Thinking Maps and Science Inquiry

An Examination of Thinking Maps in the Context of Inquiry-Based Science Education for Fifth-Grade Students.

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ABSTRACT

This study examined the effectiveness of Thinking Maps® in support of inquiry science. A representative sample of student work was coded; these included scientists' notebooks, unit evaluations, and questionnaires. This coding revealed unanticipated outcomes. Students receiving reading instruction in the school resource room were able to more effectively use Thinking Maps than either the Gifted and Talented or Average learner groups. The representative sample consisted of two students receiving services from the Gifted and Talented program, two "average" learners, and two students receiving reading instruction in the school resource room.

Increasing student achievement is at the heart of this study. Thinking Maps and science inquiry use are widely supported by scientists and researchers alike. Zemelman, Daniels, and Hyde suggest science lessons should include the use of materials which are related to the area of study. Marzano, Pickering, and Pollack suggest graphic organizers, particularly David Hyerle's Thinking Maps, are useful tools to increase student achievement.

This study involved six fifth grade students from two small New England communities with a school population of approximately 2,400 pre-kindergarten through grade 12. Shortly after the start of the school year, students learned techniques to familiarize them with inquiry science methods. Lessons were completed in small learning groups of three students. At the start of each experiment students wrote an abstract stating their belief, how they would conduct the experiment and finally, adding anything they felt would affect the outcome. Teams of three students worked to answer the probe, kept data, and make observations. Students wrote research findings independently of their groups members. Students completed a science unit evaluation as well as questionnaires. The evaluation was designed to correlate to the eight Thinking Maps.

Key words: Thinking Maps, inquiry science

DEDICATION

The Road Not Taken
By Robert Frost

Two roads diverged in a yellow wood,
And sorry I could not travel both
And be one traveler long I stood
And looked down one as far as I could
To where it bent in the undergrowth;

Then took the other, as just as fair,
And having perhaps the better claim,
Because it was grassy and wanted wear;
Though as for that the passing there
Had worn them about the same,

And both that morning equally lay
In leaves no step had trodden black.
Oh, I kept the first for another day!
Yet knowing how way leads on to way,
I doubted if I should ever come back.

(1966, p. 84)

I must believe that what I do, what I try to do, must be of value to others or it is for not. And it is with this belief that I dedicate this study to all the children I have had the privilege to be with these thirty plus years.

Additionally, I appreciate my wife, Gayle, for not just the time I've taken to complete this study, but for all the years she has supported me. My son, Ian, is an important part of my life, and I hope he will continue to share my love of learning, that he will coach lacrosse, and he will grow in his faith in God.

My mother, brothers, Mike and Marc, and sister Sharon need share in this work for without them I would not have continued. I am grateful to Marc for taking on the burden of caring so much for my early college education.

We are all given gifts and therein lies our destiny.

Annonymous

Sharon, my sister, is one of the many gifts I have received throughout my life. For, I could not have completed this program without her. Sharon, this is *our degree*. It is with the greatest love a brother could have for his sister that I thank you for all that you have done for me, Chris

Peter A. Morgan

September 1, 1956 – March 15, 1992

Dennise Maslakowski

October 16, 1954 -- December 19, 2008

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PREFACE

Teaching becomes more joyful every year that I teach, in this way I have found my life's work. What prompted this study is my curious nature, which at times can be a bit of a strain. In his book *Outliers: The Story of Success*, Malcolm Gladwell suggests, "Ten thousand hours is the magic number of greatness" (2008, p. 41). While I do not claim to be great, I believe after 33 years and more than 10,000 hours of teaching I have attained some measure of success.

I could write a book about my adventures. In some ways this dissertation is a book in which I tell the tale of those adventures. From beef bones and chicken bones to connecting writing and math and research and science I have enjoyed learning. My newest, and I've found most successful strategy, is using Thinking Maps throughout my day. Students reported that they would use Thinking Maps for recipes, putting words into writing, and would surely use them in college (How flattering!). Inquiry science is fun for me and I know from events, responses, and interaction with students, science activities are fun for them. One student put the general feeling that inquiry science is effective, "Hands on because you really get to experiment what happens and its way funner than reading about it." I am also very proud that when our district Special Services Director was observing the science class she could not pick out a student with multiple special needs who was born with Fetal-Alcohol Syndrome. I must add that one student who loved washing machines used several

Thinking Maps to describe them, compare one brand with another, and show the cause and effects of a broken Maytag. The class decided to build one for Maytag (his nickname). So, while I have studied the effectiveness of Thinking Maps and inquiry science, it is this kind of fun that has sustained me.

CHAPTER ONE

Introduction

An intense interest in education began in 1957 when the Soviet Union launched the space satellite, Sputnik. Reaction was one of fear; surely someone had to be responsible for our obvious lack of superiority against our Cold War adversaries. The ever-present criticism of education began with blaming President Dwight D. Eisenhower and continues to this day (1981, p 13). The resulting pursuit to regain our superiority brought science and technology to the forefront of American education.

The National Defense Education Act (NDEA) was enacted in 1958; its primary goal was to advance education through science and mathematics. However, it did include monies for studying foreign languages, geography, and English as a second language, as well as monies to improve school libraries. While the NDEA targeted the improvement of elementary and secondary education, it also provided low cost loans to college students. A major provision of this federal legislation prevented the government from interfering with school curriculum, which is unlike any federal legislation in recent years. This legislation began with somewhat of a benign approach, which is quite unlike our present attempts to improve our education system. No Child Left Behind (NCLB) requires yearly testing and consequences for not achieving the goal of literacy for all school students by 2014. No Child Left

Behind has politicized our educational system with both sides of the aisle claiming their position is correct.

The Cold War fear continues to affect educational policies throughout present day America. Attempts to fix our educational system have gone unabated. No Child Left Behind, (NCLB) being the latest in a long line of federal legislation, springs from criticism found in reports, newspapers, and television. Based on this perception there is an ongoing debate between many stake-holders of our society: parents; school boards; teachers and their unions; government agencies; and partisan legislators. We have taken our fears to a new level; NCLB is unlike any previous legislation. Schools must make Adequate Yearly Progress (AYP) by measuring student progress. Failure to meet federal standards can result in federal intervention. We have turned the corner and arrived at federal control of education. Unlike any past attempts, NCLB is both restrictive and punitive. The debate about its effectiveness rages from both sides of the fence. Defenders report it as a good measure of schools' improved achievement; critics suggest the tests measure rote information with out assessing problem solving abilities.

NCLB is based on standards-based education and requires each state to develop standards and assessments in reading, writing, and math, and to implement them in grades 1-3, 4-6, 7-9, and 10-12, and additionally requires schools to use research-based methods to teach science and measure the results. (2008) However vague, NCLB offers practitioners a unique opportunity: by using research based instructional practices, we can answer the federal legislation's call for increasing achievement. While standards-based instruction has some merit, I believe NCLB is flawed. While NCLB can provide information over a long period of time, it provides no immediate and relevant information that teachers can use to adjust instruction. Research suggests an entirely different approach is warranted. "An alternative approach to sanctions-driven accountability would be a partnership between the government, the teaching profession, and empowered low-income parents" (2009, p. 361).

Alfie Kohn points out the opinion of the National Science Foundation and the RAND Corporation, "While test scores are rising, the improvements may have nothing to do with whether schools have upgraded their teaching and curricula but instead reflect students and teachers' increased familiarity with the state assessments and improved test-taking skills unrelated to the curriculum" (2000, p. 33).

The threat of not making Annual Yearly Progress (AYP) has produced metamorphic changes in education; where once there was surety, now there is uncertainty and fear. Schools spend significant time, money, and effort to comply with federal regulations. With little to show for the nearly quarter of a billion dollars spent annually, one wonders why we continue trying to be "accountable."

The state of Maine is one case in point since standardized-test results have remained relatively flat, which is not atypical. (Table 1) Any real gains on the reading scores made have been made during the 2007 tests; however it is entirely appropriate to question the validity of such gains because, like most states, the assessments have undergone changes. The state education department develops new questions each year, which limits yearly comparisons. Changes in the academic areas and the grade levels calls into question the effectiveness of the testing. Additionally, it is appropriate to suggest the effectiveness of the yearly testing is diminished due to the increase student familiarity.

Table 1

Reading Scores

Year	Average Score
2007	221
2005	219
2003	218
2002	219

Standardized tests cover a wide range of material that requires teachers to cast their nets widely, but not deeply enough to ensure sustainability. Test preparations prevent teachers from effectively conveying important content. This is especially true in science, where the best way to teach is diametrically opposed to raising test scores. The use of textbooks, lectures, worksheets, and rote memorization do not afford students the time for active learning. It has been my experience and this research confirms my belief, students' learn best through the use of materials, batteries and bulbs, magnets, nails, paper clips, wire, and other materials suitable for discovery of electrical properties. The former is about coverage; the latter is about discovery, which we will discuss further. Thus schools that frown on teaching to tests might be singled out as underperforming and penalized for doing what is best its students.

The sense that we need to fix our education system began in 1958 with the passage of NDEA. I have connected the first attempt to reform education to the most recent. Our most recent attempts to remain competitive and superior to other industrialized nations came about with the publication of *A Nation at Risk: The Imperative for Educational Reform*. (1983). This publication suggested that American schools were in danger of rendering us incapable of remaining competitive with other nations. I believe this reformation has failed, for we continue teaching much as we have before NCLB began; we have simply become test oriented. The time necessary to administer tests robs students of education time; is cumbersome, and allows for no immediate feedback, and provides false surety. My use of Thinking Maps and inquiry science techniques led me to question their effectiveness.

Research Questions

Question One:

How is the use of inquiry science an effective instructional practice?

- Do students use science inquiry methods correctly?
- How do students show their understanding of science concepts?

Question Two:

How is the use of Thinking Maps an effective instructional practice?

- Do students use Thinking Maps to show their thinking?
- Do students use Thinking Maps for the purpose for which they were designed?
- What is the difference between high and low ability students in the use of Thinking Maps?

Significance of the Study

During their lifetime, students will spend nearly fifteen thousand hours in school before entering the work force or attending an institution of higher learning. Between lunch, recess, and daydreaming, students must learn skills they will need for life in the 21st century (Morgan-Janes, 2007). Our present approach to education, standards-based learning, requires a fresh look at our curriculum. Through federal legislation, No Child Left Behind (NCLB) states, “Schools must ensure the use of research-based methods to teach science and measure results. Establish partnerships with universities to ensure that knowledgeable teachers deliver the best instruction in their field” (2001). While this statement has merit it is the process that is used to measure student knowledge that I call into question. It is important to understand student knowledge but NCLB does a poor job of carrying out its mission. To be effective, assessments need to provide students and teachers with information in a timely manner. It is with this belief that this research has been conducted.

This study’s foundation is predicated on David Hyerle’s Thinking Maps, learning theory, education philosophy, and Bruno’s constructivism. (1960, 1971), Additionally, Dewey’s philosophy of education (1916), Caine & Caine’s learning principles (1997), Gardner’s Multiple Intelligences (1993), and Marzano, Pickering, and Pollack’s research-based strategies for increasing student achievement (2001). The practical aspects of this study is to examine the effectiveness of the use in the content areas, the implications for curriculum development, and the connection with other research in instructional practices that increase student achievement.

Definition of Terms

Inquiry science: The process of constructing knowledge based on investigation. Students use a combination of mathematics, literacy, and science exploration as they seek to solve authentic problems.

NCLB: No Child Left Behind Act of 2001: federal legislation which requires accountability through yearly testing in reading, writing, math and science.

Pull-out model: Structured delivery of services as required by federal legislation. Students are "pulled" from the classroom to receive special instruction by personnel other than the classroom.

Individual Education Plan: commonly known as an IEP, is mandated by federal law as part of the Individuals with Disabilities Act. This is both a written document and an appropriate, free education. Testing is required to determine eligibility in the areas of diability. Goals and objectives are developed and students must be educated in the least restrictive environment.

