mindmaps over group mindmaps. In 80% of the cases, according to the survey, students thought mindmapping helped them understand concepts and ideas in science. However, 95% of the students said they had not transferred their use of mindmapping in other classes.

Of the studies summarized above, two involved corporate adults (Williams and Mehegan), one involved ESL teachers and an ESL student (Conner), and two involved science students (Parisian, Goodnough & Woods). There is limited research relating to mindmapping, particularly as an effective teaching and learning practice in Science

Education. More research is needed to determine the effectiveness of mindmapping.

Statement of the Problem

Current high school science teaching and learning practices are inconsistent with what we know about how people learn. Traditional practices are not facilitating achievement for all students. Students, especially in high school science classes, are afforded limited opportunities to experience learning that promotes active involvement and sense-making, or understanding (Bransford, Brown & Cocking, 2000; Given, 2002; Wycoff, 1995). Helping students develop proficiency in learning, which translates into using that expertise to construct knowledge in subject domains, is a crucial goal of education. Students are expected to become expert learners. However, they are rarely provided opportunities to construct useful learning strategies (Mayer, 1998). This needs to change. Students in science need to be exposed to teaching and learning practices that serve all students in every classroom, as well as in their future learning as they take their places in tomorrow's workforce (Ettinger, 1998; Longley, Goodchild, Maguire, & Rhind, 2001; NRC, 1996; Texley & Wild, 1996). Expectations for today and the future require individuals to possess the ability to obtain, organize, process, and make use of information in different ways (Hurd, 1997). Jennings (1995) describes these requirements in terms of "learning a living" and "thinking for a living." As such, a basic education in science is the right of all students. It is this education that allows them to participate as scientifically literate citizens (AAAS, 1993).

Purpose of the Study

The purpose of this study was to determine if achievement in high school science courses could be enhanced utilizing mindmapping. Does mindmapping offer a framework that facilitates understanding and achievement in science?

Goodlad (1984) found that lecturing and explaining continue to be the most frequently used teaching methods. As students progress from primary to secondary classes, this pattern of passivity becomes increasingly dominant. Jackson & Davis (2000) found that most middle school classes centered on passive instructional practices in basic subjects including science. Active and interactive instructional approaches were infrequently used while drill and practice were habitually employed. Cawelti (1997) noted that the nation's high schools are still plagued by too much teacher lecturing and passive presence.

Research Question

This study addressed the issue of student achievement in high school biology. The main focus was whether mindmapping facilitated achievement. The research question was: Does mindmapping improve achievement for high school biology students?

Other considerations included student and teacher perceptions and attitudes surrounding mindmapping as a practice. How does the mindmapping experience influence the individuals involved?

Study Assumptions

1. All participants in the study will participate willingly and honestly.
2. The randomly assigned participants are assumed to be statistically similar.
3. The biology content pretest/posttest instrument will maintain a high degree of content validity.

4. The biology content pretest/posttest instrument will measure student achievement of the biology content studied.

Rationale and Theoretical Base

NSTA's *Pathways to the Science Standards*, High School Edition, promotes learning as an active process to be achieved by enthusiastic students (Texley & Wild, 1996). According to Novak (1990), science educators' primary challenge is finding ways to organize instructional material to better facilitate student learning. Citing research, Gabel (1995) points to finding ways of holding students' focus as a priority. Mindmapping, a graphic organizer, may offer a framework for the organization of material that facilitates student focus, engagement, and subsequent learning (Buzan, 1993, 1997; Margulies, 1991).

The researcher has been acquainted with the practice of mindmapping since the mid 1980's and has used it with upper elementary, middle school, and university students. She began using it as it "made sense" to her, and appeared to produce positive effects for her students such as active engagement, sense-making, and academic achievement, primarily in science. As with many practices found in classroom use, she consulted neither research nor theory prior to or during her use of mindmapping (Donovan et al., 1999).

This study seeks to determine the effectiveness of mindmapping as a practice. Will the practice of mindmapping move students from passivity to more active engagement in an academic subject, thus improving science achievement? This study seeks to add to the research concerning the effectiveness of mindmapping on achievement in a high school biology course, and to provide teachers with an alternative to traditional passive teaching methods.

Theoretical Framework

Mindmapping, while offering a framework by which to organize science content and a connecting place for prior and future knowledge, offers the learner an opportunity to personalize his or her map to facilitate sense-making unique to the learner. Yager (2000a) makes reference to the contemporary, productive research agenda in Science Education during the previous decade.

> This productive research reveals that: most persons have misconceptions about nature; typical schooling is ineffective in altering misconceptions; many of the most able students (such as university physics majors and engineering students) have as many misconceptions

> about science as the average high school student (p. 44).

He continues in the same breath to reveal the difficulty involved in simulating the precise pathway for learning. Is this not the case because all learners construct their own knowledge and therefore must take their own pathways to conceptual constructions?

Mindmapping is supported by the theory of Human Constructivism according to Novak (1993).

> The major claim I am making is that all human beings have an enormous capacity to make meaning and use language to construct and communicate meanings…What really counts is how to empower human beings to optimize their phenomenal capacity to make meaning, including their awareness of and confidence in processes that are involved. This capacity for meaning making is what I refer to as human constructivism (p. 190).

Two major ideas of Human Constructivism that address the possibilities of mindmapping are humans as meaning makers and active intervention of well-prepared catalysts.

Humans as meaning makers speaks to the ability of humans to make connections between prior knowledge and new knowledge constructed as they encounter new concepts, events, and experiences. This knowledge construction produces learning that is both slow and rapid. The major outcome of meaning making is a conceptual framework that contains a hierarchical, dendritic, and organized set of interrelated concepts (Mintzes & Wandersee, 1998; Novak, 1993; Novak & Gowin, 1984).

Active intervention of well-prepared catalysts speaks to teachers as active participants in facilitating opportunities for intense interaction and thoughtful reflection. This active participation provides the context, sets the stage, and encourages meaning-making and construction of new knowledge for students. Metacognitive strategies such as mindmaps facilitate this process (Mintzes & Wandersee, 1998; Novak, 1993; Novak & Gowin, 1984).

Statement of Hypothesis

In this study, the following null hypothesis was tested at the alpha 0.05 level of significance: There will be no significant difference in science achievement between students who use the mindmapping method versus those who do not use the mindmapping method for learning biology.

Independent Variables

Mindmapping, a graphic organizer, was employed as the treatment or intervention in a Biology I course. It was the independent variable in this study.

Dependent Variable

The dependent variable was achievement as measured by a teacher-developed, panel-validated test. This test was administered by the teacher prior to and immediately following the conclusion of the treatment.

Control Variables

The control or extraneous variables were age, gender, ethnicity, and grade point average. The possible influence of these variables was addressed by the random selection of the classes.

Sample

The target population was a group of students in Biology I at a suburban South Texas high school. The sample in this study was primarily 9^{th} and 10^{th} graders ($n = 147$) randomly assigned to six regular Biology I classes.

Data Analysis

To evaluate the effectiveness of mindmapping on science achievement, analysis included a one-way analysis of covariance (ANCOVA), using the pretest as the covariate and independent samples t-tests. Analysis of the data was facilitated by the use of a computer program, Statistical

Package for Social Sciences (SPSS) Version 12.0 for Windows (2003).

Qualitative research techniques were employed to better understand the meaning and value of the procedure for the individuals involved. Data from student informants were collected via individual semistructured and transcribed interviews. Data from the teacher informant were collected from an open-ended and transcribed interview. Data collected were analyzed to identify emergent themes.

Importance of the Study

Providing students and teachers with teaching and learning practices that actively engage students in making sense of content, and therefore promoting academic achievement, is a major goal of education (AAAS, 1993; NRC, 1996). Following the January 2002 signing of *No Child Left Behind* into law, the need for evaluation of performance and identification of "best practices" continues to be a priority (Protheroe, Shellard, & Turner, 2003; Villa, Thousand, Van der Klift, Udis, Nevin, Kunc, Kluth & Chapple, 2005). Calls for reform and current research on how people learn highlight the need for teaching practices that facilitate active student involvement and sense making which results in understanding, learning, and achievement (Boyer, 1983; Cawelti, 1997; Stigler & Hiebert, 1999). Examples of these practices are interactive instruction, graphic representation of thoughts that makes thinking visible, and the learner's active participation in his/her own learning. Interactive instruction and active participation by learners during class facilitate sense-making, achievement or cognitive growth, (Bransford et al., 2000) and feedback to and from students. Graphic representations offer a means to make the invisible thinking and organization of material visible.

One tool that utilizes graphic representation is mindmapping, a graphic organizer, which spatially organizes information using key words, images, codes, symbols and color. This type of organizer may address the visual-spatial and bodily-kinesthetic intelligences of some students (Gardner, 1985, 1999). And, while the content resembles that found on a topic outline, the structure of the mindmap is nonlinear and lends itself to personalization by the student (Buzan, 1993, 1997; Margulies, 1991; Wycoff, 1991). In personalizing mindmaps, students must focus on and interact with the subject matter on a personal level as they decide how to make sense of the presented content (Fogarty & Bellanca, 1995). In the process of constructing their maps, they add sketches, symbols, and other details which aid them in making connections among concepts, thereby facilitating understanding. Students use color as well making it easier to discern patterns and detect relationships. Color is used in fields such as geographical information systems to aid in the recognition of patterns and contrasts (Audet & Ludwig, 2000; Bransford et al., 2000; Jacobson, Eggen, & Kauchak, 2002; Longley, Goodchild, Maguire, & Rhind, 2001).

This study sought to provide teachers and researchers with a starting place or baseline for future study. It hoped to provide a springboard that would enable research to move to the next level. This study hoped to demonstrate that mindmapping is an effective practice that enhances student achievement.

Definition of Terms

1. <u>concept map</u>: A concept map is a spatial representation, showing key concepts, structured hierarchically. These concepts are connected by

linking words that indicate relationships (Novak, 1991).

2. <u>content validity</u>: Content validity determines whether test items are an adequate representation of the material or content to be taught (Brown, 1981).
3. <u>interactive lecture</u>: Interactive lecture combines planned interaction between teacher and students through discussion and questioning embedded within the lecture designed to increase student involvement (Freiberg & Driscoll, 1996; Martin, 1998).
4. <u>mindmapping</u>: Mindmapping is a tool used to spatially organize information around a central topic, using key words, images, codes, and symbols. The information represented follows a literal translation of material found on a linear topic outline. The placement of subtopics and supporting details are spatially and hierarchically arranged using multiple colors. The display lends itself to personalization by the user through placement of additional key words, images, codes, symbols and color (Buzan, 1993, 1997; Margulies, 1991; Wycoff, 1991). See Figure 1.1 for mindmap format and Appendix A for mindmaps used in the study.

5. open-ended interview: An open-ended interview allows the researcher and informant to dialogue in a manner that is a mixture of conversation and embedded questions (Erlandson et al., 1993).
6. semistructured interview: Semistructured interviews are somewhere between highly structured and unstructured interview formats. Most of the interview is directed by guiding questions prepared a priori. However, these questions are not necessarily used as written in order or wording (Merriam, 1998).
7. topic outlining: A topic outline is an organized, structured list of information arranged linearly according to major ideas (denoted by Roman numerals), major details (denoted by capital letters), and supporting details (denoted by Arabic numerals). Each level is subsequently indented (Carroll, Wilson & Forlini, 2001).
8. visual tool: Visual tools are constructed by individuals or groups using paper, board, or computer screen, and can be linear or nonlinear. Symbols are graphically linked by mental associations to create a pattern of information that

forms concepts or ideas for the user. They include mindmaps, concept maps, flow charts, Venn diagrams, webs, etc. (Hyerle, 1996).

Delimitations

This study was restricted to students in Biology I at a single South Texas suburban public high school. All students in the study were instructed by the same teacher, in the same classroom, during the same timeframe.

Student and Teacher Perspectives

A related qualitative component was employed in an effort to better understand the meaning and value of mindmapping for the individuals involved. Its intent was to investigate student and teacher perceptions related to the use of mindmapping. Qualitative measures enhance understanding by offering a holistic view of the participants' perceptions. Semistructured interviews were conducted with a purposive sample of students (n=7) to elicit descriptions of their mindmapping experiences. An open-ended interview with the teacher was conducted to elicit a description of her mindmapping experience.

The researcher hoped to discover emergent themes as they related to teacher and student perceptions regarding the practice of mindmapping. In order to maximize the researcher’s ability to identify emerging themes, interviews were recorded, transcribed, chunked, and coded. The information derived from this process was used to enhance the researcher’s and the reader’s view of the process (Erlandson, Harris, Skipper, & Allen, 1993; Patton, 1980).

Outline of Remaining Chapters

The focus of this research was to investigate the effectiveness of mindmapping in a secondary science course. Chapter 2 contains a review of related literature as well as the theoretical underpinning for the study. Chapter 3 describes the research design, instrumentation, methods, and procedures. Chapter 4 presents the results and conclusions. Chapter 5 presents the summary, discussion, conclusions, implications, and recommendations for further research.

CHAPTER 2: REVIEW OF RELATED LITERATURE

Our thinking processes have always yielded riches when we've approached things openly, letting free associations form into new ideas. Many would argue that we've used such a small part of our mental capacity because of our insistence on linear thinking.

Margaret Wheatley, 1992, p. 116

Introduction

High school science teaching and learning practices outside effective curriculum projects and laboratory experiences often revert to lecture as the traditional means of conveying information (Cawelti 1994, 1995, 1997; Grinder, 1991; Jackson & Davis, 2000; Jenkins, 1996). Students, especially in high school science classes, are afforded limited opportunities to experience learning that promotes active involvement and sense-making, or understanding (Bransford, Brown & Cocking, 2000; Given, 2002; Wycoff, 1995) when they are not otherwise engaged in laboratory activities or hands-on endeavors. Students in science need to be exposed to teaching and learning practices beyond lecture that serve all students in every classroom, as well as in their future learning as they enter today's rapidly changing world (Ettinger, 1998;

Longley, Goodchild, Maguire, & Rhind, 2001; NRC, 1996; Texley & Wild, 1996).

This study seeks to determine the effectiveness of mindmapping as a teaching and learning strategy. A review of the relevant literature highlights five key topics: Science Education, learning, graphic organizers, mindmapping, and constructivism.

Science Education

Science Education groups have worked to further the causes of scientific literacy, science achievement, and effective science curricula that move away from both the layered and the "inch-thick and mile-wide approach" (Hartman & Glasgow, 2002). To that end, Science Education reform has seen the development of several major curriculum projects.

In 1958, a grant from the National Science Foundation to the American Institute of Biological Sciences (AIBS) established the Biological Sciences Curriculum Study (BSCS) project. This project was a collaborative effort with leadership from scientists, science educators, administrators, parents, and educational psychologists. It produced an extensive study of course content and was intended to address teaching and learning for all students. Now, 50 years later, BSCS has an international reputation, a newly funded NSF grant proposal, and three new centers (Center for Curriculum Development, Center for Professional Development, and Center for Research & Development) (BSCS, 2005).

The American Association for the Advancement of Science (AAAS) began Project 2061 in 1986, with the goal of promoting scientific literacy for all Americans. *Science for All Americans* (1986) delineated the habits of mind and understandings to be attained by a scientifically literate citizen (Texley & Wild, 1996). This publication was followed in 1993 by *Benchmarks for Science Literacy,* which addressed minimum goals for what students should know and be able to do. It addressed several content areas by grade level (AAAS).

The National Science Teachers Association (NSTA) introduced the Scope, Sequence, and Coordination of Secondary School Science project (SS&C) in 1989, with the intent of providing a carefully sequenced, well-coordinated program of instruction in all of the sciences every year. This program progressed from concrete to abstract and was intended to parallel student development (Texley & Wild, 1996). The SS&C project specifically targeted students in middle school to promote interest in science during their formative years. Its intent was to see that interest carried into higher levels of education to include careers in science (Hurd, 1997).

The National Science Education Standards (NSES) for kindergarten students through grade 12, published in 1996 by the National Research Council (NRC), presented a vision for Science Education. Rather than acting as a prescriptive or concrete curriculum, the Standards are intended to be a vision or descriptive guide addressing science for all children, one of the strongest principles underlying this document (Texley & Wild, 1996). Users are reminded to utilize the content standards in conjunction with the outlined teaching and assessment standards avoiding traditional teaching and assessment strategies. To do otherwise would defeat the purpose of the Standards (NRC, 1996). The NSES envision and propose systemic changes that include major shifts in the way Science Education has been traditionally taught.

Science Education leaders have worked diligently to create the vision and direction necessary for students of the 21st Century. This work has not stopped with curricula projects but has continued by promoting specified instructional time to be devoted to hands-on experiences. The State of Texas, through its Texas Essential Knowledge and Skills (TEKS) document, has mandated that at least 40% of the instructional time allotted to high school science be devoted to field and laboratory investigations (Texas Education Agency, 1998). The TEKS correlate to the National Science Education Standards (NSES) on this matter under *Standard A: Science as Inquiry* as NSES also supports at least 40% of high school instructional time be spent in field and laboratory experience (Charles A. Dana Center, n.d.).

The National Science Teachers Association (NSTA) adopted laboratory guidelines for the amount of time to be spent on laboratory-related activities in January 1990. Its Board of Directors recommended a minimum of 40% for high school students. Their recommendation for elementary students was 60%, for middle school students 80%, and 40%, preferably 50%, for college level students (NSTA, 1990).

The National Association of Biology Teachers (NABT) adopted guidelines for laboratory and field instruction in September 1990. Its Board of Directors recommended that 50% of the allotted time in biology courses be spent in laboratory and field experiences. These experiences are intended to be integrated into the curriculum of the biology courses (NABT, 1990b). The Board of Directors also adopted guidelines delineating the characteristics of outstanding biology teachers. Among the guidelines are designing curricula that meet the needs of all students, using and continually reassessing a variety of approaches to facilitate learning, teaching students how to learn, and teaching well organized concepts for conceptual learning rather than rote memory (NABT, 1990a).

Much has been done to improve teaching and facilitate achievement in the area of Science Education. Innovative curricula projects and mandated laboratory time have been major accomplishments. However, the need remains to address that portion of instruction devoted to the transmission of content through the traditionally passive lecture method still prevalent in most science courses (Joyce, Weil, & Calhoun, 2000).