Velo-Cardio-Facial Syndrome: a genetic syndrome, which includes many symptoms: heart disease, defects of the palate, which are related to neuromuscular problems. Autoimmune disorders can occur later in life with the risk of psychiatric illnesses

Adequate yearly progress: AYP is a part of the federal legislation, No Child Left Behind. Schools across the country are required to perform academically according to the results of standardized testing. At least 95 percent of all students are tested for reading and mathematics; 95 percent of all students must achieve the minimum annual target for meeting or exceeding standards for reading and mathematics; and finally, 95 percent of all students must meet minimum standards set by the state. State education agencies determine annual yearly progress and identify schools that fail to do so, as schools needing improvement incur federal penalties, often including replacement of staff and administration.

Constructivism: Theory attributed to Jerome Bruner in which learners construct meaning from previous learning experiences.

Formative Assessments: entail teacher observations, which take place during the learning process. Teachers evaluate student work and make adjustments in activities; these are never completed at the end of a unit, so as not to affect grading.

Thinking Maps: a system to show thinking through eight mental processes which learners use to process information as developed by David Hyerle. Thinking Maps is a registered trade mark of David Hyerle.

Otis-Lennon School Ability Test (OLSAT): a test of abstract thinking, which can be group-administered. It is a multiple choice, pencil and paper test, which measures reasoning ability. A total score is derived from the verbal and nonverbal scores; it is a normed test with sub-tests organized into five areas: verbal comprehension and reasoning; pictorial, figural, and quantitative reasoning.

Limitations and Delimitations

One limitation of this study is my limited science training. Typically, state elementary school teacher certification requires one science methodology class. While my efforts to increase the effectiveness of my instructional practices I joined a school-wide effort to realign our science curriculum with state standards. I also attended inquiry science training sessions offered by the Maine Math and Science Alliance. Elementary school teachers are generalists, we know a lot about teaching reading, writing, and math but often have misconceptions about science. I am a typical teacher in this way. Further training would impact my work with students and possible change the outcomes of this study. A second limitation of this study is the narrow scope of the science unit: concepts of electrical energy. By examining only one unit of study with a small representative sample, the results may not be able to be duplicated. Using Thinking Maps across the curriculum would give more information about their effectiveness. A third limitation results from the limited formal Thinking Maps training. My attendance at the Thinking Maps Trainer-of-Trainers program included a five-day training program with two follow up days several months after the initial instruction. Given additional time the comparisons of student outcomes would yield still more information.

Overview

This study is at once investigative and practical. Constructivist theory guided me as I hope to add to the body of knowledge already influencing educational decisions. Believing learners build knowledge from previous experiences, I designed science lessons and began the process of data analysis. Employing grounded theory methods to guide my work, I gathered artifacts in which language skills, science understanding, and Thinking Maps were coded. From student work the analysis revealed patterns, which suggested students receiving reading instruction in the resource room used the Thinking Maps more often and with greater skills.

The effectiveness of Thinking Maps have been adopted by schools throughout the southern United States and in several foreign countries (2008). A second method of providing research-based instruction, inquiry science, improves student achievement. This researcher believes they are effective alternatives to the testing required by NCLB. This study analyzes six fifth grade students' understanding of science concepts through science inquiry methods. The study group received instruction in using Thinking Maps before the start of the science unit.

In Chapter One I outlined the history of educational reform beginning with the 1958 launch of the Soviet missile, Sputnik. I connected The National Defense Education Act with the latest efforts, NCLB. I stated the significant difference between past and present efforts. The newest effort is standards-based, which requires yearly testing and which I believe is counterproductive to its goal. Finally, I offered an alternative means to increase student achievement. In Chapter Two I present further information about NCLB as it connects to increasing achievement. Learning theories, brain-based research, constructivism, and best practices will also be examined.

CHAPTER TWO: REVIEW OF THE LITERATURE

No Child Left Behind

The latest reform effort, NCLB, states, "Schools must ensure the use of research-based methods to teach science and measure results. Establish partnerships with universities to ensure that knowledgeable teachers deliver the best instruction in their field" (2000). With this statement, the contradictory nature of NCLB becomes evident. Schools engage in quick fixes and not what really works. "One "quick fix" is obvious and immediate: it has the illusion of certainty and the reward of short-tem efficiency. But is diverts attention away from the real or fundamental source of the problem, and ultimately it does not sustain itself."

NCLB uses standardized tests requiring students to respond to an array of questions that are designed to assess their knowledge; multiple choice and constructed response make up the bulk of the assessments. While NCLB's testing model limits the scope of its testing, it is the amount of time between the administration of tests and the availability of test results that limits the effectiveness of this testing. This lag time provides little benefit to the students as teachers cannot adjust instruction quickly to ensure deep understanding. Ideally, the time between assessment and feedback should be in close proximity; several months is of little value to anyone. An additional weakness is that each state develops its own standards, so accurate state-by-state comparisons cannot be made, further weakening any effectiveness of the testing. Without standardized objective measures the testing is flawed.

The guiding principles of NCLB are also difficult to translate into measurable objectives. In the English Language Arts Content Area of the State of Maine Learning Results, Process of Reading states, “Students will use the skills and strategies of the reading process to comprehend, interpret, evaluate, and appreciate what they read.” In the behavioral objectives, this publication goes on to state, “…students will be able to: Seek out and enjoy experiences with books and other printed materials” (1997, p. 11). This objective is determined by teacher observation and is subjective; therefore, it cannot be measured on a standardized test. This type of objective may be lofty, but gives little support for testing in the first place. Finally, the learning of one student is unlike that of another, yet standardized tests reduce understanding to a single question and a single response. It uses a cookie-cutter, one-size-fits-all method to assess learning.

A different option, formative assessments, provides a better understanding of cognitive abilities. Through observation teachers are better able to evaluate student understanding. Formative assessments are based on authentic evaluations and provide immediate information for both student and teachers. Teachers can alter their instruction quickly to broaden students' deep knowledge. Formative assessments provide a better and quicker understanding of students' thinking and knowledge.

Regardless of the efforts NCLB makes to reform education, controversy continues. A vocal critic, Alfie Kohn, suggests we are measuring what matters the least, stating, "Standardized testing has swelled and mutated, like one of those creatures in one of those old horror movies, to the point that it now threatens to swallow our schools whole" (2000, p. 1). He believes NCLB is "unredeemable" and should be scrapped as its main effect is to sentence poor children to endless testing. His objections often center on the inequities standardized-tests produce, further reducing the use of instructional practices that increase student achievement. NCLB mandates schools use research-based methods; yet, brain-based research indicates standardized testing is of little value. Learning is a complex task, not easily assessed, certainly not by standardized measurements. NCLB does not produce more competitive students, just better test takers.

In this section I have traced the history of education reform from its 1958 to the enactment of NCLB. From 1958 the United States has sought to remain competitive in technology. With each reform a greater control by federal agencies has occurred. I examined No Child Left Behind's weakness and offered alternative authentic assessments. The next section examines alternative practices to NCLB's requirements and processes.

Learning Theories

Little in the way of education has changed; schools look and operate as they have for decades. There is limited application of our knowledge of what learning is or how it is done, and just as importantly, how to apply it. Examining how best to engage learners involves communicating and understanding thinking. This study attempts to analyze how students engage in learning science and how they use Thinking Maps. I believe it is important to examine what thinking is, in order to put scientist notebooks and Thinking Maps in context of what learners need to become critical thinkers rather than mere vessels.

In Webster's 11th Edition Collegiate Dictionary (2005, p. 1299) there are five meanings as well as multiple synonyms for thinking. Google the word thinking and you will find about 276,000,000 sitations. Besides the dictionary definition you will find a Britannica Concise Encyclopedia listing, antonyms, language translations, idioms, and even a Dental Dictionary definition. Philosophers, educators, researchers, and legislatures have all grappled with thinking; most would have different beliefs about what one does when thinking.

It is difficult to define thinking because we are not certain how it is done. Is it possible that true thinking is a result of our thinking about thinking; metacognition, or the knowledge of our own thoughts and what influences them is an, or should be, important part of education. Learners must be taught how to become critical thinkers.

Jonassen and Land suggested that constructivists believe that learning is "Willful, intentional, active, conscious, constructive practice that includes reciprocal intention-action-reflection activities. Therefore, learning is conscious activity guided by intentions and reflections" (2000, p iv). Constructivism is the belief that new learning is built on previously established knowledge.

This researcher has come to believe that learners construct knowledge through experiences in individual ways be it through logic, movement, math, or art. Educators must exploit brain-based research to structure all activities for the sole purpose of teaching critical thinking.

This study is based on philosophy and theory; however, it is a practical study. Learning needs to be active, it can be messy, must be learned through experiences, and must be shared with others. Thinking Maps is an effective way to share thinking; after students engage in experiments they need to discuss their data so new knowledge becomes their own.

Learning theory has three dominant perspectives: behaviorism; cognitivism; and constructivism. We associate B. F. Skinner with behaviorism, which focuses on what can be observed and learning is fairly permanent. Lev Vygotsky's theory suggests all learning is a result of social interaction. Jerome Bruner's learning theory is closely related to David Ausubel's advance organizers. Constructivism espouses new learning builds on previous knowledge, which is active and not permanent.

B.F. Skinner is most closely associated with behaviorism suggesting, "Knowledge is action, or at least rules for action." He believed that knowledge was gained as a reaction to stimuli. Both positive and negative reinforcement resulted in a desired outcome. Motivation to learn came when there were appropriate, "Scheduled positive and negative reinforcements" (1976, p 58). His theory of cognitive development relied on a mechanical responses to environmental stimuli. The limitation to this theory is that reinforcement needed to occur each time a desired behavior was observed. His theory did not consider what processes were taking place in a person's brain, the social component of cognitive development, nor did he consider the influence of a culture. While there is value in Skinner's behaviorism, it does not advance our understanding brain-based learning.

A second learning theory, cognitivism, marked a shift from Skinner's behaviorism as an, "Approach, which did not investigate the internal states of the learner claiming that such states cannot be directly observed and instead focused on stimulus-response strategies" (Scheurman, G. 1998, p. 6). Cognitivism considers the changes social interaction has on the brain as it integrates new learning. Vygotsky states: "Every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level" (1978, p. 57).

The connection between Vygotsky's belief that learning is developmental connected him with Jean Piaget's theories. According to Piaget children's cognitive potential depended on their level of social interaction. He believed that leaning depended on the "zone of proximal development" (ZPD). He defined this as, "The distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers" (1962, p. 4).

According to Piaget development depended on a culture's words, actions, level of social interactions, and its social cues. These cultural cues contributed to the change in cognitive abilities. With social interaction, a greater ability to use these cues and psychological tools brought independent learning. While adult guidance is important to a child's cognitive growth, Vygotsky believed other social situations also contributed to scaffolding (the building on knowledge). Goodman and Goodman's research used Vygotsky's theory to show the connection between social interaction and language literacy, an important learning tool (1990, p. 83). They believe our successful acquisition of language become internalized, leading to greater cognitive development.

The theoretical framework of Vygotsky's social development model provides insight into the social aspect of learning. Because there is a relationship between our culture and learning it behooves us to understand the impact socialization has on our learning. Vygotsky believed that children's cognitive development is linked to the culture in which they are raised and that each function began on a social level (inter-psychological) before becoming internalized (intra-psychological). His work set the stage for further examination of social and cognitive development.

Piaget's theory of cognitive development suggested four cognitive stages begin at birth and continue into the mid-teens: sensorimotor; preoperational; concrete; or formal operations stages. During the sensorimotor stage infants begin understanding how things work through experiences. Infants learn at this stage when they interact with and organize objects (people and things) fitting them into previous conceptual patterns.

The preoperational stage begins about two years of age and continues until approximately four years. The inability to think abstractly results in learning through concrete experiences; this stage is accompanied by where and why questions. By using their senses, children are able to think abstractly. Piaget believed a child moves into the concrete operational stage during the 7th year and continues through age 12. Children in this stage begin applying the use of logic.