Learning

The wisdom of classroom practice tells us that no one strategy is equally effective for all students. In an action research investigation with high school science students, Trimarchi (2002) identified four groups for whom lecture seemed to be particularly difficult. These groups included second-language learners, females, low-income students, and students of color. Individuals have different learning styles, needs, abilities, feelings of efficacy, and thus respond to different opportunities for learning. The implication here is that the most effective practice includes teaching strategies that address individual differences. Strategies that address relevant, meaningful learning within an environment that promotes consideration for individual differences and active engagement in knowledge construction are intended for all students (Grinder, 1991; Lambert & McCombs, 1998; Sprenger, 2003; Texley & Wild, 1996).

Research, theories, and literature on how the brain learns, and the effect this information has had on the development of intellectual tools and learning strategies, has expanded dramatically in the previous decades (Caine & Caine, 1994, 1997; Jensen, 1998; NRC, 2000). The resulting plethora of literature urges researchers and practitioners to continue their pursuit of more effective teaching and learning strategies. Wandersee (1990a) notes the need to explore the use of graphic representations in the area of science and science education. Research should be directed to improve the teaching of science to include helping students organize their thinking in a manner that facilitates construction of new knowledge, problem solving, and decision making based on reasoning and evidence. Science education as rote teaching or translation of currently held science conceptions must give way to science education as a thinking, scientifically literate pursuit (Hurd, 1997; Yager, 2000b).

As the educational community looks more closely at the potential of all children, it must look at countless ways to facilitate learning. Formal educational environments of the past may have been "better at selecting talent than developing it" (Donovan et al., 2000, p. 5). Furthermore, if given the opportunity to experience different instructional strategies, "those who did well in traditional educational environments might have developed skills, knowledge, and attitudes that would have significantly enhanced their achievements" (p. 5). It is no secret that some individuals find traditional teaching strategies appropriate for their learning while others struggle.

Graphic Organizers

Graphic organizers are visual tools not commonly used in the traditional classroom setting. These tools may appeal to a variety of learners because they represent information spatially by utilizing key words and phrases. Information is thus communicated to the user without extensive text passages. Graphic organizers found in today's classrooms come in many shapes and forms. Variations of these tools include concept maps, mindmaps, story maps, fishbone illustrations, flow charts, matrices, Venn diagrams, and roundhouse diagrams, but all rely on the spatial placement of key information to help students make sense of the content (Fogarty & McTighe, 1995; Trowbridge & Wandersee, 1998) and can be traced to David Ausubel's advance organizer (Merkley & Jefferies, 2001) and his assimilation theory of meaningful learning (Ausubel, 1963, 1968, 2000).

David Ausubel's (1963, 1968; Ausubel & Robinson, 1969) advance organizers were not the spatial organizers seen today, but rather organized prose passages introduced in advance of the expository teaching of that material. The evolution of these early advance organizers laid the groundwork for the flourish of today's graphic organizers.

Today’s organizers are used prior to, during and after instruction in a variety of settings (Hyerle, 1996). They are used to show cause and effect relationships, comparisons, chronological sequences, answers to problems or questions in reading (Readance, Bean, & Baldwin, 1985), organization of content in some science textbooks (e.g., Johnson & Brusca, 1994; Miller & Levin, 2004), assessment of conceptual understanding in science (Novak, 1984, 1990, 1991), retention and recall of science knowledge (Spiegel, 1994), note taking in any discipline, and corporate brainstorming (Buzan, 1979, 1993, 1997; Lewis, 1997; Wycoff, 1991, 1995). Some reasons cited for this increased use of graphic organizers in classrooms today point to the growing use of technology and visual presentation of information, the move to more student-centered learning environments that promote interactive learning, and greater understanding of the constructivist-cognitive paradigm that encompasses thinking processes, metacognition, and creative analysis (Hyerle, 1995, 1996).

A major theoretical underpinning supporting graphic organizers is Ausubel’s assimilation theory of meaningful learning (1963, 1968, 1969, 2000). This theory is based on meaningful reception learning. Meaningful reception learning involves the building of new meanings by the learner from potentially meaningful material presented in its final organized form. The concept of potentially meaningful material assumes the material to be learned is not arbitrary or verbatim, but rather appropriately organized into a form that readily anchors the new material to the learner's cognitive structure. To facilitate this connection, the learner must possess the relevant prior knowledge to which the new material can be linked, related, and anchored. This process allows the learner to make sense of the new material. Assimilation of this new, potentially meaningful material into the learner's cognitive structure then allows the learner to use the knowledge later for associated learning, problem solving, or replication.

The primary goal of schools is to promote the highest degree of meaningful learning possible. Yet teachers spend the majority of their time engaged in expository teaching while students spend the majority of their time engaged in reception learning (Cawelti, 1997, Grinder, 1991; Jackson & Davis, 2000; Jenkins, 1996). Ausubel (Ausubel & Robinson, 1969) supports expository teaching and reception learning. He believes the most efficient means for promoting the highest degree of meaningful learning is by presenting new content in its final organized form. Learners must receive content, in its final organized form, in a manner that facilitates connections and sense making. Additionally, learners must be motivated to make sense of and assimilate into their cognitive structure material presented. This implies proactivity on the part of the learner.

In summary, the material to be assimilated must be potentially meaningful and presented in an organized form. The learner must also possess the relevant prior knowledge to which the new knowledge will be linked and anchored. The learner must be motivated to integrate this new knowledge in a nonarbitrary and nonverbatim manner into his or her cognitive structure (Novak, 1998).

The most widely researched graphic organizer in the realm of Science Education is the concept map (Wandersee, 1990b). Studies have been conducted and many articles have been written on the use of concept maps to teach science. A review of science education literature reveals that over one hundred references related to concept mapping have been published (Al-Kunifed & Wandersee, 1990). The articles, written primarily in the 1980s, address topics including environmental education (Bar-Lavie, 1988; Brody, 1984; Raven, 1985), various sciences (Ault, 1985; Boschhuizen, 1988; Okebukola & Jegede, 1989; Pankratius, 1986), reading (Hanf, 1971; Prater & Terry 1988), and pedagogy (Amaudin, Mintzes, Dunn, & Schaffer, 1984; Beyerbach, 1988; Morine-Dershimer, 1989; Wandersee, 1990b). Although the value of concept mapping is supported by research, more empirical studies need to be conducted (Duit, Treagust, & Mansfield, 1996).

Early pilot studies were conducted by Novak (1983) and Carter and Lehman (1982). Novak’s studies were directed at determining whether concept maps and Vee diagrams could be used with students younger than university students. He also considered whether these study aids facilitated acquisition of science knowledge and problem-solving performance. Novak arrived at positive conclusions to both questions. Likewise the results of Carter and Lehman’s pilot study indicated significantly higher biology achievement test scores for students using concept maps and Vee diagrams.

Some research into the use of concept maps has reported mixed results. Lehman, Carter, and Kahle (1985) conducted a pretest—posttest control group design study with a nonequivalent control group. The study explored the effectiveness of concept maps and Vee diagrams compared to traditional outlines as study aids. A panel-validated instrument testing higher-level thinking measured the effectiveness of these aids. Higher-level thinking was defined as questions ranked at the application level or higher according to Bloom's (1956) Taxonomy. The participants in the study were 250 students from two large, urban, primarily black, inner-city high schools. The results of their study failed to produce significant differences in the groups. Both ANOVAs and ANCOVAs with the pretest as a covariate were conducted. Neither indicated a significant difference at the 0.05 alpha level indicating a failure to reject the null hypothesis.

Okebukola (1990) conducted a pretest/posttest control group design study with predegree biology students (n=138) at Logos State University. Concept mapping was used as the treatment. Prior to the initial pretest, the experimental group received four hours of instruction and practice in the use of concept maps. Both groups received pretests, instruction, and posttests on units in genetics and ecology. The panel-validated instruments consisted of items rated at the comprehension level (40%), application level, (30%), analysis (10%), synthesis (5%), and evaluation (5%) according to Bloom's (1956) Taxonomy. The experimental group scored significantly better than the control group on the tests for meaningful learning in genetics and ecology.

Guastello, Beasley, and Sinatra (2000) conducted a pretest/posttest control group design study with low achieving seventh-graders (n=124) from an inner city school in Brooklyn. The intervention was conducted over a two-week period with the control group using a traditional read and discuss method of instruction while the experimental group constructed concept maps with the teacher during their discussion. The experimental group showed statistically significant results as measured by an analysis of covariance using the pretest as the covariate.

Rye and Rubba (2002) conducted post-instructional standardized interviews with eighth-grade physical science students following five weeks of instruction. The intent of the study was to determine whether embedding a concept mapping process within interviews would facilitate the extraction of students' conceptual understandings of chlorofluorocarbons and their role in global atmospheric change. Interviews and concept maps were scored using a predetermined list of concepts. Correlations were computed between these scores and students' scores on the California Achievement Test (r=.729) and their Pathfinder index (r=.474), a measure of structural knowledge. Revised map scores were statistically significant (p=.031) predictors of the Pathfinder index. Rye and Rubba (2002) point to concept mapping as a versatile tool for displaying and assessing student conceptual understandings in science education.

While researchers were testing the effectiveness of concept maps in science classrooms, others were exploring insightful connections. In his article, *Concept Mapping and the Cartography of Cognition*, Wandersee (1990a) uses mapping with its capacity to represent scientific knowledge as a metaphor to make obvious information regarding cartography as it applies to concept mapping. This comparison is brought into the review as it also relates to mindmapping.

Wandersee begins, “To map is to construct a bounded graphic representation that corresponds to a perceived reality” (Wandersee, 1990a, p. 923). Accordingly, “to map” is “to know.” Wandersee lists four basic purposes of map making: “(a) to challenge one’s assumptions, (b) to recognize new patterns, (c) to make new connections, and (d) to visualize the unknown” (p. 924). Mapping is a human endeavor that represents meaning-making or knowledge construction. It allows thoughts and connections to be seen and manipulated spatially. Important cognitive connections are made when students move from prose or linear, text-based representations to spatial representations using key words. This facilitates learning for those students who struggle with traditional methods.

Mindmaps

Many students struggle with traditional methods of knowledge representation. One such struggling student was Tony Buzan (2000), who found that traditional practices thwarted his ability to learn and remember material presented in class. The difficulties he encountered during his early school days created less than favorable memories.

> When I was a young boy at school, I found myself perplexed and confused by many questions to which I found I had no answers, and demotivated by comments from my teachers that seemed to confirm my lack of intelligence, concentration and energy (p. xv).

He was plagued by comments indicating laziness, lack of concentration, and disruptive behavior. He was considered by some of his teachers to be “non-college” material.

These difficulties continued to plague him during his university experience as he studied psychology, English, mathematics and general science (Buzan, n.d.). As the quantity and complexity of his workload increased, he felt increasingly distressed. Prior to his university years, he had begun to modify his traditional class notes to include color to emphasis important information. Faced with an overwhelming volume of information to be assimilated, Buzan continued to refine his note taking method. He was determined to organize and make sense of that material necessary for his success at the university level.

Through continuous refinement, Buzan (1993) created a type of graphic organizer called a "mindmap." He developed the mindmap to facilitate note taking and help him make sense of information he encountered during his educational experience. The "non-college material" student graduated from the University of British Columbia with double Honours in Psychology, English, Mathematics and the General Sciences. He continued his pursuit of mental literacy becoming the "Founder of the Memoriad, the World Memory Championships, and co-Founder of the Mind Sports Olympiad, the 'Mental Olympic Games.' He is the holder of the world's highest 'creativity IQ'" (p. 7). And as might be expected, he now devotes much of his work to those students considered learning disabled.

Buzan's mindmaps display spatially organized information using key words, images, codes, symbols, arrows, and color. While the *content* resembles that found on a topic outline, the *structure* of the mindmap is nonlinear and lends itself to personalization by the student. In personalizing mindmaps, students must interact with the information aiding them in making connections between their prior knowledge and the content being studied. It is these connections and the construction of knowledge that facilitates understanding (Buzan, 1993, 1997; Fogarty & Bellanca, 1995; Margulies, 1991).

It is the mindmap's spatial organization of subtopics and key points around a unifying topic that allows the user to "see" key components as well as the big picture (Novak & Gowin, 1984). It allows the opportunity to see the forest and the trees (Hyerle, 1996). As Caine and Caine (1994) and Caine, Caine, and Crowell (1994) note in their principles of brain-based learning, the brain simultaneously perceives and creates parts and wholes. It perceives the interconnectedness of information and experience. Gelb (1988) proposes that the greatest power of mindmapping is training the brain to perceive the whole picture as well as individual components. As graphic organizers are generally shown on one page, students have the opportunity to see the big picture, or whole, and its parts simultaneously.

David Hyerle (1995, 1996) organizes visual tools or graphic organizers into three types: brainstorming webs, task-specific organizers, and thinking process maps. Mindmaps were designed to facilitate note taking and memory while offering a framework for brainstorming, organizing concepts, and the display of thinking processes (Buzan, 1979).

Mindmaps are used for a variety of purposes in a variety of subjects. Due to the lack of empirical studies discovered during the literature search, anecdotal and informational items have been included in this review to give the reader a view of the use of mindmaps.

Multinational businesses have incorporated mindmapping into their training and used it as a strategy to facilitate brainstorming, organizing, and displaying information. "Jean-Luc Kastner, an executive with Hewlett-Packard Medical Products Group Europe, had two days to design a highly technical, four-day training course" (Buzan, 1997, p. 1). The person usually responsible for the course took a sudden leave with a protracted illness. The course involved training specialists to use a cardiac arrhythmia computer system to detect heart malfunctions. Kastner used mindmapping to brainstorm, organize, and display his training presentation. He had the participants use mindmaps to organize and learn the material. When the participants were given the final test, they scored higher than previous classes. In follow-up testing, the participant recall was well above 70%. The previous recall percentage was below 40. Feedback on the course included comments of more successful, more useful, and more fun than the usual courses. In addition, some participants (from England, France, Germany, Italy and Ireland) remarked that the mindmap-based course worked well for people with less than perfect knowledge of English (Buzan, 1993).

Studies involving corporate training courses using mindmapping found the mindmapping groups scored higher, though not significantly, on posttests. Mehegan (1996) conducted a study (n = <20 in both groups) that was less than optimal and included a posttest only. The study included two courses conducted over a two-day period. Williams (1998) studied mind mapping as a note-taking strategy with employees in a large high-tech firm (n=120) during a two-day training course. The study determined, through a pretest/posttest control group design, that mind mapping, when used in training learners how to learn, was an effective learning strategy. Course ratings and positive participant responses were consistently high in both.

Mindmaps can be used to analyze plans, conflicts, and issues relating to business and financial concerns from a department to a corporate level. According to Lewis (1997), management accountant and consultant founded *Illumine*, they improve creativity and offer visualization of thinking processes involving product and business development. Mindmaps improve understanding, retention, and application of material received during training. Training courses designed for the education of executives are using mindmapping to facilitate active and meaningful learning while offering executives a practice to use with their corporate teams (Mento & Jones, 2002; Mento, Martinelli, & Jones, 1999).

Parisian (1997), addressing mindmapping in a science classroom setting, used mindmapping as one strategy in the cognitive learning techniques section of his study of 9^{th} grade earth science students ($n = 97$). Following treatment, students were given a Likert scale questionnaire to determine the level of their enjoyment of the cognitive science learning techniques. Parisian reported that 41% of the Regents students (those typically successful using traditional educational techniques) enjoyed using mindmaps. In comparison, 54% of the general students (those typically less successful with traditional techniques) enjoyed using mindmaps. Parisian speculated that perhaps the mindmaps, which are rich in pictures, color, and spatial orientation, tap the spatial intelligence (one not normally tapped with traditional linear teaching techniques), and this might account for the larger percentage of enjoyment found by the general classes. Overall, 57% felt they would benefit from additional practice with the techniques used in the study.

Goodnough and Woods (2002) conducted a qualitative study with sixth grade science students (n=16) as part of an on-line curriculum unit. Qualitative data were collected over a 6-month period focusing on the perceptions of the students and the teacher. Students reported enjoying the mindmaps considering them fun, interesting, motivating, and easy to understand. In 80% of the cases, students thought mindmapping helped them understand concepts and ideas in science.

Woods, the teacher, found the use of mindmaps cognitively demanding referring to the thinking necessary to construct them. She found the mindmaps stimulated self-reflection regarding her teaching. In her normal classroom practice, she assumed the students understood the material presented until they were asked to demonstrate that understanding. With the mindmaps, she was able to see her students' understanding readily and discuss it with them. She noted that the students enjoyed the color, symbols, and open format of the mindmap. Students who normally struggled with expository writing were able to gain confidence in their ability to explain their science understanding using a less text-based format. Woods found mindmapping to be useful and well worth the time necessary to teach it as a skill.

Mindmaps are used in higher education to facilitate learning in various subjects. Hamza and Alhalabi (1999) speak to university teachers of computer curricula in their article *Teaching in the Information Age: The Creative Way.* They remind teachers that their mission is not to assign grades but rather to teach students to think, learn, and make meaningful connections between prior knowledge and new knowledge. Divergent imagery through mindmapping facilitates thinking, helps generate ideas, and organizes connections between prior and new knowledge. Essential elements cited include central image, major themes radiating from that central image, topics of importance represented hierarchically, with a big picture view of connected information.

Budd (2004) speaks to university teachers of economics in his article *Mindmaps as Classroom Exercises.* He offers research pertaining to active and collaborative learning techniques as well as those pertaining to diverse learning styles. He suggests mindmapping as a way of addressing these student needs. Budd has used mindmapping to move beyond the chalk-and-talk lecture format in his labor relations course at the University of Minnesota. He has used mindmapping for group projects. Results from an online survey, though not statistically significant, revealed a connection between students who felt they learned a lot and those learning styles preferring active experimentation.

Binghamton University and Broome Community college collaborated to produce modules promoting self-directed learning in students entering the engineering department. The mindmapping module introduced students to using mindmaps for preclass reading, reading of difficult texts, and brainstorming. This helped students organize and identify connections and patterns in their engineering content (Fellows, Culver, Ruggier, & Beston, 2002).

Engineering departments at other universities are using mindmapping as part of their core courses. The University of Tennessee at Chattanooga uses mindmapping in its elements of design course focusing on systems thinking and creative thinking. Mindmaps are used to brainstorm and organize team projects (Wigal, 2004). Texas Tech University uses mindmapping in an engineering course focusing on complexity of design. Mindmaps are used for project decomposition and design showing both the hierarchical structure and the interactions of the components (Maxwell & Tanik, 2002).

Farrand, Hussain, and Hennessy (2002) examined the effectiveness of mindmapping versus a self-selected study technique on factual recall with medical students (n=50) in London. Treatment involved the reading of a 600-word passage followed a pretest on the passage. Students were exposed to the original passage again. The control group used a self-selected study technique to take notes on the passage while the experimental group received instruction on mindmapping and then used mindmapping to take notes on the passage. Motivation was measured for the two groups. A recall test was administered one week later with the mindmap group scoring 10% higher than the control group. Motivation, however, was considered higher in the control group.

Mindmapping offers its users a tool that is accessible to multiple learning styles and intelligences. Gardner identifies eight different types of intelligences (Gardner, 1985, 1999), and the NRC asserts that the linguistic and logical intelligences are most often addressed and valued in school environments (Bransford et al., 2000). In addition to linguistic and logical intelligences, mindmapping taps the spatial, kinesthetic, and intrapersonal intelligences as well, thus addressing the learning preferences of a larger audience (Campbell, Campbell, & Dickinson, 1999; Grinder, 1991). Providing appropriate instruction for students of all ability levels means helping all students identify and learn to use intellectual tools and learning strategies that facilitate their understanding and productivity (NRC, 2000).

Mindmapping is being used in a variety of educational settings in an attempt to offer the learner a format for sense-making through the organization of thoughts and material. Empirical data to support its use, however, are lacking. As few studies have been conducted to determine the effectiveness of graphic organizers generally, much less mindmaps specifically, research in this area is necessary (Dunston, 1992; Trowbridge & Wandersee, 1998).

Constructivism

Students do not follow a universal path to sense-making or knowledge construction, as noted in the early educational experience of Buzan (Buzan, 2000). Each learner is unique in what he or she synthesizes from a learning experience. Out of the need to explain this phenomenon, came the constructivist perspective. Constructivism is grounded in the theory that the learner is a unique individual with respect to manner, prior knowledge, and experiences. As a result, the learner shapes, or constructs, his or her knowledge in regard to his or her own reality (Brooks & Brooks, 1993; Shapiro, 1994,). George Kelly's (1955) personal construct psychology describes the learner as one who views the world in his or her unique manner. Furthermore, that unique mental framework determines a learner's perception of the world.

Although Ausubel (2000) does not support the constructivist paradigm, he believes the cognitive structure of each learner is unique. Following this uniqueness, all new knowledge occurring from the assimilation of new information is by definition unique.

While the term "constructivism" is somewhat new to the academic realm, the theory can be traced back to 1710 when Neapolitan philosopher Giambattista Vico (as cited in Yager, 2000a) wrote a treatise revealing his basic ideas of constructivism. Bransford et al. (2000) bring us into the 21st Century with the view of humans as "goal-directed agents who actively seek information" (p. 10). These tenets provide the foundation for the new science of learning in which "understanding" not rote memory is a primary characteristic.

In future generations Educational historians "will look back on the late 20th century as a time when educators began the slow, institutional transformation away from rote behaviorism, closed definitions of intelligence, and hardened perceptions of a singular, static, 'given' structure of knowledge" (Hyerle, 1996, p.13). One can only hope this cognitive revolution has begun.

The constructivist philosophy maintains that learners must connect new knowledge with prior knowledge and that learning experiences must facilitate that connection in a manner supportive of the learner's uniqueness. Traditional teaching methods that rely on the outpouring of facts for students to remember are directly counter to constructivist beliefs. In fact, constructivists explain that many times the reason students do not remember the knowledge presented to them is because they have not found the connections that take the learning experience to the level at which the learner becomes meaning-maker (Pope, 1982).

Donovan, et al (1999) suggests that people learn when they are focused on, and actively engaged in, their own construction of knowledge. This engagement facilitates the building of connections between prior knowledge and new knowledge. These connections form meaningful patterns that can be stored and later retrieved.

As Caine and Caine (1994) and Caine, Caine, and Crowell (1994) note in their principles of brain-based learning, the brain simultaneously perceives and creates parts and wholes. It perceives the interconnectedness of information and experience. One teaching/learning strategy that appears to facilitate the way the brain learns is graphic organizers.

One type of graphic organizer, the mind map, offers material organized in its final form thus providing a connection between prior and future knowledge. It also offers the learner an opportunity to personalize his or her map to facilitate sense-making unique to the learner. Yager (2000a) makes reference to the contemporary, productive research agenda in Science Education during the previous decade. One product of that research is the realization that “it is difficult to simulate the exact pathway for learning” (p. 44).

Mindmapping is supported by the theory of Human Constructivism according to Novak (1993).

> The major claim I am making is that all human beings have an enormous capacity to make meaning and use language to construct and communicate meanings… What really counts is how to empower human beings to optimize their phenomenal capacity to make meaning, including their awareness of and confidence in processes that are involved. This capacity for meaning making is what I refer to as human constructivism (p. 190).

Two major ideas of Human Constructivism that address mindmapping are humans as meaning makers and active intervention of well-prepared catalysts.

Humans as meaning makers speaks to the ability of humans to make connections between prior knowledge and new knowledge constructed as they encounter new concepts, events, and experiences. This knowledge construction produces learning that is both slow and rapid. The major outcome of meaning making is a conceptual framework that contains a hierarchical, dendritic, and organized set of interrelated concepts (Mintzes & Wandersee, 1998; Novak, 1993; Novak & Gowin, 1984).

Active intervention of well-prepared catalysts speaks to teachers as active participants in facilitating opportunities for intense interaction and thoughtful reflection. This active participation provides the context, sets the stage, and encourages meaning making and construction of new knowledge for students. Metacognitive strategies such as mindmapping facilitate this process (Mintzes & Wandersee, 1998; Novak, 1993; Novak & Gowin, 1984).

While graphic organizers graphically relate ideas for conceptual understanding, mindmaps include spatially organized information, key words, symbols, sketches, color and personal connections. Mindmap construction facilitates student focus and active engagement with the material organized in its final form. It offers a framework to support not only the organization of ideas and concepts but also a place to connect prior knowledge to new constructions, personalized by the learner's own understandings (Buzan, 1993, 1997; Margulies, 1991; Wycoff, 1991).

It is imperative to pursue the task of researching practices that promote understanding, learning, and achievement by facilitating active student involvement and sense-making during otherwise passive times such as those related to the traditional practice of lecturing. These practices are needed not only for the time students spend in classrooms today, but for their lives outside of formal education, as the need for lifelong learning strategies permeates our world as never before (Ettinger, 1998; Marzano, 2003; Weinstein & Mayer, 1986; Wycoff, 1991).

Summary

Much has been accomplished to further the goals of Science Education including major curricular projects and standards (BSCS, 2005; Hurd, 1997; NRC, 1996; Texley & Wild, 1996) and mandated or suggested laboratory time (NABT, 1990; NSTA, 1990; TEA, 1998). Still, much instructional time in high school science classes is dominated by lecture (Cawelti 1994, 1995, 1997; Grinder, 1991; Joyce, Weil, & Calhoun, 2000) with limited opportunities for students to experience learning that promotes active involvement and sense-making, or understanding (Bransford, Brown & Cocking, 2000; Given, 2002; Wycoff, 1995).

As research uncovers more about how people learn, our teaching and learning strategies need to reflect that new information. Teaching and learning strategies need to encompass relevant, meaningful learning within an environment that promotes consideration for individual differences and active engagement in knowledge construction (Grinder, 1991; Lambert & McCombs, 1998; Sprenger, 2003; Texley & Wild, 1996).

Mindmapping is being used in a variety of educational settings to offer the user a format for sense-making through the organization of thoughts and material in final form. Empirical data to support its use, however, are lacking. As few studies have been conducted to determine the effectiveness of graphic organizers, much less mindmaps specifically, research in this area is necessary (Dunston, 1992; Trowbridge & Wandersee, 1998).

This study addresses the need for teaching and learning tools or strategies that promote sense-making and knowledge construction. This study seeks to determine the effectiveness of mindmapping as a teaching and learning tool or strategy.

CHAPTER 3: METHODS AND PROCEDURES

Unless a man clearly understands and inwardly digests
what he studies, let him read ever so much; he can
only be compared to a box well filled with books.
Like that box, he carries books within him, and
like the box he is none the wiser for it.

Talmudic Saying, Mintzes, Wandersee, & Novak, 2000, p. v

INTRODUCTION

Improvement in science achievement for students in the 21^{st} century demands new avenues of instruction in Science Education. Teachers and researchers have the opportunity to move toward identifying and researching alternatives to traditional practices. Doing so collaboratively combines the "strengths of the research community with the insights gained from the wisdom and challenges of classroom practice" (Donovan, Bransford, & Pellegrino, 1999, p. 163). Thus, alternatives may be found to facilitate meaning-making and knowledge-building in science for today's students and tomorrow's workforce (Donovan et al., 1999; Ettinger, 1998; Longley, Goodchild, Maguire, & Rhind, 2001; Mintzes, Wandersee, & Novak, 2000; Wycoff, 1991).

Many current practices are inconsistent with effective teaching and learning because they fail to address the needs of students. Students need opportunities to experience learning that promotes active involvement and sense-making, or understanding. In addition, "helping students to organize their knowledge is as important as the knowledge itself, since knowledge organization is likely to affect students' intellectual performance" (Bransford, Brown & Cocking, 2000, p. 176-177). Learning and transfer research has found that organizing information into conceptual frameworks is key to a greater transfer of learning, allowing students to apply what they have learned to new settings or circumstances (Donovan et al., 1999; Novak, 1993, 1998; Novak & Gowin, 1984).

Mindmapping, an organizational tool, addresses the process of actively engaging students while they make sense of presented material in order to facilitate learning and achievement. It facilitates student focus on the task at hand and active engagement in making sense of the science content presented by the teacher. The practice of mindmapping involves spatially organizing information by using key words, symbols, sketches, and color (Buzan, 1993, 1997; Margulies, 1991; Wycoff, 1991). In this study, students follow a mindmap constructed by the teacher as she presents interactive lectures. As they follow her lecture and mapping, the students copy the teacher's mindmap. This map-making facilitates organizing and making sense of the presented material. Thus, students are focused and actively involved with the material as well as their thinking about that material. For mindmaps used in this study, see Appendix A.

This chapter describes procedures used to acquire data to assess science achievement in a South Texas high school. The following sections are included: (a) research methodology, (b) research design, (c) treatment, (d) variables, (e) research question, (f) research hypothesis, (g) sample, (h) instrumentation, (i) internal validity, (j) external validity, (k) data analysis, and (l) limitations. A qualitative component of the study describes procedures that are used to better understand the meaning and value of the practice of mindmapping for the individuals involved. The following sections are included: (a) overview, (b) methodology, (c) research design, (d) sample, (e) data collection, (f) data analysis, and (g) summary.

METHODOLOGY

A pretest-posttest control group design was used in this study. This design allowed for two randomly assigned groups to receive a pretest, followed by the treatment, and a posttest. Sources of internal validity were likely controlled by the use of random assignment, a pretest, and a control group. This is to say that the sources controlled included regression, selection factors, mortality, maturation, history, testing, and instrumentation. There was, however, the possibility of an interaction between the pretest and the treatment. Had this been the case, that weakness would call for generalizability to the pre-tested groups only (Gay & Airasian, p. 392).

Research Design

In this study, the teacher instructed six periods of regular Biology I students primarily in 9th and 10th grades. The classes were combined, with both grades in each class. The control and experimental groups were distributed through six class periods as illustrated in Table 3.1. This combination was intended to eliminate the time-of-day confounding variable (Gravetter & Wallnau, 2000).

Table 3.1

Daily Schedule of Classes

Period	Time	Group	*n*
1	8:30-9:21	Control	22
2	9:27-10:28	Experimental	27
3	10:34-11:25	Control	23
4	11:25-12:16	Experimental	24
Lunch	12:16-1:00	Lunch	-
5	1:05-1:55	Conference	-
6	2:00-2:50	Control	25
7	2:55-3:45	Experimental	26

Throughout the 6-week treatment, the teacher delivered instruction on three topics (classification, viruses and bacteria, and protists); each topic was presented for two consecutive weeks, as illustrated in Table 3.2.

Table 3.2

Instructional Topics during Treatment

Weeks	Topic
1-2	Classification
3-4	Viruses and Bacteria
5-6	Protists

Based on 15 years of experience using mindmaps, the researcher believed 6 weeks or approximately 20 hours (the duration of this study) was possibly the shortest length of treatment needed to produce significant results. Most other mindmap studies lasted from 2-7 days (Conner, 2003; Mehegan, 1996; Parisian, 1997; Williams, 1998) with only one lasting several months (Goodnough & Woods, 2002).

Treatment

The researcher provided the teacher with instruction on developing mindmaps. Initial training was three hours in duration. Due to the universal understanding of topic outlining, the time needed to understand the process was believed to be minimal. An advantage of mindmapping is its accessibility to users which minimizes the learning curve and implementation (Gelb, 1988; Hawk, 1986; Margulies, 1991; Novak, 1993; Wycoff, 1998). Following training, the teacher constructed mindmaps aligned with her biology, state-directed science curriculum. These maps were reviewed and discussed by the teacher/researcher team.

During the treatment period, the teacher accommodated the research procedure by using mindmaps to organize and display content material for the experimental group. Students copied teacher-constructed mindmaps during interactive lectures using colored writing implements on blank paper. As the teacher lectured, she wrote/drew a mindmap on an overhead projector while the students copied her mindmap onto their paper. As they worked, the students were encouraged to ask questions, offer suggestions for word placement, and personalize their maps with sketches and graphics.

As each topic was introduced, an overview mindmap gave the students a preview of that topic. Following the overview mindmap, each branch was turned into a mindmap. See Appendix A for examples from the viruses' topic. Note the first map is an overview of viruses. The second map addresses characteristics of viruses as seen on the branch in the upper left-hand corner of the overview map, while the third map addresses reproduction as seen on the branch in the upper right-hand corner of the overview map.

The teacher conducted interactive lectures using mindmaps on 5 to 8 days per each 2-week session, or approximately 20 days, during the treatment. Table 3.3 indicates the number of minutes per week devoted to mindmapping. Laboratory activities (typical practice in this teacher's classroom) were conducted throughout the course of instruction.

Table 3.3

Mindmapping Minutes per Week

Weeks	Topic	Mindmapping Minutes per week
1-2	Classification	150
3-4	Viruses and Bacteria	150
5-6	Protists	150

Instruction on the use of mindmapping was embedded in its actual use during the interactive lectures and was modeled by the teacher as students practiced and discussed it. Incorporating metacognitive instruction within subject domain learning can enhance student achievement and offer them the opportunity to practice learning independently. Teaching the use of thinking strategies should be taught across curricula and age levels (Cawelti, 1995; Dansereau, 1985; Donovan et al., 1999; Fogarty, & McTighe, 1995; Weinstein, & Mayer, 1986). It was a goal of this practice for students to become proficient and self-directed in the use of mindmapping.

The control group received class instruction, as is typical practice for this teacher, through interactive lecture using a traditional topic outline to organize and display content material. Students copied a topic outline presented by the teacher and then participated in interactive lectures and laboratory activities.

Variables

Independent Variable

Mindmapping was employed as the treatment, or intervention, in a Biology I course. It was the independent variable in this study.

Dependent Variable

The dependent variable was achievement, as measured by a teacher-developed, panel-validated instrument. It was administered by the teacher prior to and immediately following the conclusion of the treatment.

Control Variables

The control, or extraneous, variables were age, gender, ethnicity, and grade point average. The possible influence of these variables was addressed by the random selection of the classes.

Research Question

This study had one major question addressing student achievement. Other considerations included student and teacher perceptions and satisfaction with the practice of mindmapping. However, the main focus was whether mindmapping facilitated achievement in biology. Thus, the research question: Does mindmapping improve achievement for high school biology students?

Research Hypothesis

This study examined the effects of mindmapping on science achievement for high school biology students. The following null hypothesis was tested at the alpha 0.05 level of significance.

There will be no significant difference in science achievement between students who use the mindmapping method versus those who do not use the mindmapping method for learning science.

Sample

The students in this study were primarily 9th and 10th graders at a suburban South Texas high school. The sample (n=147) was randomly assigned to six regular Biology I classes at the beginning of the school year.

Students at this high school are assigned to biology sections randomly by computer. The high school curriculum supervisor, principal, and head counselor oversee this process. The process follows:

A. Pre-registration: After counselors meet with students and their parents, students select the courses (required and elective) they wish to take.

B. Total number of biology students: After the total number of students per course is identified, the number of sections needed to accommodate the students is determined by computer program, based on class size.

C. Sections: The needed sections are then randomly assigned to the biology teachers.

D. Computer selection: Students' names, their required courses, and electives are entered into the computer software program. The program assigns the students randomly to sections of their required and elective courses. These sections are assigned to the various teachers teaching that subject. Thus, the biology teachers receive the classes assigned to them (ViStA™, 2004).

E. Adjustments: Following random selection, manual adjustments are made to accommodate schedule conflicts and student or teacher requests. According to a computer-generated add/drop report, the total number of Biology I students (regular, pre-AP, and resource) for the semester of study is 410. Of those 410 students, there were two schedule adjustments. Therefore, 0.005 percent of the total Biology I students are not randomly assigned to their current classes (CPISTU, 1998-2004).

Students in the experimental group (n = 77) were enrolled in three of the biology classes, while students in the control group (n = 70) were enrolled in the remaining three classes. The teacher's schedule offered an opportunity to study six classes receiving instruction in the same course, from the same teacher, in the same classroom, during the same semester.

Instrumentation

The researcher elected to validate the teacher's traditional content assessment instrument to study science achievement on an instrument typically used in a "real" classroom setting. To that end, all test questions normally used in the six-week period of the study will be provided (along with the textbook, course syllabus, and scope and sequence) to a panel of biology experts for content validation (Fraenkel & Wallen, 2003).