Finally, the formal operations stage begins at about 11 years old and continues until approximately age 15. This stage is marked by making rational judgments, requiring few concrete objects. Abstract thinking, which is similar to an adult's thinking, begins a period of increased learning. The implications of Piaget's theories led to Jerome Bruner's constructivist theory, that believed learning is built on previous knowledge. Constructivism is closely tied to Piaget's stages of development. Much of children's learning begins by using the limited abilities in infancy: looking, sucking, grasping, listening, and simple movements. With these abilities, infants build on their sensory stimuli towards the adult ability to reason.

While Brooks and Brooks advocate a constructivist approach to education, they caution against a simplistic view because understanding another's thinking is difficult. "Why? Learning is a complex process that defies the linear precepts of measurement and accountability through political pressure but, rather, through attention to the idiosyncratic, often paradoxical nature of learning" (1993, p.vii).

The manner in which we learn large amounts of information was the focus of David Ausubel's learning theories (1963). Essentially, when learners are presented with information in school or elsewhere, superordinate, representational, or combinatorial processes occurs. Superordinate is the relationship between words; that is, animal is a superordinate of cat. Representational processes involve understanding something in a physical form, and combinatorial is linked with mathematical knowledge. Cognition, he believed, is the residue of learning experiences. His major contribution to learning theory was his proposal of advance organizers, which act as a bridge between new learning material and existing related ideas.

> These organizers are introduced in advance of learning itself, and are also presented at a higher level of abstraction, generality, and inclusiveness; and since the substantive content of a given organizer or series of organizers is selected on the basis of its suitability for explaining, integrating, and interrelating the material they precede, this strategy simultaneously satisfies the substantive as well as the programming criteria for enhancing the organization strength of cognitive structure. (1993, p. 81)

In this section I have explored learning theories and their affect on educational pedagogy. An examination of three major learning theories included behaviorism, cognitivism, and constructionism. In the next section I will more fully explore constructivism, which is the basis of inquiry science and is how Thinking Maps assist learners in showing their thinking.

Constructivism

I believe learning is active rather than passive, for knowledge cannot be injected as inoculations or genetically engineered. Knowledge is a general awareness of information, which can be applied to new learning situations. Bruner suggests learning is an active process in which ideas are constructed from current or past learning. Therefore, constructivist classrooms require teachers to be facilitators, rather than proctors and students to be independent learners. For this to happen, teachers must construct authentic learning opportunities that require students to solve problems. Traditional curriculum often relies on texts, worksheets, memorization and has changed very little from pre-'reform.' Zemelman, Daniels, and Hyde tell us, "After nearly ten years of zealous "reform," students are still sitting in pretty much the same classrooms with the same teachers, divided into the same instructional groups, doing the same activities, working through the same textbooks and worksheets" (1998, p. 3). These methods are the least effective way to teach critical thinking. Embedding assessments into the activities and units rather than creating quizzes and tests provide opportunities to altered instruction.

Zemelman and colleagues warns us that reform efforts are, at the very least, flat. This study offers alternatives to the same instructional practices that have produced very little effect on student learning. Remembering Bruner's suggestions that learning is active and built on previous knowledge we must take every advantage available to us by maximizing how students learn. The beginning of learning begins during infancy and is based on learning language. Linguistic knowledge includes the understanding of our lexicon, which is developed over many years. Language is a complete system of communication. It is the process of transferring information, especially cultural, from person to person and from one generation to the next. Through approximation, children construct meaning for themselves-they do not simply express their thoughts as adults do. Learners construct the rules of language as they experience it from birth, continuing to learn throughout life. We construct meaning through contextual clues, making inferences, drawing conclusions; we use our previous knowledge to develop our vocabulary. These and other comprehension skills build on our experiences. Making sense of our experiences is unique because our thought processes are different. Inquiry science methods use action, imagery, and language to develop student learning. Thinking Maps is an effective way to show our actions, imagery, and language as we show our thinking to others. This shared process constructs new knowledge.

Experiential learning is the process of making meaning, therefore, it is a strong connection between constructivism and experiential education. John Dewey's name became synonymous with experiential education, the pedagogical partner of constructivism. Dewy's philosophy of education continues to influence education. Through the use of manipulatives such as Cuisenaire Rods and the *Everyday Math* program designed by the University of Chicago. University of New Hampshire's Browne Center for Innovative Learning is another example of John Dewey's philosophy of education that influences education practices. Essentially, an understanding of constructivism must lead to new pedagogical practices based in authentic learning. In *How People Learn: Bridging Research and Practice*, Donovan, Bransford, and Pellegino suggest,

> Teachers must come to teaching with the experience of in-depth study of the subject area themselves. Before a teacher can develop powerful pedagogical tools, he or she must be familiar with the progress of inquiry and the terms of discourse in the discipline, as well as understand the relationship between information and the concepts that help organize that information in the discipline. But equally important, the teacher must have a grasp of the growth and development of students' thinking about these concepts. The latter will be essential to developing teaching expertise, but not expertise in the discipline. It may therefore require courses, or course supplements, that are designed specifically for teachers. (1999, p. 72)

Dewey's concepts of experiential education are at once simple, yet complex. Simply, learners acquire knowledge through their experiences, but to understand such a simple concept, it is important to first understand learning, which is more complex. Brooks and Brooks (1993, p. 68) advocate a constructivist approach to education;

however, they caution against a simplistic view because to understand another's thinking is difficult. Articulating thinking becomes a challenge for practitioners and learners alike.

Through actions, imagery, and language, students can form abstract concepts. This process requires tools to share and understand abstractly. Abstract knowledge is the ability to understand complex issues, which should be the goal of school activities. Through the use of Thinking Maps, students can process and share information and form abstract thinking. Dana and Davis write of their concern; teachers use traditional methods of assessments, which they believe is not an accurate picture of their cognitive understanding (1993, p. 49).

Because of its messiness, constructivist practitioners understand the importance of assessing student learning that considers the un-measurable qualities of learning. There are differences between traditional and constructionist classrooms. The process of writing is different from completing grammar exercises. Knowing what a participle is does not mean you can understand its importance, nor its function. Certainly, I concede learning needs facts, but the difference is how learners arrive at an understanding and an ability to apply the facts. Grading provides a means to separate learners, to disavow the process of learning for no other purpose than creating an academic cast system. An average person could give cursory definitions of DNA, but an understanding and implications for it would be beyond most of us. In constructivist classrooms, it is the building of knowledge, like blocks one on top of another, that is the purpose of critical thinking.

In this section I examined the differences between constructivism and traditional instruction. Bruner's three systems for handling information and their relationship to learning in constructionist classrooms were examined. The relationship between learning and the best ways to ensure learning is the topic of the next section of this chapter.

Best Practices

The notion that best practices are newly arrived on education's doorstep is a misnomer; good teaching always incorporates new information about how learners acquire knowledge. Recent brain-based research offers teachers a greater understanding of instructional practices aimed toward increasing achievement. Education research challenges practitioners to become knowledgeable in the principles and best practices of effective teaching, including a theoretical and working knowledge.

Because we now know more about learning through brain-based research, pedagogical approaches need to change as well. Shifting our thinking and practices that reflect our new knowledge necessitates support from administrators and from professional development including: workshops; college classes; and collegial learning communities. Through such efforts the theoretical and practical aspects of learning become possible.

In *Classroom Instruction that Works*, Marzano, Pickering, and Pollock offer nine research-based strategies to increase student achievement (2001). These strategies support the uses of both Thinking Maps and inquiry science. The nine strategies include: Identifying Similarities and Differences, Summarizing and Note Taking, Nonlinguistic Representation, Generating and Testing Hypotheses, Reinforcing Effort and Providing Recognition, Setting Objectives and Providing Feedback, Cues, Questions, and Advanced Organizers. A discussion of each strategy as it relates to the use of Thinking Maps and inquiry science will follow.

Identifying Similarities and Differences

Marzano tells us, “Researchers have found these (identifying similarities and differences) mental operations to be basic to human thought” (2001, p. 14). Providing explicit instruction followed closely by independent work are the first two generalizations. The third requires students to represent similarities and differences graphically or symbolically. Finally, this activity can be done in a variety of ways: comparing; classifying; creating metaphors and analogies. Inquiry science techniques include colleting data before making comparisons. A Venn Diagram is one organizer that shows comparisons; however, its construction implies there are fewer similarities than differences, which is not always the case. Hyerle's Double Bubble Maps' structure allows endless comparisons.

Summarizing and Note Taking

Effective note taking requires students to analyze information and keep only what is essential. Instruction should include four key points: verbatim note-taking is the least effective, notes are a work in progress, notes are effective study guides, and limiting notes is a misconception. Marzano, Pickering, and Pollack discuss and show empirical data supporting the importance of note taking, suggesting David Hyerle's Thinking Maps is effective because students can quickly summarize information in its simplest form.

Nonlinguistic Representation

In chapter six, Nonlinquistic Representations, Marzano sights the works of theorists that suggest information is stored in two ways, a "Linguistic form and an imagery form. The linguistic mode is semantic in nature. As a metaphor one might think of the linguistic mode as containing actual statements in long-term memory. The imagery mode, in contrast, is expressed as mental pictures or even physical sensations, such as smell, taste, touch, kinesthetic association, and sound" (2001, p.

73). Marzano suggests the more we use linguistic and nonlinguistic systems the better we are able to think about and recall knowledge. Because students primarily receive information linguistically or visually, they need teacher assistance to create nonlinguistic representations, which David Hyerle researched in the late 1980s. By presenting a variety of activities, student understanding is enhanced. (Howard Gardner's work supports this as well). Inquiry science is active, includes nonlinquistic representation, and requires students to create some form of graphic representation to show their understanding concepts. Asking students to elaborate invites them to explain their thinking, which is the task of Hyerle's maps. Marzano not only explains, but also uses graphic organizers. All six patterns are essentially the same as Hyerle's Thinking Maps: descriptive; time-sequence; process/cause-effect; episode; generalization/principle; and concept patterns.

Generating and Testing Hypotheses

Generating and testing hypotheses is one part of inquiry science methods. Marzano cites research suggesting an average of a 19% gain in student's knowledge when they use this approach (p. 104). Hypothesis generation and testing can be an inductive or deductive process. Inquiry science begins by accessing students' previous knowledge by asking students to generate a list of words they might use as they conduct experiments. After students conclude their experiments, they must form conclusions and then the cycle begins again. Thinking Maps assist students to clearly explain their hypotheses and their conclusions.

Reinforcing Effort and Providing Recognition

Marzano suggests that people attribute achievement to ability, effort, other people, or luck. Although it seems obvious, ability and effort have much to do with achievement learners often believe otherwise. Marzano suggests students should be recognized for efforts, which, with instruction, is intrinsically motivating. While many would argue that recognition doesn't increase achievement. Three generalizations emerge from research: rewards do not have a negative effect on intrinsic motivation; reward is effective when it is contingent on standards of performance; and finally, abstract symbolic recognition is more effective than tangible rewards. For recognition to be effective, it must be personal to individual students; praise must be given only for performance improvement; and concrete symbols such as stickers add to the effectiveness of recognition. However, reinforcing students has its critics. A recent New York Times article calls into question the effectiveness of praise, citing a Brookings Institute study which, "Found that countries in which families and schools emphasize self-esteem for students lag behind cultures where self-esteem isn't a major focus" (2008).

Setting Objectives and Providing Feedback

While most of us do not want to climb Mount Everest, we do want to be successful, and to do so, we set goals, big and small. Marzano's findings indicate that instructional goals should not be too specific is based on research with an average 26-percentile gain (p. 93). These researchers share several guidelines; feedback should be timely and realistic.

Cues, Questions, and Advanced Organizers

Cues and questions are imperative in any classroom. The importance of wait time and higher level questions produce deeper learning than lower level questions. Wait time is an effective teaching method, teachers wait a short time, perhaps 15 seconds or so, before accepting answers. Waiting briefly before accepting responses from students has the effect of increasing the depth of students' answers. In The Taxonomy of Educational Objectives, Bloom (1956) considered the level of questioning and its importance to the learning process. An overuse of specific, easily answered questions is often found on quizzes and tests; however, Bloom believed little knowledge is constructed by asking these types of questions. Lower level questions are questions students are asked to recall facts or terms. Most deep understanding requires questions, which ask students to show comprehension by organizing, comparing, translating, interpreting, or describing. Additionally, students gain knowledge by analyzing, synthesizing, and evaluating.

In conclusion, four instructional practices that directly relate to this research includes: identifying similarities and differences; non-linguistic representations; generating and testing hypotheses; and cooperative learning. While there is not a direct connection between the remaining practices, successful teachers use them in all parts of a school day.

New perspectives from brain-based research are having a strong impact on education as it relates to pedagogical practices. It is the practitioners' challenge to use brain-based knowledge to create authentic learning experiences to increase achievement.

From Jensen's brain-based research we understand more about learning than any time in education's history (1998). We understand how the spinal cord, made of a bundle of nerves running up and down the spine, is similar to a superhighway, speeding messages to and from the brain. We understand sensory information is gathered in our daily lives through sight, sound, taste and touch. The increased research by neuroscientists in brain function and its influence on learning tells us that the human brain is constantly searching for meaning through making patterns and searching for connections. Still further, we understand the connection between learning and its social interaction. While it is important to conduct research of the brain's structure and function, it is particularly valuable to understand that the research allows us to connect with each other-to carry the essential culture forward through language. Our brain carries us from the past into our future. From infancy to complex problem solvers, we construct new meaning based on previous knowledge. Our construction of new knowledge occurs individually, unlike any other learners because we learn in unique ways.

The three major learning theories include Skinners' behaviorism, Vygotsky's social interaction, and Bruner's constructionist. This study is based on the belief that learning takes place through social interaction and that new learning is constructed from previous knowledge. A secondary pillar of this study is that learners are individual in both their approach and construction of knowledge. Howard Gardner's theory that learners have individual learning preferences currently holds great weight in education circles.

From Garner's work we know practitioners need to consider students' learning styles. Gardner's theory of intelligence differs from Piaget in that he believed children could be at different developmental stages at the same time. Children could have an advanced number sense while being less able to successfully write legibly. His theory suggested that Piaget was wrong because intelligence is not fixed and with enough support and practice physical, academic, artistic, and interpersonal skills can be mastered. Gardner's intelligences include: bodily-kinesthetics; interpersonal; verbal-linquistic; logical-mathematical; naturalistic; intrapersonal; visual-spatial; musical.

Gardner's theory considers people's strengths; therefore, instruction should include learning styles.

Body-kinesthetic is a person's ability to learn through movement. This ability suggests this type of learner needs to move and by doing so is able to acquire knowledge by using their bodies.

Interpersonal skills are highly prized because these learners are most often extroverted and their temperament includes an ability to work well with other people. These learners are social and work well in groups, often taking on leadership roles.

Verbal-linguistic learners might be referred to as wordsmiths. They have an ability to learn languages easily and have strong-skills as readers and writers. Verbal-linguistic learners are often skillful teachers, editors, or interpreters.

Logical-Mathematic learners usually have highly developed logical-mathematical skills. Abstract reasoning appeals to them, as does number puzzles, computer games, and science experiments. These learners have an ability to solve complex problems involving algebraic formulas, calculus, trigonometry, and other advanced mathematics-they often are strong scientifically.

Naturalistic learners are people who may protest the destruction of ecological systems. They understand how our world needs balance and how humans are but one part of this world. They often enjoy working with animals or growing their own food. Their preferred leaning style puts them in out-of-door activities.

Intrapersonal learners would be comfortable with Plato as he is one example of an intrapersonal learner. Thinking an idea through is important to such introverts. These learners are aware of their emotions and motivations. Psychologists have strong self-knowledge. They reason without help from others and enjoy learning alone.

Visual-spatial learners enjoy solving puzzles. Engineers, architects, and artists have several things in common, such as their ability to solve problems involving mental manipulation of objects, strong visual memories, and good hand-eye coordination.

Musically gifted learners have a keen sense of rhythm, an ability to sing or play musical instruments, and some have a greater developed skill so that they are able to compose music. Musicians of note often have advanced musical abilities that set them apart from other types of learners.

In some ways practitioners need to go beyond theory. We need to consider practical aspects of learning as we construct classrooms that are beneficial to learning. Constructing classrooms that focus on critical thinking need guidance to support learners' efforts as they build new knowledge. Caine and Caine's (1997) 12 principles of learning support the work of practitioners, while using sound theory.

Principle 1: All learning engages physiology, thus we must consider physical movement as part of our instruction. Movement can be an effective strategy to strengthen learning, improve memory, and retrieve information. Inquiry science enhances learners motivation as they use equipment to explore science concepts.

Principle 2: Research shows that all learning involves social connections which may be supported through cooperative learning, which is the relationship in a group of students that requires positive interdependence (a sense of sink or swim together), individual accountability (each of us has to contribute and learn), interpersonal skills (communication, trust, leadership, decision making, and conflict resolution), face-to-face promotive interaction, and processing (reflecting on how well the team is functioning and how to get it to function even better). Both are social activities requiring group work.

Principle 3: Practitioners can increase meaning making by enhancing relaxed alertness. Caine & Caine define relaxed-alertness as, "…is the state in which we experience low threat and high challenge at the same time" (1997, p. 153). A sense of surety allows learners to risk not knowing, to be willing to explore, and to make mistakes. Inquiry science is exploration as they search for information and solve the puzzle

Principle 4: As people search for meaning, they use patterning, organizing, categorizing, and classifying. Essentially, we try to make sense of our world by doing this moment-to-moment. Inquiry science techniques assist learners as they organize their thinking. Thinking Maps were designed to show thinking, to share and sharpen understanding. It is a system to process information as we form patterns, organize, categorize, and classify.

Principal 5: Most importantly, learning is enhanced when our emotional well-being is supported through ‘relaxed alertness.’ Caine and Caine define relaxed-alertness as a personal sense of competency and confidence. Whenever emotional and social elements are supported, achievement increases. Inquiry science can support student learning because of the group process-learning is not done in isolation.

Principal 6: Understanding whole-to-part relationships is how the brain and body make sense of the world. In the classroom, this process begins each day as students construct new knowledge. Conducting experiments begins by writing abstracts, gathering data, making observations, and drawing conclusions.

Principle 7: Teachers constantly work to keep students' attention and whenever they succeed, learning is maximized. New understanding can be formed through participation. Learning requires active participation.

Principle 8: We often learn through our consciousness, but learning occurs in other ways as well. Unconsciously, learners continue processing information long after the lesson is complete. Such teaching methods as wait-time capitalize on this knowledge.

Principle 9: We often associate memorization with schooling, but learners need other methods to be successful. Learners also need "dynamic memory." During our daily learning we encounter situations that require the use of previous memorized information: bus routes, simple recipes, or lacrosse plays and rules. Inquiry science involves memory due to experimentation. Memories of past activities are required to conduct experiments. Thinking Maps assists learners form visual memory that can be used again in repetitive activities.

Principle 10: Early theories established that learning is developmental. New learning cannot begin unless the required skills are present. A sense of numbers, words, and speech must be present before science experiments can be conducted.

Principle 11: Caine & Caine suggest that it is imperative for teachers to focus on creating a sense of safety, so students can be empowered while learning. By their very design, empowered learners to take risks as there is less need to get the right answer.

Principle 12: Every human is similar, having DNA, yet how one's DNA is wired is essentially what makes humans unique. Learning is also individual and that is in itself the challenge to teachers. Brain function is unique and we need to be cognizant of students' uniqueness, which creates another challenge for teachers.

Our examination of brain-based research began with theory of learning and practitioners as they construct classroom instruction, with teaching critical thinking as its goal. After examining the types of learners I reviewed Caine and Caine's 12 principles of learning. Their work provided the framework for pedagogical practices. In the next section I will explain David Hyerle's Thinking Maps as they apply to this research.

Thinking Maps

Attempts to "show" our thinking began long ago and far away. The cave paintings in Lascaux, France, are early efforts to do just that. From cave paintings to laptops, we have attempted to show our thinking visually. We do so primarily because, “80% of all information that comes into our brain is visual; 36,000 visual messages per hour may be registered by the eyes” (2007, pg. 12). Without visual records much of what is essential is lost--many native languages are no longer spoken-and our thoughts disappear with an ever-increasing amount of information we need to process.

It is in this need to process large amounts of information that the use of Thinking Maps is most valuable. While this research study concerns examined Thinking Maps on fifth grade science instruction, there was no limit to the possible uses beyond the classroom, and herein lays their greatest strength. Thinking Maps are not simply a worksheet elementary school teachers use as part of a lesson. Thinking Maps offer a lifetime ability to communicate ideas.

Thinking Maps, as designed by David Hyerle, is a language that visually represent thinking processes. They provide students with a system to expand their ideas and construct new knowledge. It is also important to note that the maps are not limited to any area of curriculum and can be expanded; it is in fact one of their intended purposes. Hyerle states, “Thinking Maps based on research beginning with Piaget’s identification of concrete operations that are mirrored in the cognitive processes that are the foundation for the maps” (D. Hyerle, personal communication, July 10, 2009).

David Hyerle's work began as a student at the University of California at Berkeley; he began developing a mapping system for his own use. The sequence of events leading up to its present level of development began with the work of Albert Upton. On his Thinking Maps Foundation website Hyerle offers a vision for transforming teaching and learning for every student through an explicit focus on thinking processes and language development. The Upton Model is an important model for the development of Thinking Maps and its theoretical foundation.

Throughout the 1970s, this work continued until David Hyerle created Thinking Maps. With his first resource, *Expand Your Thinking*, (1998) Hyerle's work continued; focusing on learners' thinking processes, it is used by individual teachers and schools as well as school districts across the country. An international conference is held annually and is attended by hundreds. It is important to note that school districts throughout Texas, California, and Florida have adopted his Thinking Maps.

It is with Hyerle's definition that we begin exploring the research and uses of Thinking Maps. Novak and Gowin support Hyerle's work by suggesting, " Concept maps, used as tools for negotiating meaning, can make possible new integrative reconciliations that in turn lead to new and more powerful understanding" (1984, p. 104). Teachers need to make an effort, so that students can communicate their ideas; through the use of student's multiple intelligences, brain-based instruction, the writing process, experiential learning, and the use of advance organizers. Hyerle's Thinking

Maps is one method to show learners' thinking, to share that understanding with others.

Dewey felt students' knowledge grows from experiences, that meaning come directly from them, and that these must occur within a social environment. It is only when students engage in social situations that they are able to analyze and bring new understanding forward.

Piaget was interested in the way children think and learn. He believed learning was connected to psychological development and this is connected to discovery. Essentially, leaning during one stage could later be seen as untrue. Thinking Maps allow students to form cognitive beliefs, examine them, and change them accordingly. Vygotsky similarly believed, as other constructivist do, that children learn concepts through interactions with others. Materials, experiences, peers and teachers are essential to growth. Finally, Jerome Bruner influenced constructivism by suggesting discovery requires students to make decisions about what, how, and when learning can occur-they cannot be made to learn. The connection between constructivist theory and Thinking Maps is that students must first attend, form concepts, and alter them through experiences. Thinking Maps connects the experiences with further learning by showing thinking.

Humans are, by nature, curious; we generally like to investigate the unknown. From early cave dwellers to builders of multi-use devices such as Apple's iPhones, our need to communicate ideas is ever present. In order to share our ideas, whether between people in small groups in an elementary school or product developers half way across the world, we need systems for doing so. As we've already established, these systems for communicating have changed; however, what remains constant is the need to "show" our thinking, our understanding, and our concepts of the world. Novak and Gowen report:

> Concept Maps are intended to represent meaningful relationships between concepts in the form of prepositions. Prepositions are two or more concept labels linked by words in a semantic unit. Concept maps work to make clear to both students and teachers the small number of key ideas they must focus on for any specific learning task. A map can also provide a kind of visual road map showing some pathways we may take to connect meanings of concepts. (1984, p. 15)

The process of education parallels that of our technological advancement. The wheel sent us on our way, Guttenberg's press sent our words to others, and space shuttles sent us to new frontiers. With each new invention people have gone further--they have developed new concepts from old ones.