The validation panel consisted of two Assistant Professors from the Physical and Life Sciences Department at a Texas university and the Curriculum Director (formerly a biology teacher) from the study-site district office – all of whom possess biology content expertise. Each panel member received a packet containing a letter of instruction, 3 unit tests typically given by the teacher during the 6-week period, a scope and sequence chart, the course syllabus, and the textbook adopted by the district (Fraenkel & Wallen, 2003). The experts were asked to rate each question according to how well it reflected, or tested, course content, using a Likert scale of 1 to 5 (1-unacceptable, 2-poor, 3-fair, 4-good, 5-excellent). The researcher and teacher selected questions only from those with a 4 or 5 rating to create the pretest/posttest instrument.

The newly composed instrument was then returned to the panel for review. The panel was asked to evaluate the instrument, and make necessary adjustments to ensure the best fit of presented content with tested content.

The instrument was prepared in final form following necessary adjustments as recommended by the panel. See Appendix B for the teacher-developed panel-validated instrument. The pretest and posttest contained the same questions, randomly ordered for each administration. The teacher administered the instrument immediately prior to and immediately following the conclusion of the treatment.

Data Collection and Recording

Prior to beginning this research project, permission to proceed was requested from the IRB (Internal Review Board) at The University of Texas at Austin. See Appendix C for the form granting permission to conduct this study.

Permission was obtained from the school district superintendent, high school principal, and parents of the students involved in the study. Written consent from the administration and the parents of the students involved in the study was obtained prior to data collection. Requests for permission were completed in February 2004. See Appendix D for letter requesting permission to conduct the study. See Appendix E for letter of consent from the school district. See Appendix F for sample parent consent form for participation in the study. These letters and forms are copies of the originals using pseudonyms to protect the confidentiality of the district and students. The original letters and the signed consent forms are held in reserve and not included in this report (Gay & Airasian, 2000).

Data for the research question were collected during February and April by using both the pretest and the posttest instruments. Student demographics were obtained from the registrar's office at the high school and will include gender, ethnicity, grade, age, and grade point average.

The pretest and posttest were administered by the teacher. Following each, the tests were scored and returned to the researcher for tabulation. Data collection and demographic information were compiled by the researcher.

Following the administration of the test, internal consistency reliability of the instrument was assessed using split-half reliability analysis. Test items were split into even and odd subtests. Each student's score on the two halves was computed giving each a score for the odd items and a score for the even items. The two sets of scores were correlated with the Spearman-Brown correction formula, and the results were evaluated. A high coefficient indicates a good split-half reliability (Gay & Airasian, 2000).

An internal consistency estimate of reliability, split-half coefficient expressed as a Spearman-Brown corrected correlation, was computed for the teacher-developed panel-validated instrument. For the split-half coefficient, the questions were split into two halves such that the two halves would be an equivalent as possible. The first half included odd questions, and the second half included even questions. The split-half coefficient was .693, indicating fair reliability (Green, Salkind, & Akey, 2000).

Data Analysis

To evaluate the effectiveness of mindmapping on science achievement, analysis began with a one-way analysis of covariance (ANCOVA), using the pretest as the covariate. This test adjusts posttest scores for initial differences in the pretest scores since randomization does not guarantee equivalent groups. The ANCOVA statistically removes the advantage one group might have over the other in terms of known content (covariate). Thus, the results of the posttest can be compared fairly as if both groups began equally.

Before computing the ANCOVA, the homogeneity-of-slopes assumption was tested to determine the interaction between the covariate (pretest) and the factor (group) in the prediction of the dependent variable (posttest). If the interaction was significant, results from an ANCOVA would not be meaningful, and therefore would not be calculated. Instead, the researcher would have considered the Potthoff adaptation of the Johnson-Neyman technique (Green, Salkind, & Akey, 2000). This would follow a significant group-by-covariate interaction. Should the interaction not be significant, an ANCOVA would be conducted to determine the effect of the treatment on achievement (Gay & Airasian, 2000; Green, Salkind, & Akey, 2000).

To further determine the effectiveness of mindmapping on science achievement, independent-samples *t* tests were conducted to evaluate the difference between the means of the two independent groups. Each student must have a score on the grouping variable and the test variable. The *t* test tells "whether the mean value of the test variable for one group differs significantly from the mean value of the test variable for the second group" (Green, Salkind, & Akey, 2000).

Analysis of the data was facilitated by the use of a computer program, Statistical Package for Social Sciences (SPSS) Version 12.0 for Windows (2003). Had it become necessary to move beyond the scope of that computer program's capability, Huitema's (1980) *The Analysis of Covariance and Alternatives* would have been consulted.

Limitations

The limitations imposed on the study include the following:

The sample was composed of selected intact classes within a particular district. Generalizing to dissimilar classes, or school districts, may be limited or inappropriate.

The implementation of mindmapping by a teacher new to the method may have been a limiting factor. The researcher provided an initial three-hour training session. However, understanding the premise of a practice and implementing it are not necessarily synonymous.

The length of treatment (six weeks) may have resulted in non-growth due to insufficient time for learning, and processing the skills necessary to receive the full benefit of mindmapping. The researcher believed 6 weeks was the shortest length of treatment needed to produce significant results.

The teacher-developed, panel-validated instrument may have been a factor in the failure to reject the null hypothesis in that it may not have appropriately tested the learning or achievement of the students in the experimental group. The instrument, a compilation of tests normally used by the teacher, was directed more at factual recall than conceptual understanding. Mindmaps are believed to facilitate making sense of organized content rather than facilitating factual recall.

Qualitative Content

Qualitative research techniques were employed to better understand the meaning and value of the procedure for the individuals involved. Informants included the biology teacher (n=1) and a purposive sample of high school biology study participants (n=7). Data from the student informants were collected from individual semistructured and transcribed interviews. Data from the teacher informant were collected from an open-ended and transcribed interview. Analysis of the data included chunking and coding the transcripts to identify emerging themes.

Methodology

Qualitative research seeks to understand the meaning of processes, events, or experiences as they relate to how people feel or perceive these phenomena. Qualitative researchers seek to offer insights into people's feelings and perceptions (Gay & Airasian, 2000) in connection with or because of those processes, events, or experiences. A related qualitative element was employed in an effort to better understand the meaning and value of the mindmapping experience for the participants. Its intent was to investigate student and teacher perceptions related to the use of mindmapping.

Research Design

Semi-structured interviews were conducted with a purposive sample of students (n=7) to elicit descriptions of their mindmapping experiences. An open-ended interview was conducted with the teacher (n=1) to elicit descriptions of her mindmapping experience. The researcher hoped to discover emergent themes as they related to student and teacher perceptions regarding the practice of mindmapping. In order to maximize the researcher's ability to identify emergent themes, interviews were recorded, transcribed, chunked, and coded. The information derived from this process will be used to inform and get at the effectiveness of mindmapping (Erlandson, Harris, Skipper, & Allen, 1993; Patton, 1980).

Sample

Purposive sampling was employed to identify seven high school biology students to participate in the individual interviews. Good informants are able to express their feelings and perceptions concerning the interview topic (Merriam, 1988). Six student informants for this purposive sample were selected by the high school biology teacher because they were articulate and receptive to being interviewed. One student informant was selected by the researcher following a laboratory activity observation.

Table 3.4

Purposive Student Sample Demographics

Academic Notes (from Teacher)	Grade	Age	Gender	Ethnicity	GPA
Gifted & Talented	9	14	M	Other	96.72
Transfer from Italy	9	15	F	Other	91.5
Lacks Motivation	9	15	M	Hispanic	86.0
Regular Education	10	16	F	Hispanic	90.07
Hard Worker	9	15	M	Caucasian	94.14
*Grade/Behavior Difficulties	9	16	M	Hispanic	71.54
Special Education	10	16	M	Caucasian	82.14

Note. An asterisk (*) indicates the student informant selected by the researcher.

Data Collection

An open-ended interview was conducted with the teacher informant (n=1). This type of interview allows the researcher and informant to dialogue in a manner that is a mixture of conversation and embedded questions (Erlandson et al., 1993). It allows a more free-flow of thoughts uninterrupted by the next preplanned question.

A semistructured interview was conducted with each student informant (n=7). Semistructured interviews fall somewhere between highly structured and unstructured interview formats. Most of the interview is directed by guiding questions prepared a priori. However, this does not dictate the exact wording, order of the questions, or whether the questions will be used during the interview (Merriam, 1998).

Written consent from the parents of the students involved in the semistructured interviews was obtained before the interviews began. This consent was in addition to the consent form signed requesting participation in the study. Requests for permission were completed in April 2004. See Appendix G for sample consent form for the interview. The signed consent forms are held in reserve and not included to protect the confidentiality of the students (Gay & Airasian, 2000).

Students were released from their biology classes to participate in the individual interviews. The teacher participated in her interview outside the school day.

The interviews received level one member checking and were recorded for transcription. Level one member checking occurred within the interview and was used to clarify, correct, and expand emergent thoughts or constructions. This offered the researcher and informant the opportunity to confirm communicated ideas, to make sure the researcher understood what the informant was saying and to clarify its meaning (Lincoln & Guba, 1985). (The researcher must rely on level one member checking as the teacher expressed a need to minimize the time students were away from class due to the standardized testing schedule.)

Questions prepared a priori guided the semistructured interviews. However, during the interviews neither the order nor the exact wordings of the questions were necessarily followed. In addition, questions may or may not be used (Merriam, 1988). See Appendix H for a list of the proposed interview questions.

Data Analysis

Analyzing qualitative data required making sense of and interpreting the data in a manner that brought to light the constructions of the informants. It included processes such as chunking, organizing, coding, and reducing followed by identifying and describing emergent themes (Schwandt, 1997). Data analysis is the process of "bringing order, structure, and meaning to the data, of discovering what is underneath the surface" (Hubbard & Power, 1993, p. 65).

Data collected from the teacher interview and the semistructured individual student interviews were transcribed to offer a written picture of the conversation. The transcriptions were chunked or broken into sections that identified particular thoughts or views related to the informants’ mindmapping experience. These sections or chunks were coded to facilitate sorting and identification of emergent themes (Creswell, 2002).

Summary

A pretest-posttest control group design was used in this study allowing two randomly assigned groups to receive a pretest, followed by a treatment, and a posttest. The pretest and posttest were forms of a teacher-developed, panel-validated instrument originating from tests typical in high school classrooms. The treatment was mindmapping, a graphic organizer or visual tool that spatially organizes information by using key words, symbols, sketches, and color. This pretest-posttest control group design was intended to investigate the effectiveness of mindmapping on science achievement for high school biology students. It compared the biology content achievement between the control and the experimental group of Biology I students.

A related qualitative element was employed in an effort to better understand the meaning and value of the procedure for the individuals involved. Its intent was to investigate student and teacher perceptions related to the use of mindmapping. Semi-structured student interviews and an open-ended teacher interview was conducted, transcribed, and analyzed to identify emerging themes.

In the next chapter, results of the study will be presented. Both quantitative and qualitative results will be included.

CHAPTER 4: FINDINGS

While each of us is ultimately responsible for his or her own learning, we usually need a teacher's help to "crack the code" of the document in the field.

Mintzes, Wandersee, & Novak, 1998, p. 347

Introduction

Contained herein are the data analyses and results. A description of the sample and the statistical analyses of the results collected at the completion of the treatment are included. Additionally, a qualitative component is presented which highlights student and teacher perceptions related to the use of mindmapping. These perceptions were obtained through individual interviews.

This study addressed the issue of student achievement in high school biology. The main focus was whether mindmapping facilitated achievement. The research question: Does mindmapping improve achievement for high school biology students?

The purpose of this study was to determine if achievement in high school science courses could be enhanced utilizing mindmapping. An experimental pretest/posttest control group design was implemented.

Student achievement was measured by a teacher-developed, panel-validated science instrument.

Data for all analyses were collected during the 2004 spring semester. All students were required to return a parent consent form giving permission for participation in the study. See Appendix F for a sample of the informed consent required for participation in the study. The signed consent forms are held in reserve but not included herein to protect the confidentiality of the students (Gay & Airasian, 2000).

The pretest was administered by the biology teacher during the week of February 23-27, 2004. The treatment period was followed by a posttest administered by the biology teacher during the week of April 19-23, 2004. Missing data were handled by the statistical computer program, Statistical Package for Social Sciences (SPSS) (Version 12.0 for Windows, 2003).

Description of the Sample

The target population was a group of students in Biology I at a suburban South Texas high school. Of the accessible population of 410 Biology I students, the sample was comprised of 143 9^{th} and 10^{th} graders, and four 11^{th}

graders. (The 11^{th} graders were taking Biology I for the second or third time.) The participants (n=147) were randomly assigned to six regular Biology I classes taught by the same teacher. A demographic description of the sample involved in the study is presented in Tables 4.1 and 4.2.

Table 4.1

Gender and Ethnicity

	Female	Male	Caucasian	Hispanic	Other	Total
Control	42	28	41	20	9	70
Experimental	33	44	53	13	11	77
Total	75	72	94	33	20	147

Table 4.2

Grade and Age

	9^{th}	10^{th}	11^{th}	14	15	16	17	Total
Control	31	38	1	9	35	22	4	70
Experimental	34	40	3	11	20	38	8	77
Total	65	78	4	20	55	60	12	147

The descriptive data revealed almost twice as many males in the control group as in the experimental group. The ethnicity distribution approximated that of the community. The distribution of ethnicity within the study was Caucasian 64%, Hispanic 22%, and Other 14%. The distribution of ethnicity within the school community was Caucasian 66%, Hispanic 22%, and Other 12%. This information was collected from the district's Academic Excellence Indicator System (AEIS) Report for 2003-2004 (internal district document).

Most students were 15 or 16 years of age and in the 9th or 10th grade. Tests for differences indicated growth in both the experimental and control groups with no significant difference between the groups.

Results

An independent samples t-test was conducted to determine whether students in the experimental group scored significantly higher than students in the control group on mean pretest scores of science achievement as measured by the teacher-developed, panel-validated instrument. Based on Levene's test, Equality of Variance between the two groups was assumed, F (1, 140) = 3.319, p =.071. The mean pretest score of the students in the experimental group was 22.60, while the mean pretest scores of the students in the control group was 23.58. The mean difference between the two groups was .977. The results of the independent samples t-test indicated that a significant difference did not exist. The null hypothesis was accepted, $\underline{t}$ (140) = 1.069, $\underline{p}$ =.287. There appeared to be no significant difference in the mean pretest scores of science achievement between the two groups. The means and standard deviations of the mean pretest scores for the two groups are presented in Table 4.3.

Table 4.3
Comparing Groups' Mean Pretest Scores

	N	Mean	Std. Deviation
Experimental	73	22.60	4.963
Control	69	23.58	5.905

Null Hypothesis

There will be no difference in science achievement between students who use the mindmapping method versus those students who do not use the mindmapping method for learning science.

An independent samples t-test was conducted to determine whether students in the experimental group scored significantly higher than students in the control group on the mean posttest scores of science achievement as measured by the teacher-developed, panel-validated instrument. Based on Levene's test, Equality of Variance between the two groups was assumed, F (1, 130) = .202, p =.654. The mean posttest score of the students in the experimental group was 34.26, while the mean posttest scores of the students in the control group was 36.14. The mean difference between the two groups was 1.882. The results of the independent samples t-test indicated that a significant difference did not exist. The researcher failed to reject the null hypothesis, t (130) = 1.216, p =. 226. There appeared to be no significant difference in the mean posttest scores of science achievement between the two groups. The means and standard deviations of the mean posttest scores for the two groups are presented in Table 4.4.

Table 4.4

Comparing Groups' Mean Posttest Scores

	N	Mean	Std. Deviation
Experimental	69	34.26	9.032
Control	63	36.14	8.712

An independent samples t-test was conducted to determine whether a significant difference existed between the control and experimental groups' mean difference on the pretest and posttest scores of science achievement as measured by the teacher-developed, panel-validated instrument. Based on Levene's test, Equality of Variance between the two groups was not assumed, F (1, 125) = 4.183, p =.043. The mean difference for the experimental group was 19.247, while the mean difference for the control group was 20.350. The mean difference between the difference scores of the control and experimental groups was 1.103. The results of the independent samples t-test indicated that a significant difference did not exist. The null hypothesis was accepted, t (125) = .475, p =.635. There appeared to be no significant difference in the mean difference in science achievement between the two groups.

A one-way analysis of covariance (ANCOVA) was conducted to test the null hypothesis. Before computing the ANCOVA, the homogeneity-of-slopes assumption was tested to determine the interaction between the covariate (pretest) and the factor (group) in the prediction of the dependent variable (posttest). The analysis evaluating the homogeneity-of-slopes assumption indicated that the relationship between the covariate and the dependent variable did not differ significantly as a function of the independent variable, $\underline{F}(1, 123)=.405$, MSE=61.39, $\underline{p}=.526$, partial $\eta^2=.003$. Based on these results, an ANCOVA was appropriate (Gay & Airasian, 2000; Green, Salkind, & Akey, 2000).

A one-way ANCOVA was employed to determine the effect of the treatment on science achievement. The independent variable was mindmapping, the treatment. The dependent variable was the posttest, with the pretest used as the covariate. The ANCOVA was not significant, $\underline{F}(1, 124)=.370$, MSE=61.10, $\underline{p}=.544$, partial η^2 .247.

Table 4.5

ANCOVA for Pretest-Posttest

Effect	F	df	p	η^2
Pre-test	.370	(1,124)	.544	.247

The strength of the relationship between the group factor and dependent variable was weak, as assessed by a partial η^2, with the group factor accounting for less than 1% of the variance of the dependent variable. Therefore, the researcher failed to reject the null hypothesis at the 0.05 level of significance.

Results: Student and Teacher Perceptions

This section presents an account of the related qualitative findings highlighting student and teacher perceptions related to the use of mindmapping. It contains a description of the purposive sample, procedures, and results of the findings.

The purpose of this study was to determine if achievement in high school science courses could be enhanced utilizing mindmapping. A related qualitative element was employed in an effort to better understand the meaning and value of this intervention for the individuals involved.