Elementary school children, nay, not just school children, but also any person who needs to exchange ideas, must have some type of system for doing so. And just as Guttenberg invented his press for the purpose of communicating ideas, we have invented various shortcuts for communicating. Morse Code, short hand, or satellites are attempts to get to an understanding of our ideas quickly. So it is with cognitive mapping.

By using cognitive maps, we can quickly show salient information without misinterpretation. If, in fact, there are misinterpretations, cognitive maps can serve to clarify them because all learners can see another's thoughts. Because we bring unique thinking to learning communities, new concepts can be formed from sharing our concepts with others. Learners, be they elementary students or adults, need some type of mapping system, to show their thinking, their way of constructing knowledge. Hyerle suggests there are eight fundamental thinking skills: defining; describing; comparing and contrasting; classifying; showing part-whole relationships; sequencing; showing cause and effect; and seeing analogies. Each of these has a corresponding map, which we will explore in the next section of this paper.

As with many education tools, David Hyerle found success using his "webbing techniques" to understand his thinking. When he began teaching at a middle school, he introduced them to his students. These initial steps were sometimes used with traditional outlining because he was familiar with such techniques. While teaching a "thinking skills" class, he developed maps linked to thinking; however, he continued questioning and eventually his questions provided their own answers.

Thinking Maps are based on constructivist theory. Constructivism is a belief that learning is based on previous knowledge; we store this information linguistically and non-linguistically. Thinking Maps allow students' to use organizers to express and share their cognitive ideas. Hyerle's eight maps represent the basic cognitive processes and are useful to learners as young as preschoolers and as old as this researcher and beyond. They are not hierarchical as thinking processes are neither set nor are they dependent on one another, and they can be used across all curriculum areas. The eight Thinking Maps' are consistent, flexible, developmental, integrative, and reflective.

Of special importance is the need for teachers, schools, and school systems to be cognizant of high stakes testing required of NCLB and the need to show yearly improvement. Research in the use of Thinking Maps in math conducted by Janie MacIntyre shows results that indicate their effectiveness. As North Carolina's Christa McAulife Fellow, she analyzed the effect Thinking Maps had on math scores. "I found that after an entire year of Thinking Maps implementation, exceptional and regular education students' end-of-grade tests results indicated developmental gains of up to four year's growth in one year's time (2004, p. 88).

In North Carolina, graduation is tied to student performance and proficiency as well as is student credit and promotion. As a special education teacher, she was aware that students with learning difficulties must meet the same standards as their counterparts. It was with this knowledge that MacIntyre came to know,

> The use of Thinking Maps resulted in cognitive gains. Prior to instruction, students performed basic computation, knew how to tell time to the nearest five minutes and could make change for $20. After instruction in the use of Thinking Maps, MacIntyre's students made, "…cognitive leaps and are successfully mastering concepts of solid and plane geometry, exponents and scientific notation…to mention only a few" (2004).

In her comparison study between students with and without a working knowledge of Thinking Maps, those who received direct instruction in their use either met the expected growth or exceeded it. Her study confirmed two findings: students that have a working knowledge of Thinking Maps they show developmental growth.

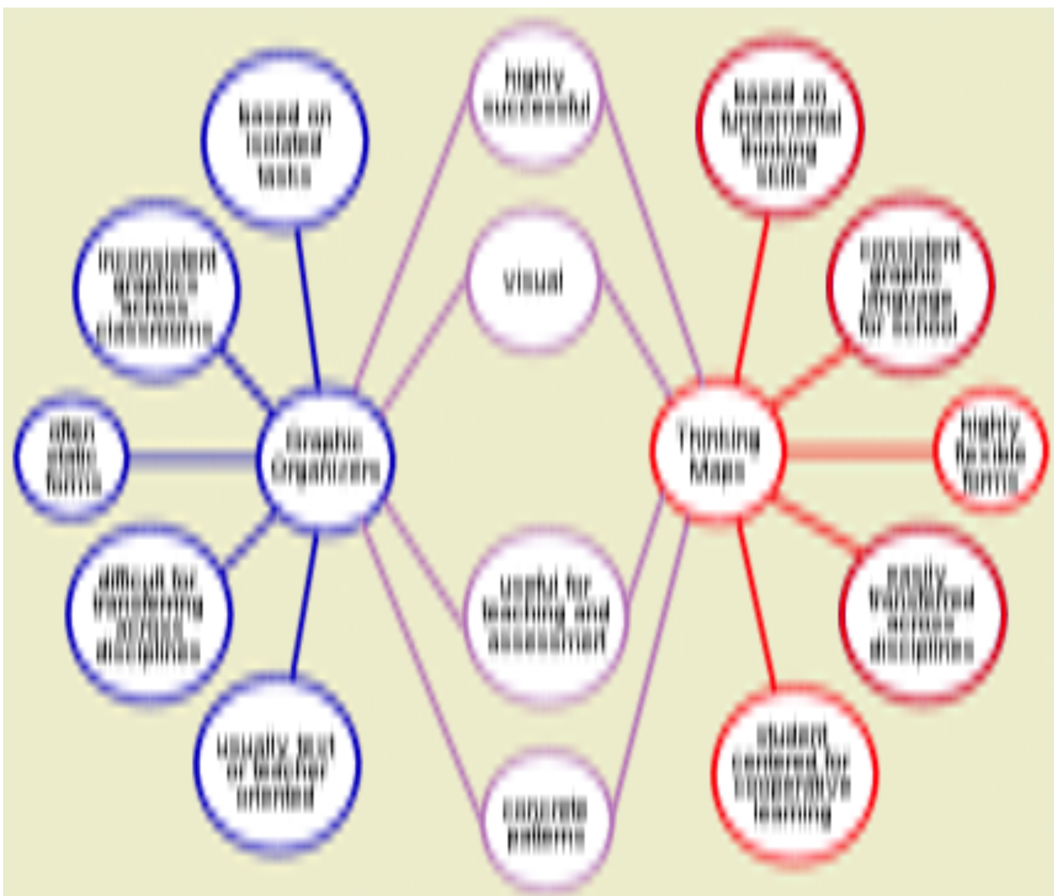
Teachers also report the ability of their students to apply higher-order thinking: analyzing relationships and organizational principles; synthesizing and combining elements into new patterns; and evaluating after explicit instruction in the use of Thinking Maps has been part of instruction across the curriculum. It is time for us to turn our attention to the individual maps and how they might be used.

The Thinking Maps website provides a comparison between graphic organizers and Thinking Maps as illustrated in Figure1. Because graphic organizers are task specific they are most often used by teachers as worksheets. They are often used to determine right/wrong answers. Graphic organizers can be successful; however, they cannot show cognitive growth because they are used once. Herein lies the important difference between graphic organizers and Thinking Maps. The use of a Double Map compares David Hyerle's Thinking Maps with the traditional graphic organizers such as a Venn diagram.

David Hyerle fully developed Thinking Maps when he used the Upton Model to write *Expand Your Thinking*. His understanding of the eight fundamental thinking skills brings a useful tool to expand learners' cognitive development. The usefulness of Thinking Maps across the curriculum makes them more valuable than graphic organizers. Because of the flexibility and correlation to the eight thinking processes they are important tools for handling large amounts of information that learners in the 21st must use daily.

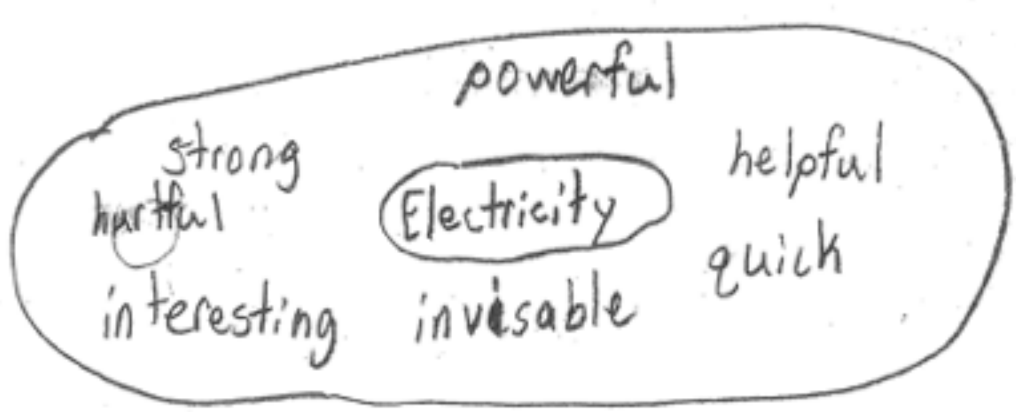
Figure 1: Hyerle Double Bubble Map:

Thinking Maps and Graphic Organizers Comparison



Circle Maps: Circle Maps (Figure 2) are used to define things in its context; brainstorming is often thought of when we first are introduced to this map. When we ask learners to define what a fruit is or tell us about themselves, we are generating information that we know before a lesson begins. Hyerle and Yeager suggest ten key words which frame a learner's knowledge: context; list; define; and tell everything you know. Additionally, brainstorm, identify, and relate prior knowledge, as well as explore the meaning, associate, and finally, generate. The key information about Circle Maps include: generating ideas without making any connections to other knowledge; they are often used before other maps. Any number of things can be generated to include within a Circle Map: defining self or a food; a poet such as Robert Frost or artist such as Winslow Homer. Learners can use them to self-assess by developing one prior to and post instruction. A teacher could use a Circle Map as a formative assessment. Using a Circle Map as a formative assessment in any area of the curriculum-science, language, history, geometry provides a teacher with information concerning future lessons.

Figure 2: Student Work: Circle Map

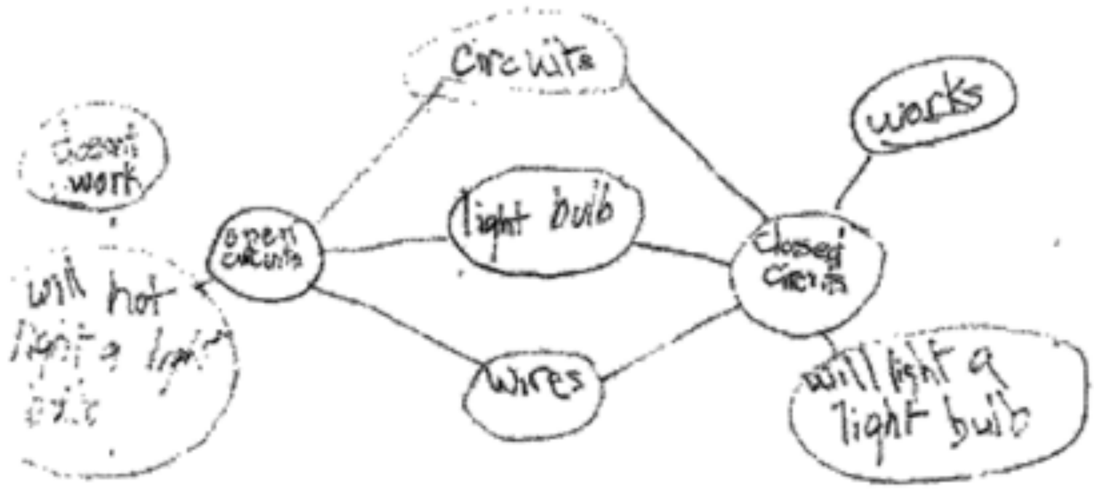


Bubble Maps: (Figure 3) If we describe a fruit, city, profession, or any other number of things in which we use adjectives, we are going beyond defining it; we are providing characteristics, attributes, qualities, or properties. When we show information about books, we might think about how they are made, what they are used for, what materials are needed to make them, what types they are, or how to use them. This information could be shown using a Bubble Map, which, in turn could be shared with classmates to extend out knowledge. The key words: describe; use vivid language; use your five senses; qualities; attributes; characteristics; and properties help to frame thinking.

Figure 3: Student Work: Bubble Map

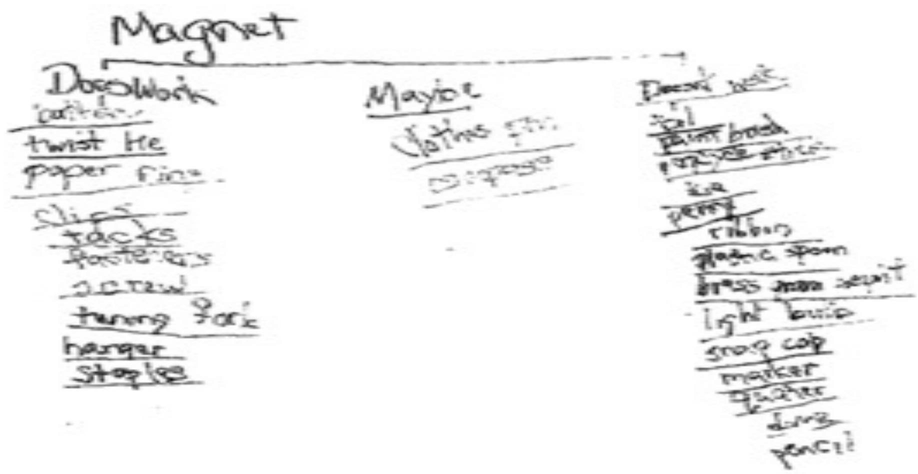
Double Bubble Maps: (Figure 4) Standard use of a Venn diagram limits rather than expands the users' thinking. The construction of a Double Bubble Map allows nearly endless possible comparisons to be made; whereas, a Venn diagram's construction implies there are greater differences than similarities between two things. Again, Thinking Maps expand a learner's thinking because they are not teacher generated, lesson specific worksheets, but rather a way to show thinking in limitless ways. Double Bubble Maps are but one map that learners and teachers have to assess knowledge rather than statically grade. Hyerle and Yeager suggest the key words for framing a Double Bubble Map include: compare, contrast; similarities; differences; distinguish between; and differentiate.

Figure 4: Student Work: Double-Bubble Map



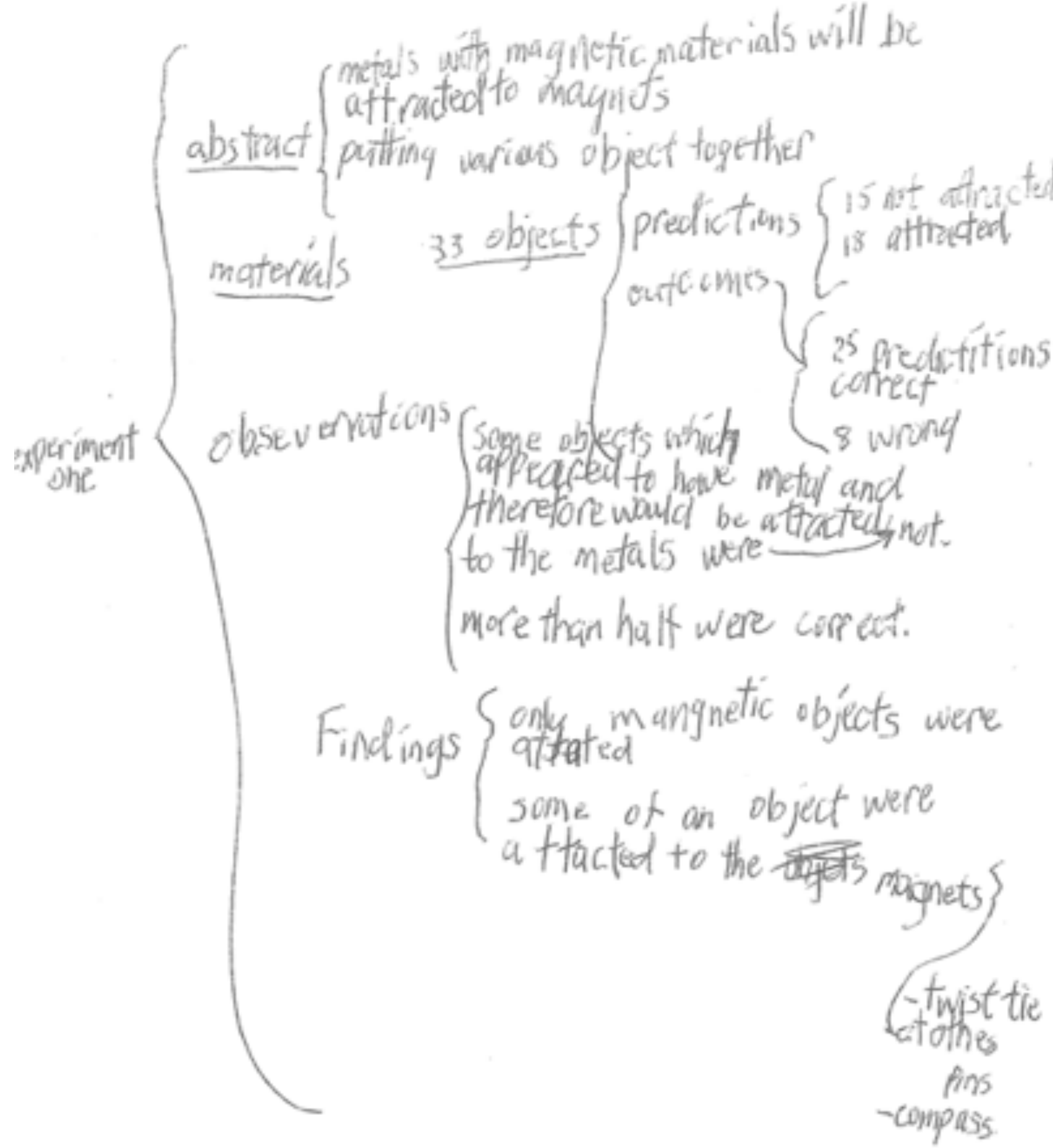
Tree Maps: (Figure 5) Providing details for classifying and/or identifying a main idea is what Tree Maps are designed to support. Within the map, main ideas are supported by details, i.e. categorizing plant and animal taxonomies, providing elements of a system, or elements of a branch of science. Subcategories can be added as needed and can be designed either inductively or deductively. Hyerle and Yeager offer the following as key words: classify; sort; group; categorize; identify the main idea and supporting ideas; give sufficient and related details; and the kinds of taxonomies.

Figure 5: Student Work: Tree Map



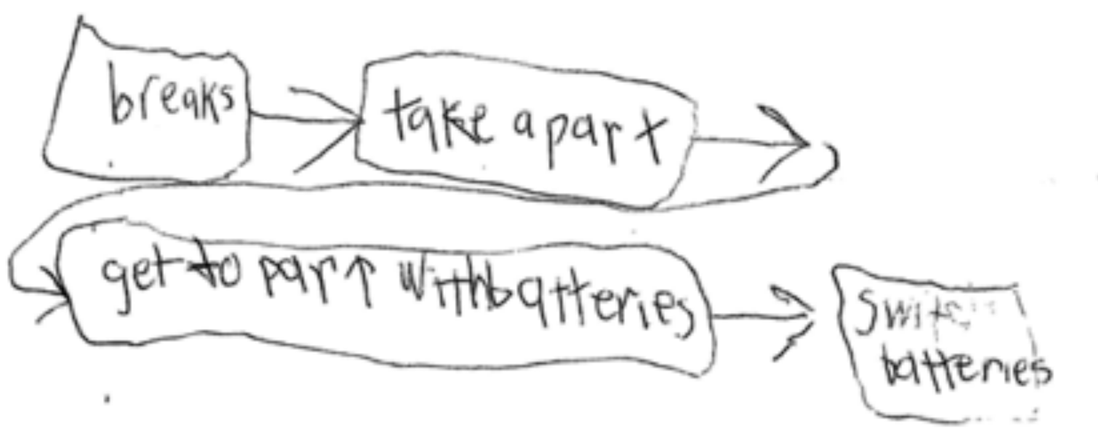
Brace Maps: (Figure 6) If a learner needs to show the relationship between whole to part, a Brace Map is useful. As with all of Hyerle's maps, the Brace Map is flexible and can be used in a number of ways. The key words show the construction relationship between the whole and its subsequent parts: parts of; show the structure of; take apart; identify the structure; physical components; or anatomy. Its use is with concrete objects so that all the subcategories equal the elements. For instance, a car is made whole when systems are joined, without them they fail to be an entire car (e.g.. car=chassis, electronics, safety equipment, steering mechanisms, etc.)

Figure 6: Student Work: Brace Map



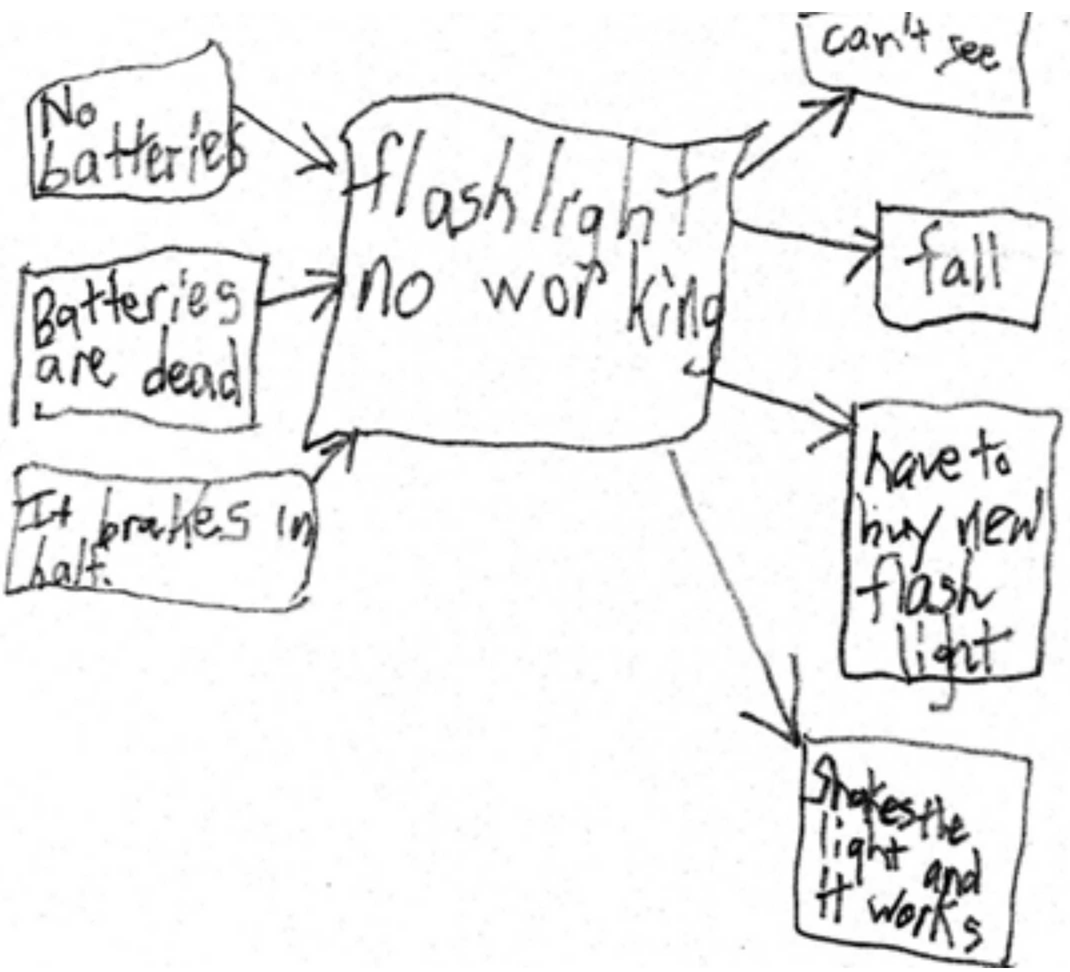
Flow Maps: (Figure 7) Classically, historical events are shown through time lines, however limiting they are, whereas the Flow Map can be used in all curriculum areas. Once learners become fluent in its construction, they can be used to show daily events, in unit development or in seeing the step-by-step relationship to solve a problem. Again, the key words lead us to understanding the many uses Flow Maps can be used for: sequence; put in order; retell or recount; cycles; patterns; show the process; and solve multi-step problems. Flow maps differ from time lines in that they do not have to be drawn in a linear fashion. The only requirement is that each box must be connected to the next, with an arrow showing the next step in its progression.