Purposive Sample

The purposive sample consisted of student informants (n=7) from the high school Biology I students who participated in the study, and the teacher (n=1). The informants (n = 6) were selected by the teacher because they were articulate and receptive to being interviewed. An additional informant (n = 1) was selected by the researcher following a laboratory activity observation.

Procedures

Semistructured interviews were conducted with a purposive sample consisting of the students (n=7) and the teacher (n=1). The purpose of this qualitative element was to elicit descriptions of participants' mindmapping experiences. The researcher hoped to discover emergent themes as they related to student and teacher perceptions of the practice of mindmapping as well as the teacher's use of the method. In order to maximize the researcher's ability to identify emerging themes, the interviews were recorded, transcribed, chunked, and coded. The information derived from this process was used to enhance the reader's view of the process (Erlandson, Harris, Skipper, & Allen, 1993; Patton, 1980).

The Students' Perceptions

Student informants were selected by the high school biology teacher because they were articulate and receptive to being interviewed. An additional informant was selected by the researcher based on that student's performance during an intricate dissection activity. Good informants are defined by their ability to express their thoughts, feelings, opinions, and perceptions regarding the topic being studied (Merriam, 1988). Students were allowed to select a pseudonym to be used in the study. Table 4.6 shows demographic data for the student purposive sample for ready reference.

Table 4.6
Purposive Sample Demographic Data

* Informant Pseudonym	Academic Notes (from teacher)	Grade/ Age	Gender	Ethnicity	GPA
Bianca	Regular Education	10/16	F	Hispanic	90.07
Daniel	Hard Worker	9/15	M	Caucasian	94.14
Jose	Lacks Motivation	9/15	M	Hispanic	86
Julie	Transfer from Italy	9/15	F	Other	91.5
Robert	Gifted & Talented	9/14	M	Other	96.72
Skater	Grade/Behavior Difficulties	9/16	M	Hispanic	71.54
Theo	Special Education	10/16	M	Caucasian	82.14

* Pseudonyms selected by students

Semistructured interviews were conducted individually with each student informant and with the teacher. The student interviews were guided by questions prepared a priori. See Appendix H for a list of the proposed interview questions. However, neither the questions as they were written nor all the questions were used during the interviews. The questions were intended only as a place of beginning to illicit responses related to the use of mindmapping.

The responses were recorded, transcribed, and analyzed for recurring thoughts or emergent themes. During the process of analyzing, similar ideas, feelings, and experiences were noted. While sorting and classifying the emerging themes, it became evident that certain themes were common across all the informants.

Table 4.7 provides an overview of the common themes as well as the frequency of each theme across the informants. "Yes" indicates a theme was addressed specifically during the interview. "No" indicates the theme emerged but the response to that theme was negative or neutral. A "?" indicates an implied response to that theme. A blank space indicates the theme did not emerge during the interview.

Table 4.7

Common Themes across the Student Informants

	Bianca	Daniel	Jose	Julie	Robert	Skater	Theo
Sense-Making	yes	yes	yes	yes	yes	yes	yes
Mindmap/ Outline	yes	yes	yes	yes	yes	yes	yes
Color	yes	yes	yes	yes	yes	yes	yes
Engaged	yes	yes	yes	?	no	yes	yes
Easy to Find	yes	yes	yes	yes	yes	yes	no
Emotions	yes	yes	yes	yes	yes	yes	
Organized	yes	yes	yes	yes		yes	
Topic in Middle	yes	yes	yes			yes	
Transfer	yes	yes	?	no	no	yes	no

Themes Shared by All Student Informants

While sorting and analyzing emerging themes, it became apparent that all the students in the purposive sample shared similar views on several issues. Table 4.8 indicates the shared themes.

Table 4.8

Themes Shared by ALL Student Informants

	Bianca	Daniel	Jose	Julie	Robert	Skater	Theo
Sense-Making	yes	yes	yes	yes	yes	yes	yes
Mindmap/ Outline	yes	yes	yes	yes	yes	yes	yes
Color	yes	yes	yes	yes	yes	yes	yes

sense-making.

Students, especially in high school science classes, are afforded limited opportunities to experience learning that promotes active involvement and sense-making, or understanding. As cognitive research increases regarding how the brain receives and processes information, more thought must be given to practices employed by teachers to engage students and thus support their sense-making ability (Bransford et al., 2000; Kaufeldt, 1999; Mayer, 1998).

All informants referenced sense-making or learning. Daniel said mindmapping was helpful and he understood more when using it. He explains,

> It just makes more sense. I normally don't like to take notes…I just see what's up there, and then I copy it down. I don't process it in my head. I just kind of write it down and when the test comes around I don't have any idea what I'm doing. But those mindmaps, they are like explained out, I understand what's going on, and I know what I'm writing down and know what's coming on the test because of it.

Theo related paying attention and getting the material, pointing out that, "It sticks in. The colors…it's a different way of learning. Things would stick."

Robert talked about having notes without understanding their meaning:

> I mean all you have is your notes. It doesn't make any sense. I mean you just have to understand it like…they can tell you all the answers and if you don't understand them, then there is no reason to put it there.

The informants appeared to genuinely care whether they were making sense of the information presented. Several indicated that mindmapping was helpful to them. Jose made comments to that effect several times during his interview.

> It has really helped me to get used to a new way of taking notes. I like how I get all the different colors and then spreading it out and drawing it. It helped me understand a lot more than normal note-taking.

mindmap versus topic outline.

This study sought to determine the effectiveness of mindmapping as a practice. The teacher accommodated the research procedure by using mindmapping to organize and display content material for the experimental group. Students copied the teacher-constructed mindmaps during interactive lectures. Did the practice of mindmapping move students from passivity to more active engagement in the academic science subject?

The control group in this study received class instruction, as is typical practice for this teacher, through interactive lectures using a traditional topic outline to organize and display content material. Students copied a topic outline presented by the teacher and participated in interactive lectures and laboratory activities. See Appendix I for topic outline used in the study.

During the interviews conducted with the purposive sample from the experimental group, all informants made comments on the practice of note-taking using a topic outline versus the use of mindmapping. Skater pointed out a more active involvement in questioning the material: "[Before], everybody just came in, sat down, wrote the notes, and that is it. But with this [mindmapping], we come in; if we see something there we don't understand, we can ask questions. We ask way more questions."

Julie moved beyond herself to include other students.

> It’s [mindmapping] been very helpful because it’s... helped a lot of people with all their studying... because we look up our information and it’s right there when we need it, instead of having to go through a whole bunch of papers. So it’s an advantage for everyone.

To the contrary, Jose thought the outlines were time consuming, difficult to use, and difficult to understand. “She would explain it to us, but I would get lost because it was not all spread out, it was compressed.” He had difficulty understanding what the teacher was talking about while trying to find where she was in his notes. “It was just harder to get information from; I just could not use them that well.”

Theo was the only informant who preferred the topic outline. He said the mindmaps were fun, but he thought the outlines were a little better. They were easier for him to understand. “Because this one word stuff—it’s just not enough information. The outline has more information I guess.”

color.

“Colour is one of the most powerful tools for enhancing memory and creativity” (Buzan, 1997). Color is also used in fields such as geographical information systems to detect relationships and discern patterns (Bransford et al., 2000). Would students have a better understanding of material organized in a spatial format that included graphics, color, and key words in lieu of isolated text?

Although Theo preferred the topic outline, he did like the color associated with the mindmap. “I was paying attention better because you have color, and the colors helped me to pay attention better…I’m ready to learn.”

Bianca was excited about the colors beyond the prospect of learning. “I would always want to get to class early because everyone just runs to get the markers. It was neat and colorful not just black or blue, it was really neat.”

A mindmapping positive for Jose was finding information quickly. He said the different colors and format helped him. “If I forgot the topic or something, I could find it in the corners…or just the different colors.”

Themes Shared by 5 or 6 Informants

Table 4.9

Themes Shared by 5 or 6 Student Informants

	Bianca	Daniel	Jose	Julie	Robert	Skater	Theo
Engaged	yes	yes	yes	?	no	yes	yes
Emotions	yes	yes	yes	yes	yes	yes	
Organized	yes	yes	yes	yes		yes	
Easy to Find	yes	yes	yes	yes	yes	yes	no

Table 4.9 provides an overview of themes which were shared by five or six informants. "Yes" indicates a theme was addressed specifically during the interview. "No" indicates the theme emerged but the response to that theme was negative or neutral. A "?" indicates an implied response to that theme. A blank space indicates that the theme did not emerge during the interview.

active engagement.

"Engage" is the first phase in the BSCS "5E Instructional Model" that encourages curiosity, activates prior knowledge, and "hooks" the learner (Powell, Short, & Landes, 2002). Did the practice of mindmapping move students from passivity to more active engagement in an academic subject, thus improving science achievement?

Skater talked about how much easier the visual format of mindmapping was for him saying,

> It was just so easy being able to look at it and then not even having to read it, but just having to look at it and seeing what it says over here and what it says over there. It is way easier than just reading plain, boring notes.

When asked if he was able to become involved, he replied, “I did [was]. It just seemed more interesting once I started; before, all I did was write them [notes] down. I did not even read them. When we did the mindmapping, it all seemed so much better.”

Daniel talked about not paying attention when he copied his topic outline. “You could write it, and your mind will go off. But if you are doing that [mindmapping], you have to pay attention so you won’t lose yourself…just ask questions so you understand it all the way.”

emotions.

Learning is described as an emotional experience (Schallert, Reed, Fowler, & Lissi, 1993). Trowbridge and Wandersee (1998) found high school students to be proud of their completed concept maps. They were quite animated in articulating their accomplishments. Most informants in this study enthusiastically reported enjoying the experience of being successful, of being capable of constructing meaning during the process of copying the teacher's mindmap.

When asked about her feelings regarding the mindmapping process, Bianca exclaimed, "Excited! I actually knew what I was doing. I was learning, and I was happy because it stayed in my mind. If I forgot, I just went back to it." After confirming that she really had learned a lot, she continued, "Yeah, it was like a good feeling inside to know that I actually learned something from the notes [mindmaps]."

Skater's thoughts relating to his feelings, "It just makes everything more fun…I think these notes [mindmaps] are great!"

organization.

Teachers at all levels from elementary school through high school recognize the necessity that their students be able to organize their thoughts and ideas. This is a major reason why graphic organizers are becoming so popular in schools at every level. Graphic organizers are visual tools used to manage and display information (Hyerle, 1996). They offer users a view of the big picture and its related parts without lengthy text passages.

Jose commented on the usefulness of mindmaps. The information they provided helped him review and study for tests. He liked that the mindmaps were "not all compressed, like in normal notes [outline]. There is a bigger area to work off of, different colors, different parts of that main topic. It is easier to find what you are looking for, more organized."

Julie agrees that mindmaps were more organized. She prefers "mindmapping because it's easier and it doesn't take time looking up what you need to find out. And it's more organized in different little categories so it's a lot easier."

easy to find.

Students' capacity for learning is influenced by learning tools that are accessible and easy to use. They impact learning primarily through the impression received from features such as color, size of print, and spacing (Jacobson, Eggen, & Kauchak, 2002). That visual image stays with them after the written word has departed.

When trying to find information on the mindmaps, six of the seven informants thought it was easier using the mindmap. Daniel said, "You are able to pick up stuff a lot easier…It's harder to find out where stuff is [on the outline] and with the mindmapping thing, you know where everything is."

Skater found the visual representation to be helpful.

> That worked really good for me. It was just so easy being able to look at it, and then not even having to read it, but just having to look at it, and seeing what it says over here and what it says over there. It is way easier than just reading plain, boring notes.

Themes Shared By 4

Table 4.10

Themes Shared by 4 Student Informants

	Bianca	Daniel	Jose	Julie	Robert	Skater	Theo
Transfer	yes	yes	?	no	no	yes	no
Topic in Middle	yes	yes	yes			yes	

Table 4.10 provides an overview of the themes shared by four informants. "Yes" indicates a theme was addressed specifically during the interview. "No" indicates the theme emerged but the response to that theme was negative or neutral. A "?" indicates an implied response to that theme. A blank space indicates that the theme did not emerge during the interview.

transfer.

The successful use of mindmaps in science gives students, in this case the informants, the confidence to apply this practice in other subjects. Trowbridge and Wandersee (1998) suggest that success in concept mapping has a similar effect. Following successful use of concept maps, students in their research stated that they would pursue using concept maps as study tools in other courses.

Three of the seven informants in this study had actually transferred their use of mindmapping to other subjects (Spanish, History, English, and World Geography). Jose was thinking about it, but "it takes planning and understanding to do it that way." Therefore he elected to save it for another day.

Bianca transferred her mindmapping to two other classes explaining,

> I used it in my Spanish and my History classes because she gave us a topic, and we had to outline a chapter. So I put like the main part, then I put parts on the side, and just added stuff and she thought it was a better way because it was more organized.

Daniel was thinking about mindmapping in English but he was frustrated "because it's harder, and I just want to get everything on the mindmap because it helps me a lot. I do bad in English but I do good with the map even if I'm not good in English.” He has actually tried mindmapping in world geography.

> When I go home to do my homework, I’ll just get my outlines and write them out kind of in mindmap. And everything in populations I’ll highlight one color because we sometimes get to use our notes on tests and it helps a whole lot.

Skater has given mindmapping a try in English.

> Whenever I am writing a paper for English, I know I wrote the subject in the middle and then off to the side I was brainstorming. That is what I do, I think that is way easier for me to write a paper…then in the middle I go to the left and that to me is the most important and then down is the second, over across to the right is the last. It goes starting sentence, middle, middle, and the end.

topic in the middle.

In an effort to clarify for the reader the students’ point of view, a sample topic outline format followed by a sample mindmap format is provided.

Topic Outline (topic of the outline)

I. major idea

A. major detail

B. major detail

1. supporting detail

2. supporting detail

II. major idea

A. major detail

1. supporting detail

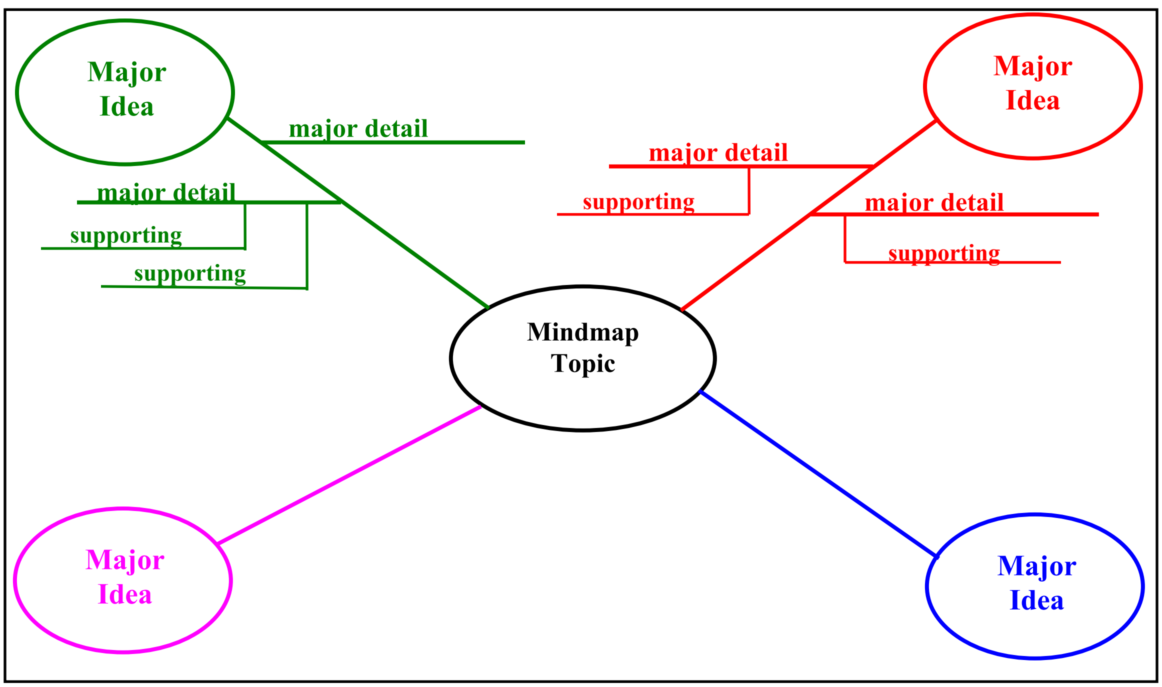


Figure 4.1. Mindmap format illustrating its relationship to the linear topic outline, and the placement of the topic in each.

It was significant to several of the students that the topic appeared in the center of the page on the mindmap. This caused the researcher to wonder if the students understood the format of a topic outline.

When asked about the two formats, mindmaps and topic outlines, Daniel said it was harder to find things on the outline. However, "with the mindmapping thing you know where everything is. In the middle, it tells you the subject of everything that's around it so you just look in the middle of all the papers…and look around it for the details." As an afterthought, he added that having everything on one page made it a lot easier also.

Bianca thought mindmapping was so much easier because you could start "with the virus in the middle, then the stuff that makes a virus…just so much more organized than just like in words." It was easy for her to go back to review her mindmap because "that big thing in the middle and then like on the sides the categories and all of that. So that was like so much more organized, so it was better."

Skater described why the mindmap was better for him. He said he used a blank sheet of paper with:

> a circle and that is the main topic. In the notes [outline], we do not have a main topic. It is just the numeral, the topic, and then there are five or six

> things that you have to say about it. In the other one [mindmap], there is the circle, the subtitle, and the facts branch off to the side. That is way easier than writing the other way.

Skater added that having fewer words to write made it even better.

During the interviews, the researcher became quite curious about the mindmap format with the topic in the middle. From her view, the topic of the mindmap was, indeed, in the middle of the map and therefore easy to find. However, the topic was equally easy to find in a topic outline since it appeared on the first line. The researcher was intrigued. She decided to question the next informant, who, incidentally, also mentioned that the topic was in the middle and therefore easier to find.

When asked about the topic in the middle, Jose responded:

> Being in the center, it is right there in the middle and a different color than the rest. It is just easier to understand and to think about it. I just find it easier.