Figure 7: Student Work: Flow Map



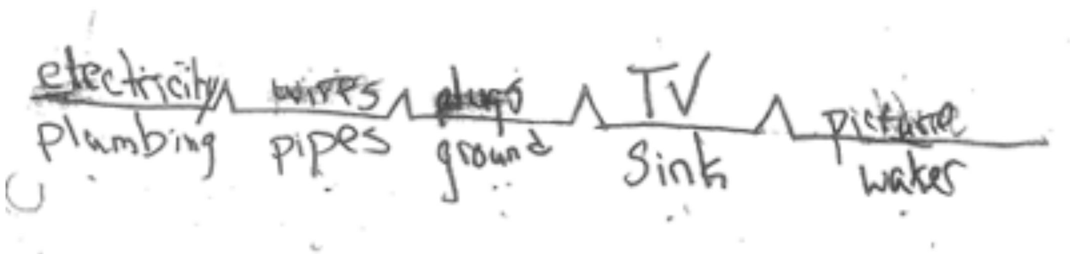
Multi-Flow Maps: (Figure 8) At the center of each Flow Map is an event preceded by the causes and followed by the effect. The causes and effects are connected with arrows from left to right. The causes and events do not have to be the same in number. Several key words used to frame these maps include: discuss the consequences, predict, describe the change, and identify.

Figure 8: Student Work: Multi-Flow Map



Bridge Maps: (Figure 9) Identifying similarities between relationships and creating analogies is the focus of a Bridge Map. Bridge Maps are not restricted to one set of analogies. The relationships between any number of things can continue beyond by focusing on a relating factor. A house is related to shelter as a car is related to transportation as a computer is related information processing; in this case, each pair shows the relationship between a man-made item and its primary purpose. A Bridge Map can be used to identify a relationship, show rules, symbolic relationships, metaphors, allegories, analogies, and similes. These maps can successfully be used with preschoolers, college students, and adult learners. Finally, the strength of Hyerle's maps is that they can be used to show thinking from four years of age to forty and fifty and still further. Thinking Maps is a useful tool to bridge the generational, gender, and cultural gaps as we level the playing field.

Figure 9: Student Work: Bridge Map



In this section I explained the importance of showing thinking from the earliest times to present attempts to communicate ideas. The need to convey large amounts of information over many time zones requires a system understandable to many people. I explained the development of David Hyerle's Thinking Maps as well as their structure, and use for student learning. I explained how the maps can be used and how they correlate with the eight fundamental thinking skills. Students use the maps to show defining, describe, compare and contrast, classify, show whole-part relationships, sequence, explain cause and effect relationships, and to show analogies.

Inquiry Science

> Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity. It means that a person can ask, find and determine answer to questions derived to every day questions.
>
> National Science Education Standards (2003, p.22)

Whatever happened to curiosity? So often we get caught up in competing in the global market that we forget the joy that can be found in learning, the joy that is science. Yet reality steps in on a daily basis for teachers and students alike as we prepare for yet another standardized test. Standardized-tests assess information that has little to do with preparing to learn, reason, think creatively, make decisions, or solve problems and more to do with showing AYP. While realities have a way of creeping into classrooms, the cost is detrimental to students' wonder of the natural world. There is an alternative: using formative assessments to inform us of student understanding of science keeps one foot in reality and the other in the wonder of the natural world.

To accomplish the sometimes difficult tasks that reality demands, teachers can use children's natural curiosity to meet those demands. Inquiry seems easy enough and science is manageable, so the question becomes what is it and how is it constructed. First, what is it? Inquiry science is a pedagogical practice beginning with questions. Using hypothesis methods, students write abstracts, conduct experiences, collect data, and finally, offer research findings, much like professional scientists (Appendix, Figures C-1, 2, 3).

Secondly, how do I do it? This is a bit trickier, but manageable to every day teachers at every grade and level of instruction; not just science teachers and not just the experts. Inquiry science quite simply begins with questions. Does the size of a battery change its ability to attract metallic objects? It usually ends with a deeper understanding of the science concepts By experimenting, students construct meaning for themselves as they engage in written and oral discourse. Very rich discourse that includes formulation of ideas, conducting experiments, collecting data, and writing research findings. Inquiry science is "best practice."

Zemelman, Daniels, and Hyde (1993) suggest that many national reports, which were drafted by scientists and science educators, support the use of inquiry science techniques. "They call for making science learning experiential instead of lecture-oriented, cognitive and constructivist rather than focused only on facts and formulas, social and collaborative rather than isolating students from another" (1993, p.94). Because inquiry science is problem solving it requires teachers and students to act differently. Teachers must facilitate learning by asking questions, constantly assessing student knowledge, stepping back so students can construct meaning for themselves, and finally, guiding discussions and reflections on the results. They must recognize that facts are not the goal of inquiry science. Students must also change by being active as they solve authentic problems. They must construct meaning for themselves and engage in the oral and written discourse. This discourse requires students to become active in their learning, seekers rather than mere vessels of knowledge. To do so they must be willing, nay, required, to use equipment rather than texts. Inquiry science is based on incrementally building on prior knowledge toward a deeper understanding of concepts.

Regardless of their age or ability level students naturally come to school filled with awe and with much knowledge; yet as the school years roll by, much of this natural desire is lost. Instruction at the elementary level is too often textbook driven while inquiry science is based on gathering empirical evidence that builds on a students' previous knowledge. Elementary students can learn and use inquiry science techniques effectively. The only difference is that inquiry science at an elementary level does not require expertise, only curiosity and an ability to use that curiosity to collect data. Inquiry science is one way to renew that natural desire, as it recognizes students' ability to use information and then figure and explain concepts in active ways.

While there is little difference between elementary scientists and science researchers, there are differences between inquiry science and textbook-driven instruction practices. The effectiveness of inquiry science techniques is well documented. U.S. textbooks fail to guide teachers in how to build on students' understanding, to contextualize science in meaningful problems, or to treat complex ideas other than superficially (Kesidou and Roseman, 2002; Schmidt, Houang, and Cogan, 2007).

Although there is a movement to change this, research corroborates that the elementary level instruction continues to rely on lecture and memorization of facts. As part of NCLB's requirements, teachers work to cover the materials, leaving little time to examine concepts in depth. Students begin to work toward getting the right answer, which further hinders our ability to compete in the global market.

Science inquiry is powerful in and of itself; it integrates curriculum in effective ways and it incorporates many of Marzano's Best Practices. When students learn-by-doing science, they respond to cues, questions and advance organizers. As they gather and describe data, they are testing their hypotheses and summarizing and taking notes. Finally, inquiry science uses cooperative leaning, which teaches the positive interdependence that researchers and the business community desire. Science inquiry, with one foot in reality, and the other in the wonder of the natural world, is a powerful combination of instructional practices. It also meets the requirements of NCLB, for it ensures the use of research-based methods to teach science and measure results. Most importantly, it allows learners to use their sense of wonder.

CHAPTER THREE

Methods

The combination of methodologies employed in this study is unique. Research of both Thinking Maps and inquiry science has been conducted but the combination of both as a single study has not been done. An opportunity to study the effectiveness of the combined practices offers the educational community additional research for increasing student achievement. This research addresses several questions: How is the use of inquiry science an effective instructional practice? How is the use of Thinking Maps an effective instructional practice? As I analyzised the data, a third question emerged: What is the difference between differing ability students in the use of Thinking Maps?

This researcher chose a qualitative method for several reasons; it includes unique limited information which do not provide statistical data. The combination of Thinking Maps and inquriy science as a research topic developed over time. Finally, the relationship between the researcher and students is symbiotic. Bogdan and Biklen offer five characteristics of qualitive reseach: naturalistic; descriptive; concerns with process; inductive; and meaning (1998, p. 4).

As previously stated, I teach with a constructivist philisophy. This pedagogical approach requires that I be involved. I must ask questions, observe student learning and adjust my teaching to either reinforce student learning or seek different methods to ensure academic achievement.

Throughout this study I was involved in every aspect, beginning with lesson designs. Using a representative sample provided sufficient information about science concepts, language and Thinking Maps use. I chose to analyze a small representative sample because of my desire to focus on the science and language skills. This grounded study was not designed to analyze data qualitatively.

The first question is grounded in constructivist theory, since inquiry science provides students opportunities to manipulate materials as they build new knowledge. Additionally, through this visual system of showing thinking, students are able to solidify their knowledge. The data were analyzed and patterns were discovered; students receiving instruction in the resource room used Thinking Maps more frequently and more effectively. Seeking to answer these questions using a representative sample of ten and eleven-year-old students' data was collected. The inquiry science lessons were based on adopted science curriculum. These lessons dealt with the science concept of energy, and particularly, electricity. Students were required to write an abstract, collect data, make observations, keep notes, and state their reacher findings. Finally, students were then asked to state what they knew about electricity through the use of Thinking Maps.

Approach

In my effort to come to an understanding of how children use Thinking Maps and inquiry science I determined that the most effective research for this study would be to use grounded theory methods. Kathy Charmaz suggests, “Grounded theory methods consist of a set of inductive stategies for analyzing data” (2003, p. 311). My involvement in the learning process suggested conducting a focused analysis was warrented. Charmaz reports, “The characteristics of grounded theory methods include: simultaneous involvement in data collection, creation of analytic codes developed from data, not from preconceived hyphotheses, and theoretical sampling” (2003, p. 336).

Using these methods I selected the work of six students: two received services in the Gifted and Talented (G/T) program; two were randomly selected; and two received reading and writing instruction in the school’s special education’s resource room. The participants from the G/T and Special Education programs were selected based on objective measurements performed by personnel from each program. The final two were selected based on several factors: non-participation in either the Gifted and Talented (G/T) or Resource Room (R.R.) programs; their state testing scores; and my formative science assessments (previous unit). The G/T and resource room programs are federally mandated and provide services to students with special needs that require individual, differential instruction.

An analysis of student notebooks, Thinking Maps use, language skills, science unit evaluations, Stanford 10 achievement test scores, and state achievement scores was completed. Choosing these five areas provided information to answer the original questions: How is the use of Thinking Maps an effective instructional practice? How the use of science inquiry an effective instructional practice?

Student journals and classroom practices are are not unique to this study. Inquiry science techniques are not this researcher's original design. In an effort to increase student achievement the assistant superintendent of schools joined a state science consortionum. Teachers had many opportunities to learn these techniques through local, regional, and state collaboration. The journal design added research abstracts and findings. Abstracts contained statements of belief, research methods, and possible roadblocks. Student research findings reflected their thinking before the experiments began. They were required to refer to their abstracts in their research findings section.

Student inquiry science work began with a probe (question) followed by the student generated list of words they felt would be used as part of the experiements. All student responses were added to the science word wall. Students formulated abstracts (see Appendix, C-1, 2, 3); collaborative research members determined that all parts of the abstract were present; for the purpose of this study the quality was not discussed by students. Research data was required, but the form was up to individuals. Group memebers influenced the construction of these charts. Research continued over several weeks. Before materials were stored, students were afforded an opportunity to make statements to their peers. These statements were not discussed until the research was complete. After students wrote their own findings a whole class scientist circle was formed in which the research is discussed. Prior to collecting artifacts for this research, students participated in lessons whose goal was to learn these techniques. Student scientists were required to speak one at a time; no member could speak again until all members had had an opportunity to participate, and student statements must have been based on their data ("If it isn't written, you cannot speak it.") No other teacher-facilitated lessons were offered. Initial lessons included a statment that my role was to observe, and by the time my research began, I was able to do so.