Teacher's Perceptions: Ms. Diego

The teacher was selected to answer questions related to the use of mindmapping as a teaching strategy in her biology lectures. She was willing to participate in an open-ended interview. This type of interview allows the researcher and informant to dialogue in a manner that is a mixture of conversation and embedded questions (Erlandson et al., 1993). It allows a more free-flow of thoughts uninterrupted by the next preplanned question. The interview was conducted in a quiet place away from people and other distractions. It began with the following open-ended question: “What was your experience with mindmapping as a graphic organizer?” From that point, questions emerged from the dialogue.

Analysis of the interview transcriptions revealed that the teacher’s perception of the mindmapping experience was similar to the perceptions of the students. Table 4.11 summarizes an overview of the emergent themes derived from the teacher’s open-ended interview and is aligned with Table 4.8. As in Table 4.8, “Yes” indicates that a theme was addressed specifically during the interview. “No” indicates that the theme emerged but the response to the theme was negative or neutral. A “?” indicates an implied response to that theme. A blank space indicates that the theme did not emerge during the interview. While sorting and analyzing emerging themes from the teacher data, it became apparent she shared views similar to those of the students.

Table 4.11

Emergent Themes Shared with Student Informants

	Yes	No
Sense-Making	Yes	
Mindmap/Outline	Yes	
Color	Yes	
Engagement	Yes	
Easy to Find		No
Emotions	Yes	
Organized	Yes	
Topic in Middle		No
Transfer	Yes	

The Beginning

When the researcher approached Ms. Diego (pseudonym) about collaborating on this research project, she jumped at the opportunity. She had been searching for something to help her make a difference in the lives of her students. Each year she found herself wondering what she might do to facilitate learning. She felt there had to be something different that she could try with her students.

She described her initial reaction saying, "Well, not hesitant, a little scared because it was something I had never done before." She reported dabbling with the concept maps available in her science textbooks. She was comfortable using them because they were already completed or at least started. She found the prospect of beginning a mindmap from scratch scary.

The researcher and teacher began working together to discuss the project. Discussion included working on the teacher-developed, panel-validated instrument used for the pretest and posttest, learning the practice of mindmapping complete with color, symbols, and graphics, and converting the topic outlines she had used for six years into mindmaps.

Ms. Diego remembers the beginning:

> When I sat down, and you showed me that I could take my own notes and map them in a different way to "see" things differently, maybe in a better perspective, I was excited. It took me a while, but once I was able to do that, once I used…the different markers and the different colors, it was actually pretty fun, just like drawing. And, I have heard that [comment] quite a bit from my kids. The students considered the maps cool and like drawing.

During the study, she allowed students to bring their own markers, pens, highlighters, or map pencils because "they were all fighting for the fine point markers."

"So it was really fun. Scary at first, but once I got going it was really fun," reported Ms. Diego.

Themes Shared

sense-making.

Recollecting her early experience with mindmapping, Ms. Diego recalled that the mindmap made sense to her because it:

> is the way I have to see things. When I put it like that I can put it in a 3-D image. I can relate to mindmapping with that 3-D image…as a puzzle, and I love puzzles. So, I was looking at it from that point of view, this piece fits here. Wait a minute; this is better off going here with this than it is right here. When I wrote the traditional outline format, which is straight from the book, it didn't flow. This [mindmap] flows better for the kids…This is so much better, it is so much better.

After a moment of reflection she added, "It would have really helped me [in my earlier education] to learn to see things differently that way, and for the kids, I hope that they pulled something from it because *I* did."

As the conversation turned to projects and their value to learning, Ms. Diego told about projects she had done at the university and later brought into her biology course.

> It worked for me, and it has always worked for all my students. When they see that visual, and they get to keep it, it makes so much of a difference. That is why I can relate all this stuff to the mindmapping, because a majority of the kids are visual learners, and they are all so tactile on this. They incorporate the visual

> with the tactile, and really get in there. So I think it makes a difference and that is the concept of what the mindmaps do. They incorporate the two together.

mindmap versus topic outline.

When Ms. Diego began using the mindmaps with her classes, she found herself customizing the maps to the individual classes even though she started from the same basic map.

> When you are sitting there, and you are writing it with them, things dawn on you because it is a different group. You're like, wait a minute, this works better with you than it did with the other group. Or maybe…this way is better with this group versus the other group. Because each class, as a whole does things differently. So, I learned that…That is how I saw it.

The conversation turned to the traditional outline format that had been typical practice in her classes.

> With the traditional outline format, you did not customize anything. It is there and that is it. I typed these notes out when I first got this book six years ago. I typed out the notes for the chapters, and it went according to the chapters and that was it. Every once in a while I would add from other books information I thought was important. With the mindmapping, even though I used that traditional outline form as a base to get the mindmaps going, I was able to use different wording [and organization] that the kids understood better…The kids were able to see it differently, understand it more.

color.

Ms. Diego mentioned the use of different markers and colors when she began learning to mindmap. She said it was fun and just like drawing. This thought was also apparent in her students as they came into class excited.

> They were up there grabbing the markers before the class even started, and grabbing their paper. They were grabbing it, and sitting down, and getting ready. I was like "YES!"

As time passed, the students wanted more color choices and were allowed, even encouraged, to bring whatever they wished to use. Ms. Diego observed that "six different colors would be really good."

active engagement.

Using the practice of mindmapping, Ms. Diego felt she had "become actually more involved in their learning…It is more of a proactive approach to their learning versus the laid back, passive approach." Beyond the engagement of the teacher and the individual students, she noticed, "They are actually more involved and interacting with each other on the assignment versus the idle chit chat."

"They have become more actively involved," Ms. Diego added, "because they are listening." When students related their thoughts on note taking, they would say things such as, “I do not pay attention when I am writing [outline], I just write the notes out.” Ms. Diego noted, “They actually participated; they actually paid attention to the subject area.”

emotions.

Ms. Diego related the emotions she experienced throughout the study beginning with feeling scared and excited, then having fun. “I did not realize how much I would like the mindmap. They are really pretty fun.”

Most of Ms. Diego’s thoughts surrounding emotions and mindmapping centered on the students. “I had more interest from the kids doing the mindmap over the ones who were doing the traditional outline…They loved it.” To her surprise, “Even ones that I expected could have cared less. I was really surprised to hear, ‘Yeah, this is too cool.’” She thinks the students enjoy something different and enjoy getting to draw. Although they did request more color choices. “They really went for it. They totally enjoyed it.”

organization.

Ms. Diego noticed that the students were better able to make sense of the material when she asked questions regarding the information. Then, “I realized the review sheet went with my outline." The review sheets following the wording, grouping, and setup of the topic outlines, and not the mindmaps. "That threw them off a bit." The students let her know about the discrepancy.

transfer.

Ms. Diego was unaware that several of the students had tried mindmapping on their own in other subjects. Her response,

> I had no idea. That is too cool. That is so neat. You know, I never realized it. I, in a sense, would do that when I had to write something out for whatever I needed to do for a class, not even realizing it was a mindmap. It was just jot things…not realizing. I guess that is the way I see things. I love it.

Themes Unique to Teacher Informants

Table 4.12

Emergent Themes Unique to Teacher Informant

	Yes
Searching	Yes
Quantitative Data	Yes
Reflectivity	Yes
Next Year	Yes

searching.

Prior to her experience with mindmapping, Ms. Diego had been searching for something to improve her students' performance. Each year she found herself wondering what she could do to facilitate their learning. She felt there had to be something different that she could try with her students.

When she had begun her teaching career, some veteran teachers cautioned her against doing things like projects. "Projects are no good for kids. They do not need to be doing projects." They told her that students would not learn from projects. Being a new teacher, she confessed, "I did not know the difference. But, just doing mindmapping and slowly adding different things like that [flip books] into my classroom…I did not realize how much projects really do make a difference. Let me tell you!"

Ms. Diego reflects, "I am always thinking about what I could do better next year…I am going to mindmap next year for all classes, and reformat because I really think that [it] made a difference."

quantitative data.

Ms. Diego continues her reflection, "I think that quantitative data would be a lot better for the Fall time [semester] than it would be in the Spring time." TAKS [Texas Assessment of Knowledge and Skills] testing causes a lot of anxiety among students and teachers alike, and it tends to put teachers behind in instruction. "When we did it, it was good. But it was that time of year when they do not want to do anything else."

reflectivity.

As the students revealed how the mindmaps helped them make sense of the content, the teacher's experience gave her "insights to the kids' learning." Ms. Diego remembered her role was to facilitate learning and even called herself an "interactive facilitator" responsible for guiding her students through the process of learning.

Mindmapping helped Ms. Diego “see” things differently from a content perspective. The overall experience:

> got me back to what I am supposed to be doing…teaching the kids. And that is neat. Even though I have only been teaching seven years, it is a whole lot different. It is easy to get in that rut of doing only what you have to do to survive.

next year.

Ms. Diego anticipates a new year saying, “I think it would be awesome to start the year off, bam, and hit it running…I did feel like ‘Man, I wish I could have started the year off this way, because this would have been cool.’ Just hit the board, hit it running, straight with it. I did not realize how much I would like the mindmap.”

Chapter Summary

The homogeneity-of-slopes assumption tested the interaction between the covariate (pretest) and the factor (group) in the prediction of the dependent variable (posttest). The analysis indicated that the relationship between the covariate and the dependent variable did not differ significantly as a function of the independent variable. Therefore, an ANCOVA was appropriate. The one-way ANCOVA employed to determine the effect of mindmapping on science achievement revealed no difference between the two groups. Therefore, the data failed to reject the null hypothesis at the 0.05 level of significance.

Analysis of the semistructured individual interview data from the student informants revealed nine emergent themes. Three themes were common across all informants: sense-making, mindmapping versus topic outlining, and color. Four themes were common between five or six informants: engagement, easy to find, emotions, and organization. Two themes occurred four times: transfer and topic in the middle.

Analysis of the open-ended interview data from the teacher informant revealed eleven emergent themes. Seven themes were common across all student informants. The remaining four emergent themes were unique to the teacher.

While there was no difference between the two groups, the qualitative data revealed that the teacher's teaching and the students' learning were affected by their use of mindmapping. Informants reported that mindmapping affected their learning and teaching. Specific examples included making sense of content, using the mindmap, using color, and being engaged in the lessons. In addition, they noted that the organization of the mindmaps facilitated their ability to find useful information. They enjoyed using the mindmaps and appeared to be intrigued by the “topic in the middle”. Specific examples unique to the teacher included searching for a better way, reflections as the teacher, quantitative data, and next year. Finally, some of the informants reported using mindmapping in other subjects.

In the next chapter, an overall summary of the study will be presented. Discussions, conclusions and recommendations will be included.

CHAPTER 5: DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

Perhaps the most basic thing that can be said about human memory,
after a century of research,
is that unless information is placed in a structured pattern,
it is rapidly forgotten.

Jerome S. Bruner, 1960, p. 24

Introduction

The purpose of this study was to determine if achievement in high school science courses could be enhanced utilizing mindmapping. The subjects were primarily 9^{th} and 10^{th} graders at a suburban South Texas high school. A pretest-posttest control group design was selected to determine the effects of mindmapping on student achievement as measured by a teacher-developed, panel-validated instrument. Follow-up interviews were conducted with the teacher and a purposive sample of students to determine their perceptions of mindmapping and its effects on teaching and learning.

This chapter contains four sections: discussion, implications, recommendations, and summary. The discussion reviews the findings of this study as it relates to other research. Implications offer suggestions to teachers. Recommendations describe suggestions for further research.

Discussion

An independent samples t-test determined there was no significant difference in achievement between the groups. A one-way analysis of covariance (ANCOVA) using the pretest as the covariate revealed no significant difference as well. While the results failed to reject the null hypothesis indicating no significant improvement for the experimental group, there was no regression toward the mean. This indicates a lack of negative consequences resulting from the use of mindmapping. Several factors may have played a role in the lack of statistically significant achievement.

The researcher elected to use an instrument that would reflect a test normally used in a "real world" classroom. Therefore, the teacher-developed, panel-validated instrument was used to determine achievement, and it may not have been designed to detect the type of achievement facilitated by mindmapping. The instrument was primarily designed to measure factual recall, as is the teacher's practice, with little opportunity for students to demonstrate their conceptual understanding. Mindmaps are intended to facilitate conceptual understanding rather than factual recall. In order to assess conceptual understanding, Novak, Gowin, and Johansen (1983) suggest the instrument reflect questions or problems at the application level or above according to Bloom's (1956) Taxonomy. This would allow students to more readily show what they understand rather than what they recall. This discrepancy likely contributed to the lack of significant findings.

In reflecting on the many components of the study, the researcher had an interesting revelation regarding the fit of the content presented and the make-up of the instrument. Prior to the beginning of the study and after training, the teacher began constructing the mindmaps she would use during instruction. In doing so, she used previously developed topic outlines as a guide. She had been using these outlines for several years and had originally made them by following the information as it was presented in the textbook. As she began organizing the material on the mindmaps, she realized that the outlines she had used previously did not represent the content in a fashion she believed optimal for student understanding or sense-making. Therefore, she rearranged the flow of the content as she created the mindmaps. This rearrangement of the content presented without rearrangement of the test may have offered a better fit of instruction to test for the control group than for the experimental group. This lack of fit may speak to the lack of significant findings as well.

Due to the district's mandated, standardized testing and holiday schedules, the duration of this study was six weeks. Although this time frame was significantly longer than most studies reviewed (Buzan, 1997; Conner, 2003; Mehegan, 1996; Parisian, 1997; Williams, 1998), it was not long enough. Woods (Goodnough & Woods, 2002), a sixth grade teacher in a similar study, found that a 6 month treatment was not sufficient to reveal growth. In light of the results of this study, the researcher believes that effective use of mindmapping as a new teaching and learning practice requires an extended period of time to allow students to assimilate and accommodate its use.

Teacher training in the use of mindmaps prior to the study was limited to three hours. This appeared to be sufficient for the teacher to understand the practice of mindmapping and to develop the mindmaps used in the study. However, this limited amount of instruction may not have been sufficient to facilitate effective teaching of mindmapping to students. Although the fundamentals of mapping can be learned in less than an hour (Clarke, 1990), expertise leading to accurate and effective use of this study technique may take weeks (Dansereau & Holley, 1984). Teachers need in-depth and sustained training for effective use of new practices. The teacher in this study was not afforded in-depth or sustained training. Donovan, et al. (1999) suggests that teachers are the key to change in the classroom. However, this change is highly unlikely without in-depth and sustained professional development.

Further, the mindmaps used in this study were constructed by the teacher and copied by the students. Although, this was a good starting place, the strength of mindmapping lies in the process of map construction. This strength lies beyond the initial stages of learning to use a mindmap by copying the teacher's map. As students begin to construct mindmaps independently, the process of organizing content into big pictures and integral parts facilitates a stronger connection between prior knowledge and new knowledge construction (Donovan, et al., 1999). As construction of student mindmaps was beyond the scope of this study, the efficacy of the treatment might be more fully realized in a longer study to include student mindmap construction.

Interviews with the teacher and a purposive sample of students were conducted to better understand the perceptions of mindmapping and its effects on teaching and learning. The findings of these interviews revealed noteworthy positive perceptions.

Informants, both students and teacher, reported that mindmapping positively affected their learning and teaching. Specific student examples included a sense that the colorful mindmaps enhanced their ability to remain engaged in the lesson and make sense of the content presented. Students noted that the organization of the mindmaps facilitated their ability to easily find useful information during reviews. Examples noted by the teacher included the opportunity to reflect on her practice and finding a possible resolution to her searching for a better way to teach. She plans to continue using mindmapping. All informants enjoyed using mindmaps and some reported using mindmaps in other subjects.

Research supports a lack of statistically significant achievement scores in studies on graphic organizers while finding noteworthy positive perceptions among the participants, both teachers and students (Goodnough & Woods, 2002; Hawk, 1982; Jay, 1994; Lehman, Carter, &

Kahle, 1985; Williams, 1998). The present study finds itself nestled within these studies.

Implications

Although the quantitative results revealed a lack of significant difference in the achievement scores of the groups, some noteworthy implications for teachers do exist. Emergent themes from the qualitative component revealed positive student and teacher perceptions toward mindmapping.

Though affective in nature, behaviors and attitudes such as increased focus, motivation to interact with and make sense of the material being mapped, and feelings of self-efficacy speak to student gains. Experiences such as mindmapping offer a greater opportunity for student learning even if quantifiable gains are not readily apparent, pointing to the value of such endeavors (Walberg, 1995).

Given the opportunity for affective gains in the form of focus, motivation, and sense-making, mindmapping may prove useful across subject areas including history, literature, and social studies. Indeed, mindmapping is already being utilized in the areas of reading, study skills, engineering, economics, and business.

Mindmapping as used in this study by the teacher served as both a teaching and a learning tool for her. During interactive lectures or expository teaching, the teacher used teacher-created mindmaps to facilitate student focus, motivation, organization of science content, and active engagement of students as they copied her mindmaps. Additionally, the teacher felt she received the opportunity to "see" the organization of the material she was teaching and make adjustments to better serve her students. She felt this "new view" helped her be an active learner and a more reflective teacher. Active learning and self-reflexivity are core principles of constructivism which support teaching practice and student achievement (Steffe & D'Ambrosio, 1996).

Mindmapping is a strategy for visually displaying large amounts of conceptual, hierarchical information in a concise, organized, and accessible format for learners. It is easy to learn as it arranges information similar to that found on the traditional topic outline into a colorful spatial display that offers the user a view of the "forest" as well as the "trees" (Hyerle, 1996; Wandersee, 1990b).

Although it is easy to use, it does require practice to achieve proficiency.

Increased use of mindmapping offers students the proficiency necessary to begin constructing and personalizing maps independently. Independent map construction promotes active learning and higher order thinking that speaks to meaningful learning. It is the map constructor who benefits most from map construction (Wandersee, 1990a). As this endeavor transfers from teacher construction to student construction, learning increases.

Mindmapping appears to show promise as a useful organizational tool for both students and teachers. Mindmaps are already being used in a variety of subjects including science, reading, engineering, writing, and business to organize information and facilitate thinking.

Recommendations

Based on the findings of this study, the efficacy of this treatment may be better supported, showing greater improvement of learning, through modification of the design. It is recommended that this study be repeated with modifications to include:

1) instrument designed to assess conceptual understanding with questions or problems written at the application level or higher,
2) study duration increased to several months, or ideally one academic year,
3) increased teacher training in use of mindmapping prior to study with observation and feedback during the study, and
4) increased student use of mindmaps to include independent student construction.

Further research using mindmaps should include a greater diversity of students, particularly those who are struggling academically. Increasing the sample size should ensure a greater diversity of student population across the sample.

Current practices such as topic outlining and lecturing, speak to students who are already doing well. These students are auditory and linear processors of information (Grinder, 1991). Mindmapping offers the visual, tactile, kinesthetic and spatial learners an opportunity to "see" the big picture and its parts, as well as how they fit together without excluding other learners. It offers color, graphics, icons, and symbols that enhance key words on the map. For students who struggle and find the word-laden page insurmountable, mindmapping offers a way of "seeing" which may transcend that hurdle. Extending students the opportunity to practice and use mindmapping may help level the playing field. A longitudinal study spanning one or more academic years might prove revealing. Finally, a study in fields other than science, such as literature or history, might prove informative as well.

Summary

The intent of this study was to determine if achievement in a high school biology course could be enhanced using mindmapping. A pretest-posttest control group design was used to determine the effects of mindmapping on student achievement.

Although an independent samples t-test and a one-way analysis of covariance (ANCOVA) determined no significant difference in achievement between the groups, there was also no regression toward the mean. The experimental group improved in achievement at least as much as the control group.

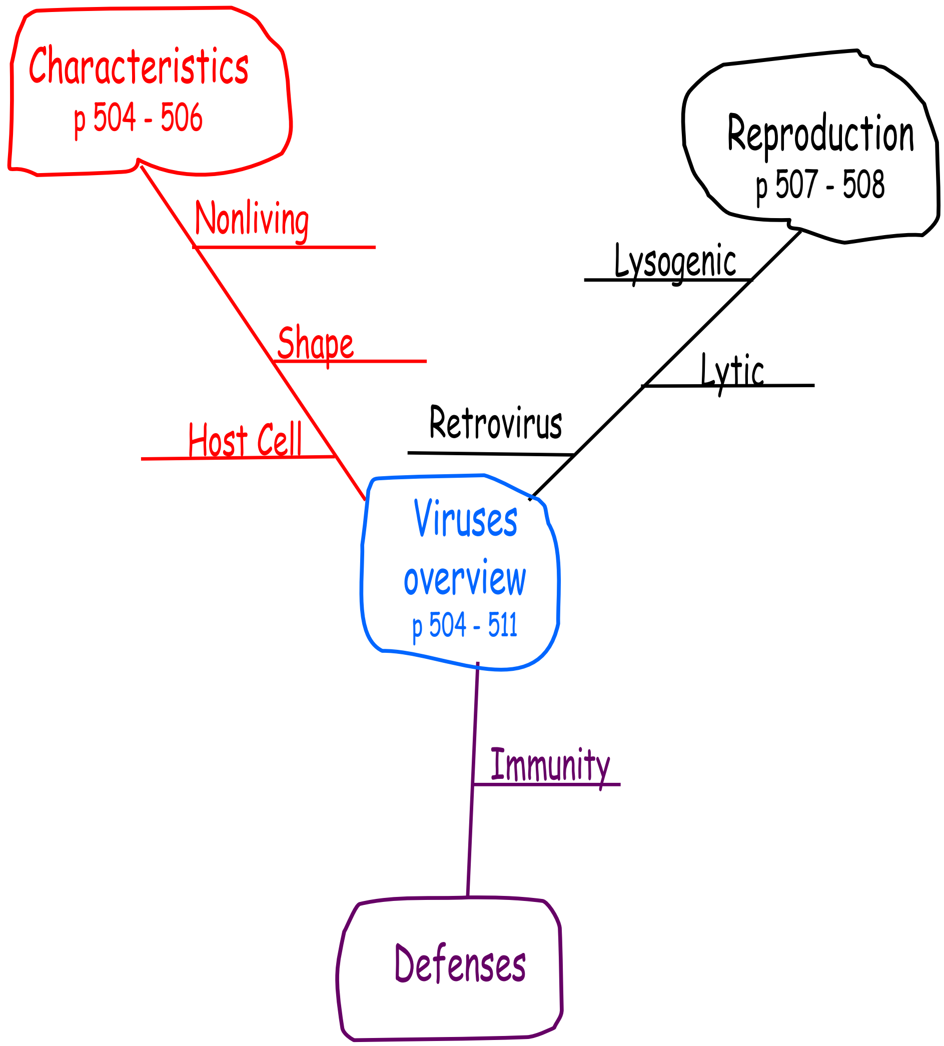
Several factors may have played a role in the lack of statistically significant results. These factors include the instrument, the duration of the study, limited teacher training, and teacher constructed mindmaps to the exclusion of student constructed mindmaps.

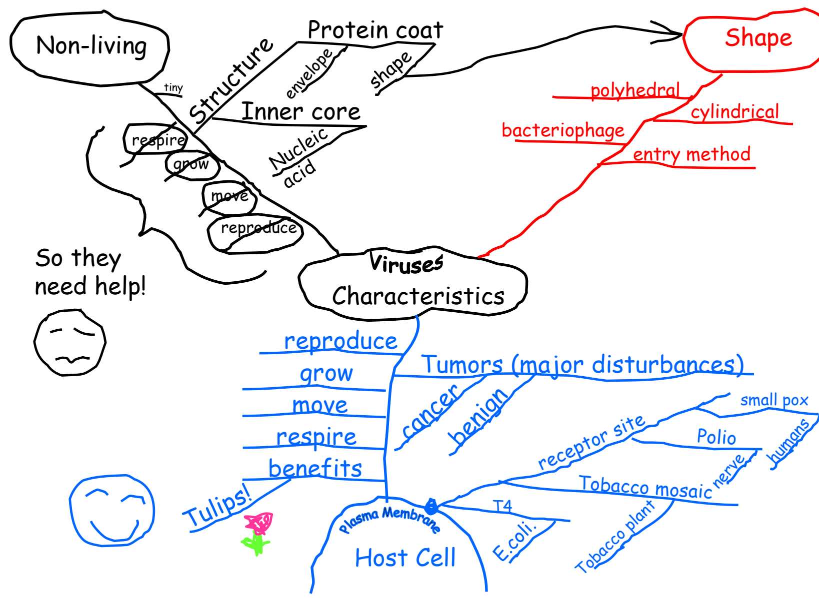
Interviews with the teacher and a purposive sample of students were conducted to better understand the perceptions of mindmapping and its effects on teaching and learning. Data from these interviews indicated noteworthy positive perceptions on the part of the purposive student sample and the teacher. Both students and teacher reported that mindmapping positively affected their learning and teaching. Themes reported included increased focus, motivation, organization, sense-making, and reflectivity.

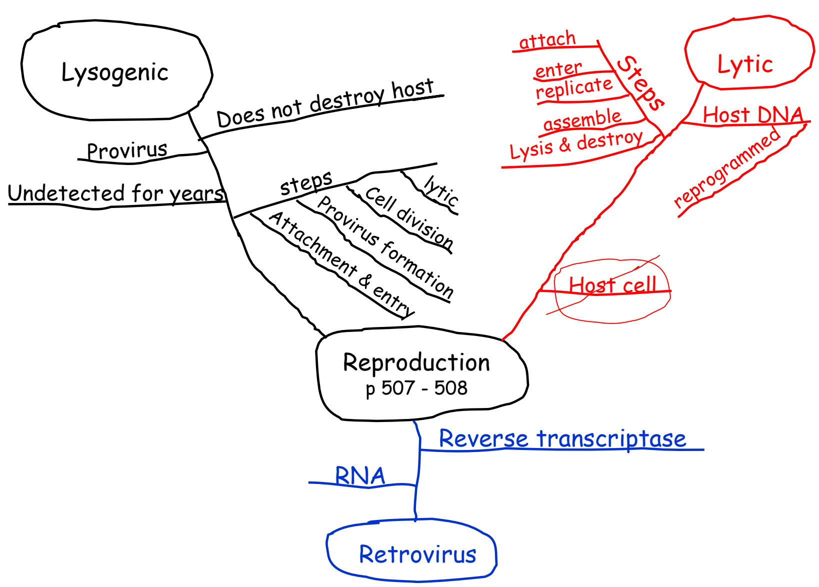
Mindmapping has affective value as a teaching and learning strategy and quite possibly cognitive value. Further research is necessary to determine the extent of its effectiveness. Issues requiring attention in future research are the instrument, duration of study, teacher training, student construction of maps, and student diversity.

Appendix A

Mindmaps Used In This Study




Non-living
tiny
Structure
Protein coat
envelope
shape
Inner core
Nucleic acid
Shape
polyhedral
cylindrical
bacteriophage
entry method
respire
grow
move
reproduce
So they need help!
Viruses Characteristics
reproduce
grow
move
respire
benefits
Tulips!
Tumors (major disturbances)
cancer
benign
receptor site
small pox
Polio
humans
nerve
Tobacco mosaic
Tobacco plant
T4
E.coli.
Plasma Membrane
Host Cell


Lysogenic
Does not destroy host
Provirus
Undetected for years
steps
lytic
Cell division
Provirus formation
Attachment & entry
Lytic
Steps
attach
enter
replicate
assemble
Lysis & destroy
Host DNA
reprogrammed
Host cell
Reproduction
p 507 - 508
Reverse transcriptase
RNA
Retrovirus

Appendix B

Teacher-Developed Panel-Validated Instrument

Name ________________________
Class ________________________

Pretest for Viruses and Bacteria, and Protist and Fungi, and Plants

I. TRUE/FALSE – Put a T in front of the true statements and an F in front of the false statements.

1. ________ Bryophytes are vascular plants.
2. ________ The group of **protozoans** that reproduce by using spores is called saprobes.
3. ________ Nonvascular plants can inhabit drier environments than most vascular plants.
4. ________ An example of a flagellate is a paramecium.
5. ________ All protist are prokaryotic.
6. ________ Mushrooms are examples of club fungi.
7. ________ Bacteria are prokaryotic.

II. MULTIPLE CHOICE – Put the letter of the best choice that completes the statement or answers the question.

8. ________ The protective coat of a virus is made up of ___.
   A. protein
   B. DNA
   C. nucleic acid

9. ________ Prokaryotic cells do not contain ___.
   A. ribosomes
   B. mitochondria
   C. nucleus

10. ________ Bacteria that can take nitrogen from the atmosphere and convert it into compounds that living things can use by a process called ___.
   A. binary fission
   B. conjugation
   C. nitrogen fixation

11. ________ Organisms that obtain nutrition from dead organisms are called ___.
   A. saprobes
   B. parasites
   C. moneran

12. ________ The name streptococcus tells you that the bacteria are arranged as ___.
A. pairs of round cells
B. long chains of round cells
C. chains of rods

13. ________ Which one of the following would be the **least** likely environment to find Archaebacteria?
A. oxygen free environment
B. salt lake
C. on the kitchen counter

14. ________ Chemosynthetic bacteria use ___ for energy.
A. sulfur and nitrogen compounds
B. sunlight
C. running water

15. ________ Amoebas engulf food by ___.
A. using its oral groove and the action of the cilia
B. osmosis
C. surrounding the food with it pseudopod

16. ________ Ringworm and athlete's feet are caused by ___.
A. bacteria
B. protist
C. fungi

17. ________ The cell wall of the fungi is reinforced with ___.
A. chitin
B. cellulose
C. glycogen

18. ________ The vector of the malaria disease is the ___.
A. mosquito
B. fly
C. tick

19. ________ Dinoflagellates are able to spin by the means of ___.
   A. a pillbox shell that opens and closes
   B. two flagella at right angles to each other
   C. a holdfast that attaches them to a rock

20. _______ The phloem is vascular tissue that _____.
   A. transports sugar from the leaves to all parts of the plant
   B. is present only in the stem
   C. transports water from the roots to the leaves

21. ________ Xylem is vascular tissue that ______.
   A. transports sugar from the leaves to all parts of the plant
   B. transports water from the roots to the leaves
   C. is present only in the stem

22. ________ The opening and closing of the stomata is regulated by _____.
   A. guard cells
   B. rhizomes
   C. light

23. ________ The plant organ that absorbs water and minerals from the soil is the ____.
   A. root
   B. leaf
   C. stem

24. ________ The waxy covering of a leaf is called a(n) ____.
   A. stoma
   B. cuticle
   C. epidermis

25. ________ ____ are food-storage organs of a plant embryo that become the plant's first leaves.
   A. cotyledons
   B. cones
   C. ovules

26. ________ Bryophytes are anchored to the ground by _____.
   A. protonema
   B. roots
   C. rhizoid

27. ________ The dominant form of a bryophyte life cycle is the _____.
   A. sporophyte
   B. gametophyte
   C. bryophyte

28. ________ In gymnosperms, fertilization does not require _____.
   A. a film of water to carry the sperm to the egg
   B. alternation of generations
   C. the production of eggs

III. MATCHING – Match the definition in Column A with the term in Column B.

Column A	Column B
29. ________ a solution of weakened or killed pathogens	A. conjugation
30. ________ process by which bacteria reproduce asexually	B. retrovirus
	C. vaccine
31. ________ viral DNA becomes part of the host cell's DNA	D. saprobe
	E. binary fission
32. ________ organisms that feed on dead organisms	AB. provirus
33. ________ RNA virus	

Column A	Column B
34. ________ pumps out excess water from the protist	A. Hyphae
35. ________ basic structural unit of a fungi	B. asexual
36. ________ a reproduction that does not involve the fusion of gametes	C. contractile vacuole
	D. sexual
37. ________ helps keep the spores from drying out	E. sporangia

---

Column A	Column B
38. ________ amoebas form this when the environment	A. algae
39. ________ the phylum of protists that has both traits of plants and animals t is not favorable to live in	B. phytoplankton
	C. Cyst
	D. endospore
40. ________ photosynthesizing protist that is ranked as a major producer of nutrients in aquatic ecosystems and a releaser of oxygen in the world	E. euglenoids

Column A		Column B
41. ________	small pore that slows for gas exchange in the leaf of a plant	A. sori
42. ________	reproductive structure in which sperm are produced	B. antheridia
43. ________	cluster of sporangia	C. stomata
44. ________	protective outer coating of a seed	D. pollen grains
		E. seed coat
		AB. Archegonium

Column A		Column B
45. ________	contains tissues of tube-like, elongated cells through which water and food are transported	A. rhizome
46. ________	thick, underground stem	B. stem
47. ________	vascular plant that produces seeds that are protected by a fruit	C. seed
48. ________	provides structural support for upright growth	D. gymnosperm
		E. vascular plant
		AB. Root

IV. IDENTIFICATION – Identify whether the statement is part of the Lytic cycle or the Lysogenic cycle. Put A for Lytic cycle,
B for Lysogenic cycle, or
C for both cycles.

49. ________ The viral DNA is copied along with the host cell DNA and goes through cell division.
50. ________ A provirus is formed.
51. ________ Viral nucleic acid is injected into the host cell.
52. ________ The cycle can go undetected for years.
53. ________ Viral nucleic acid attaches to the host cell.
54. ________ Viral parts are assembled.
55. ________ Host DNA is destroyed and new viral nucleic acid is produced.

V. LABELING – Identify the organelle, structure or organism, and write the correct number in the space provided.

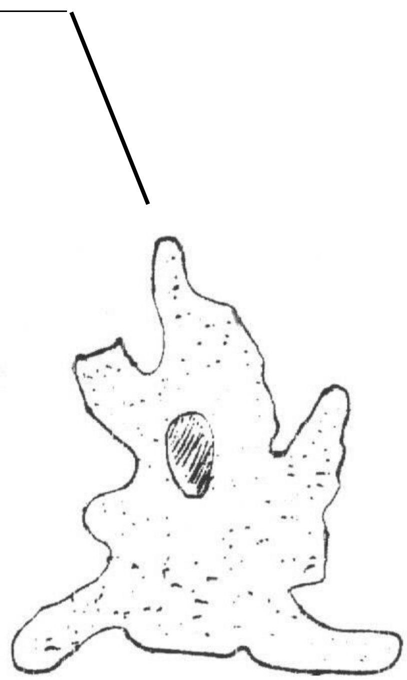
Word Bank

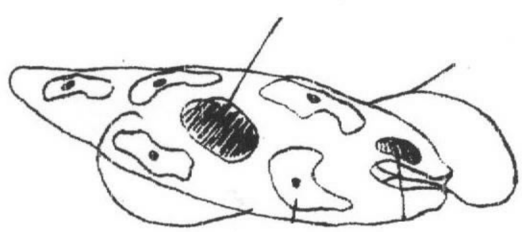
A. Amoeba	E. contractile vacuole	AE. nucleus
B. Euglena	AB. cilia	BC. chloroplast
C. Paramecium	AC. flagella	BD. gullet
D. Pseudopod	AD. eyespot	BE. oral groove

56. _______

58. _______

59. _______

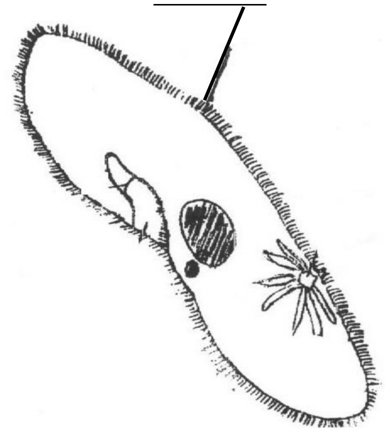




57. _______ Name of organism.

60. _______ Name of organism.

61. _______



62. _______ Name of organism.

Appendix C

OFFICE OF RESEARCH SUPPORT & COMPLIANCE

THE UNIVERSITY OF TEXAS AT AUSTIN

P.O. Box 7426, Austin, Texas 78713 (512) 471-8871 - FAX (512 471-8873)
North Office Building A Suite 5.200 (Mail code A3200)

Date: 4/5/2004

PI(s): **Glennis E Cunningham** Department & Mail Code: **A2650**

Dear: **Glennis E Cunningham**

IRB APPROVAL – IRB Protocol # **2004-03-0084**

Title: **Graphic Organizer: Its Effect on Student Achievement**

In accordance with Federal Regulations for review of research protocols, the Institutional Review Board has reviewed the above referenced protocol and found that it met approval under an Expedited category for the following period of time:

Your study has been approved from 04/02/2004 – 04/02/2005

Expedited category of approval:

(1) ☐ Clinical studies of drugs and medical devices only when condition (a) or (b) is met. (a) Research on drugs for which an investigational new drug application (21 CFR Part 312) is not required. (Note: Research on marketed drugs that significantly increases the risks or decreases the acceptability of the risks associated with the use of the product is not eligible for expedited review). (b) Research on medical devices for which (i) an investigational device exemption application (21 CFR Part 812) is not required; or (ii) the medical device is cleared/approved for marketing and the medical device is being used in accordance with its cleared/approved labeling.

(2) ☐ Collection of blood samples by finger stick, heel stick, ear stick, or venipuncture as follows: (a) from healthy, non-pregnant adults who weigh at least 110 pounds. For these subjects, the amounts drawn may not exceed 550 ml in an 8 week period and collection may not occur more frequently than 2 times per week; or (b) from other adults and children2, considering the age, weight, and health of the subjects, the collection procedure, the amount of blood to be collected, and the frequency with which it will be collected. For these subjects, the amount drawn may not exceed the lesser of 50 ml or 3 ml per kg in an 8 week period and collection may not occur more frequently than 2 times per week.

(3) ☐ Prospective collection of biological specimens for research purposes by Non-invasive means. Examples: (a) hair and nail clippings in a non-disfiguring manner; (b) deciduous teeth at time of exfoliation or if routine patient care indicates a need for extraction; (c) permanent teeth if routine patient care indicates a need for extraction; (d) excreta and external secretions (including sweat); (e) un-cannulated saliva collected either in an un-stimulated fashion or stimulated by chewing gumbase or wax or by applying a dilute citric solution to the tongue; (f) placenta removed at delivery; (g) amniotic fluid obtained at the time of rupture of the membrane prior to or during labor; (h) supra- and subgingival dental plaque and calculus, provided the collection procedure is not more invasive than routine prophylactic scaling of the teeth and the process is accomplished in accordance with accepted prophylactic techniques; (i) mucosal and skin cells collected by buccal scraping or swab, skin swab, or mouth washings; (j) sputum collected after saline mist nebulization.

(4) ☐ Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed, they must be cleared/approved for marketing. (Studies intended to evaluate the safety and effectiveness of the medical device are not generally eligible for expedited review, including studies of cleared medical devices for new indications). Examples: (a) physical sensors that are applied either to the surface of the body or at a distance and do not involve input of significant amounts of energy into the subject or an invasion of the subject's privacy; (b) weighing or testing sensory acuity; (c) magnetic resonance imaging; (d) electrocardiography, electroencephalography, thermography, detection of naturally occurring radioactivity, electroretinography, ultrasound, diagnostic infrared imaging, doppler blood flow, and echocardiography; (e) moderate exercise, muscular strength testing, body composition assessment, and flexibility testing where appropriate given the age, weight, and health of the individual.

(5) ☐ Research involving materials (data, documents, records, or specimens) that have been collected, or will be collected solely for non-research purposes (such as medical treatment or diagnosis). (NOTE: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(4). This listing refers only to research that is not exempt).

(6) ☐ Collection of data from voice, video, digital, or image recordings made for research purposes.

(7) ☑ Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies. (NOTE: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(2) and (b)(3). This listing refers only to research that is not exempt).

(8) ☐ Continuing review of research previously approved by the convened IRB as follows: (a) where (i) the research is permanently closed to the enrollment of new subjects; (ii) all subjects have completed all research-related interventions; and (iii) the research remains active only for long-term follow-up of subjects; or (b) where no subjects have been enrolled and no additional risks have been identified; or (c) where the remaining research activities are limited to data analysis.

(9) ☐ Continuing review of research, not conducted under an investigational new drug application or investigational device exemption where categories two through eight do not apply but the IRB has determined and documented at a convened meeting that the research involves no greater than minimal risk and no additional risks have been identified.

_x_ Please use the attached approved informed consent

___You have been granted Waiver of Documentation of Consent

According to 45 CFR 46.117, an IRB may waive the requirement for the investigator to obtaina signed consent form for some or all subjects if it finds either:

___ The research presents no more than minimal risk AND

___ The research involves procedures that do not require written consent when performed outside of a reserach setting 45 CFR 46.117(c)(2)

or

___ The principal risks are those associated with a breach of confidentiality concerning the subject's participation in the research AND

___ The consent document is the only record linking the subject with the research 45 CFR 46.117(c)(1)

Approval dates: 04/02/2004 - 04/02/2005 Protocol # 2004-03-0084

____ **You have been granted Waiver of Informed Consent**

According to 45 CFR 46.116(d), an IRB may waive or alter some or all of the requirements for Informed consent if:

___ The research presents no more than minimal risk to subjects;
___ The waiver will not adversely affect the rights and welfare of subjects;
___ The research could not practicably be carried out without the waiver; and
___ Whenever appropriate, the subjects will be provided with additional pertinent information after they have participated in the study.

RESPONSIBILITIES OF PRINCIPAL INVESTIGATOR FOR ONGOING PROTOCOLS:

(1) Report **immediately** to the IRB any severe adverse reaction or serious problem, whether anticipated or unanticipated.
(2) Report any significant findings that become known in the course of the research that might affect the willingness of subjects to continue to take part.
(3) Insure that only persons formally approved by the IRB enroll subjects.
(4) Use **only** a currently approved consent form (remember approval periods are for 12 months or less).
(5) **Protect the confidentiality of all personally identifiable information collected and train your staff and collaborators on policies and procedures for ensuring confidentiality of this information.**
(6) Submit for review and approval by the IRB all modifications to the protocol or consent form(s) prior to the implementation of the change.
(7) Submit a **Continuing Review Report** for continuing review by the IRB. Federal regulations require **IRB review of on-going projects no less than once a year** (a Continuing Review Report form and reminder letter will be sent to you 2 months before your expiration date). Please note however, that if you do not receive a reminder from this office about your upcoming continuing review, it is the primary responsibility of the PI not to exceed the expiration date in collection of any information. Finally, it is the responsibility of the PI to submit the Continuing Review Report before the expiration period.
(8) Notify the IRB when the study has been completed and complete the Final Report Form.
(9) Please help us help you by including the above protocol number on all future correspondence relating to this protocol.

Thank you for your help in this matter.

Sincerely,

Clarke Burnham

Clarke Burnham, Ph.D., Chair ~~TOKE~~
Institutional Review Board

cc: DRC

Appendix D

Letter Requesting Permission from District

February 19, 2004

Superintendent
Your School Independent School District
South Texas

Principal
Your School High School
South Texas

Dear Ms. Superintendent and Mr. Principal,

I am requesting permission from Your School ISD and Your School High School to conduct a study with the biology students at Your School High School in Ms. Teacher's classes. This study will partially fulfill the requirements for my Doctorate of Philosophy in Science Education from the University of Texas at Austin. The title of the study is "Mindmapping: Its Effects on Achievement."

We, as educators, are constantly seeking instructional tools and learning strategies that facilitate achievement and the inclusion of all students. Mindmapping, the process of using a graphic organizer to organize information in a colorful, spatial format, is a tool/strategy that may offer that opportunity. It holds promise by engaging students in the process of making sense of information presented to them, thus facilitating their learning and retention.

The primary objective of this study is to facilitate increased achievement of high school biology students using mindmapping. Therefore, the purpose of this study is to determine the effectiveness of mindmapping on achievement with high school biology students between two groups, an experimental group and a control group. In order to achieve this, it is necessary to determine whether statistically significant differences exist in the achievement scores of these groups after a 6-week intervention.

Students in both groups will receive a biology pretest (reviewed by a content validity panel) similar to one normally used in everyday practice. During the 6-week intervention, the experimental group will use mindmapping as their learning tool/strategy for organization and display of the content normally taught in this class. The control group will continue class as usual. At the conclusion of the 6-week intervention, both groups will receive the posttest. Anonymity will be assured for all students, and parent permission will be obtained prior to student participation in the study.

Thank you for your consideration in this matter. If you have questions or concerns, please contact me.

Sincerely,

Glennis Edge Cunningham

Cc: Dr. Instructor, Curriculum Director, Your School ISD
Dr. Instructor, Curriculum Director, Your School High School
Ms. Teacher, Biology Teacher, Your School High School

Appendix E

District Consent

Your School Independent School District
South Texas

March 4, 2004

Glennis Edge Cunningham
(Ph.D. Candidate, University of Texas)
South Texas

Dear Ms. Cunningham,

Your School Independent School District is pleased to support you in your study of mindmapping with biology students in Ms. Teacher's classes. Teachers are continuously seeking new and innovative learning strategies to improve student achievement. Graphic organizers, such as mindmapping, allow students to organize subject contents in an easy manner. Your study will help determine the effectiveness of this process on achievement with high school biology students. We look forward to reviewing your data and analyzing your results. Please feel free to contact me if additional assistance is needed.

Sincerely,

Dr. Instructor
Director of Instruction

Cc: Assistant Superintendent for Instruction

Appendix F

Informed Consent from Parents

Learning Strategies to Improve Student Learning
Glennis Edge Cunningham

Introduction and Purpose: Teachers use learning strategies as part of their regular classroom instruction. These strategies include such practices as outlining, graphing, cooperative grouping, and mapping. Their purpose is to help students make sense of the content they are studying, thus learning and remembering what they have learned.

I am an Assistant Professor for Teacher Education at Texas A&M University-Corpus Christi, and a Doctoral student at The University of Texas at Austin, Department of Science Education. My research focuses on how students learn, and how teachers might better support student learning using effective learning strategies.

Selection for participation: The participants in this study are selected Biology I classes at Your High School.

Procedure: Selected classes will use a new learning strategy as they receive regular instruction in content taught to all Biology I classes.

Risks and Benefits: The risks of participation in this study are minimal to none, as the use of the learning strategy will be incorporated into the regular classroom instruction. Benefits of participation include gaining experience and skill in a new strategy aimed at increased understanding and learning.

Confidentiality: Any information obtained in connection with this study that can be identified with your son/daughter will remain confidential. Neither your child's name, nor your name will be linked in any written or verbal report of this research project.

Questions: Your decision to allow your son/daughter to participate will not affect your, his, or her present or future relationship with The University of Texas at Austin or Your School ISD. If you have any questions about the study now or later, please call Dr. Instructor, Director of Instruction for Your School, or Glennis Cunningham, at 555-555-5555.

Voluntary Participation: You are making a decision about allowing your son/daughter to participate in this study. Your signature below indicates that you have read the information provided above and have decided to allow him or her to participate in the study. If you later decide to withdraw your permission for your son/daughter to participate in the study, simply tell me. You may discontinue his or her participation at any time.

Thank you for your time and consideration regarding your child's participation in this study.

<u>Informed Consent</u>

Learning Strategies to Improve Student Learning
Glennis Edge Cunningham
Signature Page

____
Printed Name of your Son/Daughter

________________________________ ________________
Signature of Parent(s) or Legal Guardian Date

________________________________ ________________
Signature of Investigator Date
Glennis Edge Cunningham
Doctoral Candidate, The University of Texas

"I have read the description of the study titled *Learning Strategies to Improve Student Learning* printed above, and I understand what the procedures are and what I may be asked to do. I have received permission from my parent(s) to participate in the study, and I agree to participate in it. I know that I can quit the study at any time."

________________________________ ____________________
Signature of Minor Date

Appendix G

Informed Consent for Interviews

Informed Consent for Interview Following the Study
Learning Strategies to Improve Student Learning
Glennis Edge Cunningham

As you recall, your permission was requested approximately two months ago for the participation of your student in a learning strategy study. Thank you for your permission and cooperation in that study. It is now complete, and I would like to interview a few students to hear their point of view on the learning strategy they experienced. Therefore, a few students possessing effective communication skills have been selected to participate in a follow-up interview. Please read on for a review of the study and procedures for the interview.

Introduction and Purpose: Teachers use learning strategies as part of their regular classroom instruction. These strategies include such practices as outlining, graphing, cooperative grouping, and mapping. Their purpose is to help students make sense of the content they are studying, thus learning, and remembering what they learned.

I am an Assistant Professor of Teacher Education at Texas A&M University-Corpus Christi, and a Doctoral student at The University of Texas at Austin, Department of Science Education. My research focuses on how students learn, and how teachers might better support student learning using effective learning strategies.

Selection for participation: The interview participants were selected from participating Biology I classes at Your High School.

Procedure: Selected classes used a new learning strategy as they received regular instruction in content taught to all Biology I classes. Following the study, I will interview selected students to learn more about the new learning strategy from the students' point of view. Your student has been selected to participate in the interviews. The interviews will be conducted at the high school and recorded to ensure accuracy. The audiotapes will be used by the researcher and then erased.

Risks and Benefits: The risks of participation in these interviews are essentially none. There will be no personal questions asked. The questions will focus on the learning strategy used during the study. Benefits to participants include gaining experience in an interview situation and discussing their learning experience.

Confidentiality: Information obtained in the interviews will not be identified with your son/daughter. Neither your student's name, nor your name will be linked in any written or verbal report of this research project.

Questions: Your decision to allow your son/daughter to participate will not affect your, his, or her present or future relationship with The University of Texas at Austin or Your School ISD. If you have any questions about the study now or later, please call Dr. Instructor, Director of Instruction for Your School, or Glennis Cunningham, at 555-555-5555.

Voluntary Participation: You are making a decision about allowing your son/daughter to participate in this study. Your signature below indicates that you have read the information provided above and have decided to allow him or her to participate in the interview.

Thank you for your time and consideration regarding your student's participation in this study's follow-up interviews.

<u>Informed Consent</u>
Learning Strategies to Improve Student Learning
Glennis Edge Cunningham
Signature Page

____
Printed Name of your Son/Daughter

_________________________________ _________________
Signature of Parent(s) or Legal Guardian Date

_________________________________ _________________
Signature of Investigator Date
Glennis Edge Cunningham
Doctoral Candidate, The University of Texas

"I have read the description of the study titled *Learning Strategies to Improve Student Learning* printed above, and I understand what the procedures are and what I may be asked to do. I have received permission from my parent(s) to participate in the follow-up study interview, and I agree to participate in it. I know that I can quit the interview at any time."

___________________________ ____________________
Signature of Minor Date

Appendix H

Proposed Interview Questions

Student Interview

Period ____ Student #____ Grade ____ Age ____
Gender F M
Pseudonym ______________________

1) How do you learn best?

2) What are your thoughts about the mindmapping used in your biology class?

3) How did you feel when you used mindmaps?

4) What are the positives of its use? (What did you like? What was your favorite part?)

5) What are the negatives of its use? (What did you dislike? What was your least favorite part?)

6) Was using a mindmap helpful to you? How was it helpful? How did it affect you, as a learner? (prompts if necessary)

   - Note-taking
   - Organization
   - Sense-making (understanding)
   - Learning
   - Remembering (how, why)
   - Studying for the test

7) Describe your teacher's role in the process of using mindmapping as a learning strategy. Did her role affect you, as the learner? (How? Why?)

8) Describe your role in the process of using mindmapping as a learning strategy. How did it affect (your learning) you, as the learner? (How? Why?)

9) What are your thoughts about outlining (prior common practice)?

10) How did outlining affect you, as a learner? (prompts if necessary)

- o Note-taking
- o Organization
- o Sense-making (understanding)
- o Learning
- o Remembering (how, why)
- o Studying for the test

11) Which strategy do you prefer?

12) Do you have suggestions for improvement? (Mindmapping? Process?)

13) Is there anything you would like to add?

Appendix I

Topic Outline Used in this Study

Chapter 21
Viruses
Pages 503-511

I. Viruses (p. 504-511)

A. Tiny, nonliving cells

1. do not carry out respiration, grow, or move

2. only reproduce inside a host cell

3. named for the diseases they cause

4. cause major disturbances in a cell's growth and reproduction, resulting in tumors or cancer; some are beneficial (tulips)

5. bacteriophage

B. Structure (p. 504-505)

1. 2 parts

a. inner core of nucleic acid (only 1 type)

1) coded for making copies of the virus

b. protein coat

1) determines the shape of the virus

2) some may have an envelope

a) made up of phospholipids

C. Shape (p. 505; figure 21.1)

1. determines the method of entry into the cell

2. polyhedral – ex: polio virus

3. cylindrical – ex: tobacco mosaic (rod)

4. T4 virus – has both polyhedral & cylindrical

D. Recognition of host cell (p. 506)

1. specific receptor site on the plasma membrane off a specific cell (like a jigsaw puzzle)

a. T4 – *E. coli*

b. Tobacco mosaic – tobacco plant

c. polio – nerve cells

d. smallpox – humans

E. Reproductive cycles – 1 type (p. 507-508)

1. Lytic cycle (p. 507; figure 21.2)

a. destroys the hose cell

b. reprograms host cell DNA and produces more virus cells using the host cell

c. steps:

1) attachment

2) entry – virus nucleic acid injected into host cell

3) replication – host DNA destroyed; new viral nucleic acid is produced

4) assembly – virus parts are assembled

5) lysis and release new virus particles burst out of cell killing host cell

2. Lysogenic cycle (p. 508; figure 21.3)

a. does not kill the host

b. viral DNA becomes part of the host cell's DNA (**Provirus**) and is reproduced during mitosis

c. may go undetected for years and is always recurring

1) ex: herpes simplex 1 and chicken pox in nerve cells

d. steps:

1) attachment and entry

2) provirus formation – does not interfere with normal functioning of the host cell

3) cell division – every copy of the host cell will have a copy of the viral DNA; can go undetected for years

4) Lytic cycle – provirus breaks away and enters the lytic cycle where the

virus begins reproducing and kills the host cell

3. Retroviruses (p. 510; figure 21.5)

    a. RNA virus

    b. reverse transcriptase – injected into host cell when RNA is injected

        1) copies viral RNA into DNA

F. Defenses against viral infections (not in book)

1. immunity – the body's best natural defense

    a. skin and mucous – 1st line of defense

    b. white blood cells (phagocytes)

    c. antibodies – 2nd line of defense

        1) specific to attack only that antigen (foreign protein of the virus) that has triggered the production of the antibody

        2) vaccine – a solution of weakened or killed pathogens

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VITA

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