After students were selected, the science notebooks, questionnaires, and unit evaluations were coded. Before the coding began, rubrics similar to the state assessments with numerical values were developed. Language rubrics addressed the number of words, sentences, and type of sentences. Coding of the science notebooks included: pre-unit statements of what students knew about electricity for the type of response (Thinking Map use), number of concepts, number of words, and the number of science words. The coding of the abstracts and research findings included the presence of the three required parts as well as the number of words, number of science words, and the number of observations. Coding evaluated the presence and understanding of science concepts in the notebooks, questionnaires, and end of unit assessments.

CHAPTER FOUR

Introduction

Data Analysis

This study has sought to examine two instructional practices. This researcher believes they are, in their own right, powerful tools to increase achievement; when combined, they are even more effective. The research questions, which guided this study are:

Questions:

How is the use of Thinking Maps an effective instructional practice?

- Do students use Thinking Maps to show their thinking?
- Do students use Thinking Maps for the purpose for which they were designed?
- What is the difference between high and low ability students in the use of Thinking Maps?

Question Two

How is the use of science inquiry an effective instructional practice?

- Do students us science inquiry methods correctly?
- How do students show their understanding of science concepts?

The researcher's role involved teaching the use of Thinking Maps before the study began, designing science lessons, and teaching inquiry science techniques, as well as designing evaluations of student notebooks, Thinking Maps, and science questionnaires.

Ethical issues involving students were considered. To ensure the safety of students, approval for this study from an Institutional Review Board was sought (Appendix D1). As part of this process, a request for approval from the school superintendent was granted. Additionally, a letter to the students' primary care providers informing them of the study's intention, was issued and a consent form was provided to the guardian. Guardians and students agreed to participate in this study and could choose to end their participation at any time. It was important for the information to be restricted to me, and this was stated in the consent form. Guardians could view and receive copies of their child's data; however, they were not allowed to do so for any other student.

Preliminary findings included: differences in student use of Thinking Maps and their understanding in science concepts. Student work revealed unanticipated data; for instance students receiving instruction in reading and writing skills in the school's resource room used Thinking Maps more effectively. While there was a difference among the levels of student language skills, there was no evidence that students' concepts of electricity were different. While there was a 82.5 percentile difference between the high and low ability students on the Stanford 10s, (Table 11) the data revealed lower ability students were at least as capable, if not more so, of using the correct type of Thinking Maps. (Table 12)

Stanford Achievement Tests (SAT10) assess student knowledge from kindergarten through high school. The test is divided into subtests covering reading comprehension, mathematical problem solving, sciences. Each test uses a combination of multiple choice questions, written and extended time responses.

Table 2 Standford 10 Percentile Range

	High	Low	Range
Reading	89.8	7.2	82.6
Math	98.9	5.2	93.7
Language	93.8	8.2	85.6
Spelling	93.9	14.3	79.5
Science	94.8	3.1	91.7
Listening Skills	99.9	12.3	87.6
Thinking skills	95.8	11.3	84.5

Research Question One

Thinking Maps

Research Question One began with two sub-questions; however, as the analysis of the artifacts was completed, a third question emerged. The data revealed that the learning disabled students used Thinking Maps correctly 100% of the time.

Analyzing student use of Thinking Maps was conducted using three artifacts: notebooks, a Thinking Maps questionnaire, and a science unit evaluation. Following each experiment students showed their understanding by using a Thinking Map. The questionnaire asked students to define Thinking Maps, state the purpose and how they could be used, and finally, asked how they could be used in the future. Finally, a science unit evaluation containing 8 questions, which students completed at the end of the unit The science unit evaluation was designed for several purposes: to ascertain students' knowledge of electrical energy concepts and their understanding and use of

Thinking Maps.

Thinking Maps

Student Notebooks

It is clear that students use Thinking Maps in their notebooks; however, there is a difference in frequency and the correct usage as shown in Table 12. The minimum of 75% difference is an indication that the students receiving reading instruction in the resource room used Thinking Maps as one way to show their knowledge. The concepts included statements about electricity's properties, source, production, and its use. Four of the six students used Thinking Maps to explain their knowledge; the remaining 2 used phrases, sentences, and bullets.

Table 3: Thinking Maps Frequency and Correct Use

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Number of TM	4	3	2	3	3	4
Correct Usage	25%	0	25%	25%	100%	100%

Student1 wrote about electrical energy as something that could shock you; static electricity; produced at power plants, which use water, wind, coal, and turbines;

standard process for producing electrical energy: burns coal, makes heat, heats water, makes steam, spinning the turbine, and finally, spinning the generator. While she used 4 maps she only used them correctly 25% of the time. Student 2 expressed his thinking using short phrases: “Is a source of energy;” “Is created by friction;” “Is conducted by neither the ground nor rubber; we use it for all electricity; it can be blue of yellow (especially in the form of lightning).” Student 2 did not use the maps correctly, using only Flow Maps throughout the notebook. Student 3’s notebook contained single words: volts, attracted, and made by wind farms. Only 2 maps were used and only one of the 4 was used correctly. Student 4 listed shocks you, powers stuff, in outlets, is colorless, and you can be electrocuted. Student 5 used 3 maps throughout the notebook with 100% of the maps correctly used. Finally, student 6 used a Brace Map to show his knowledge of electricity: inputs, extension cords; when: everyday; how: for light. He used more maps than any other student and used them 100% correctly.

Thinking Maps Use on the Science Unit Evaluation

The percentage of the correct use of Thinking Maps, which ranged from a low of 38 to a high of 87. Students 1 and 2 had the two lowest scores, 38 and 50 % respectively.

Table 14 shows student word use, the inclusion of science words, and the number of science concepts. the pre-instruction query and unit evaluation's first question was the same: What do you know about electricity? Comparing students' pre-unit and the unit evaluation, the data revealed changes in the number of science words and concepts students used. In each instance, students were asked to tell what they knew about electricity. A gain in the number of words used to explain their knowledge increased for the low ability students; however, they decreased for both the high and average ability students. Student 1 used 8 more words on her unit evaluation than on her pre-unit query; otherwise, students 2, 3, and 4 used 5 words less. Students 5 and 6 used a greater number of words on the unit evaluation than on the pre-unit query (+12 and +9). Student 3 used 135 words less on this unit evaluation. His pre-unit response included a 120-word narrative recalling his uncle's work to establish electrical service to rural areas. While the numbers may seem insignificant they, in fact, show a gain in the number of concepts, which increased for both students receiving reading and writing instruction in the resource room. The high and average ability students showed either no gain or a loss of science concepts expressed using their Thinking Maps.

Table 4: Unit Evaluation, Number of Words, Science Word, and Concepts Comparison

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Pre-unit query number of words	89	35	53	44	37	6
Unit evaluation number of words	82	16	18	20	49	15
Gain/Loss	-7	-19	-135	-24	+12	+9
Pre-unit number of science words	6	3	4	5	2	1
Unit evaluation number of science words	14	3	2	3	4	7
Gain/Loss	+8	0	-2	-2	+2	+6
Pre-unit number of electrical concepts	3	2	4	2	2	1
Unit evaluation number of electrical concepts	3	1	2	2	3	3
Gain/Loss	0	-1	-2	0	+1	+2

Thinking Maps use in the Science Experiments

Affirmation of students' use of Thinking Maps as shown in Tables 5, 6, 7 was evident throughout their work; however, it was more important to analyze how they used them. Were they effective in showing their knowledge clearly? The type of map students used during the unit shows the use of four different maps; eight were Bubble Maps; six Brace Maps; three flow maps; and two circle maps were used Student 6 used both a Bubble and Circle Map for the same experiment. Two students used the same map for all three experiments. Table 8 shows the total number of words used for the 3 experiments totaled 712. The six Bubble maps used 40% of the words (282); the 3 Flow Maps used merely 10% of the words (73). The 327 words used on the 8 Brace Maps represented the highest number of words (46%) while the Circle Maps used the least number of words; 30, which was only 4% of the total.

Table 5: Experiment 1

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Type	Bubble	Flow	Brace	Bubble	Bubble	Bubble; Circle
Number of Words	96	31	72	39	76	36; 17

Table 6: Experiment 2

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Type	Brace	Flow	Brace	Brace	Brace	Brace
Number of Words	30	16	67	37	22	20

Table 7: Experiment 3

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Type	Bubble	Flow	Bubble	Brace	Brace	Circle
Number of Words	35	26	0	18	41	13

Table 8: Science Experiments Word Count

	Bubble	Flow	Brace	Circle
Number of Times Used	5	3	8	2
Number of Words	282	73	327	30
Percentage	40	10	46	4
Mean	47	24	41	15

Students completed each of the experiments using different maps not all of which were appropriate to the task. While the maps show thinking, each is used for a specific thought process. First, we will briefly examine the use of each map.

- Circle: using single words to define in context.
- Bubble: begins with a topic or concept and uses adjectives, which gives qualities, attributes, and characteristics.
- Double Bubble: used to compare and contract things or ideas.
- Tree: classifies or sorts into sub-categories to show membership or a main idea.
- Brace: shows whole to part relationships.
- Flow: sequences events by order and can have sub-stages throughout.
- Multi-Flow: constructs cause and effect relationships
- Bridge Map: helps to create analogies.

Student 1

Experiment 1 asked: What is attracted to metal? Her experiment contained the required abstract, data, observations, and research findings. The Bubble Map began with a clearly stated context to frame the topic and provide for its purpose. She provided information about objects being magnetic and non-magnetic; the correctness of her predictions; thoughts about coins; and the tuning fork. Her prediction stated, "More of my predictions were correct than incorrect." She attached redundant statements, "More than 50% of my predictions were correct." "Eight of my predictions were incorrect." Some statements would have been more effective if connected as sub-categories. "Does the size of the magnet affect the number of paper clips it can pick up?" She used experiment as the Brace Map's subject. Experiment 3 showed 2 separate Bubble Maps with unrelated statements, 'Many people walking by probably thought we were crazy. These maps are used to show a learner's thinking, and student 1 did not show the relationships between like items; i.e., predictions with predictions or magnetic and non-magnetic categories.

Student 2

Using Flow Maps after experiment 1 and 2, student 2 sequenced events, which is the correct usage for this map; however, he showed only cursory thinking about the experiments. Each time the sequencing began with writing a probe followed by writing an abstract. In experiment 1 he wrote: "Predicted if an object would be pulled to a magnet by magnetic pull"; in experiment 2: "test magnets". For experiment 3, a combination of maps was used; beginning with a Bridge Map and continuing his previous use of Flow Maps. The Bridge Map did show some analogies, but failed to be completed.

Student 3

In the first two experiments he employed a Brace Map; a Bubble Map was used to show his thinking in experiment 3. The first experiment he used a Brace Map and showed the steps involved while conducting it; the information regarding the steps was properly constructed, showing whole to part relationships. His thinking about the experiment rather than the steps would have given us information that was not unique to him. After conducting experiment 2, he again used a Brace map with similar construction to experiment 1. Experiment 3 was missing a research findings statement; however, we learn about his thinking through his use of a Bubble Map. His topic was limited to magnets; the map is properly designed and accurately used and was configured with the four cardinal directions.

Student 4

Two Brace Maps were used for experiments 2 and 3; a mean of 31, a single word more than the group mean. In experiment 1 he used 6 bubbles with 6 additional connected to 3 of the primary information bubbles. He addressed issues of magnetism, trials, group members, and the style of the experiment. A total of 35 observations were made for the 3 experiments. In each of the Thinking Maps he provided information about his colleagues by name and in two, he provided additional information about the group as a whole.

Student 5

Information for experiments 1, 2, and 3 showed his thinking by using a Bubble map. His mean word score 46 was 10 points higher than the group mean. He was 1 of 2 students using a Bubble Map followed by Brace Maps. Seven science words were used for the 3 experiments: magnetic, observations, experiments, research, mean, batteries and wires. The 3 experiments he used did not show any electrical concepts directly. Some information lacked labels and there was repetition in each Brace Map. The Brace maps showed accurate information corresponding to his data. For experiment 1, he gave information about group members, number of incorrect predictions, and stated that the, “Experiment was a little different too,” as well as, “We kept are [sic] research in a different way.” There was no connection between the Thinking Map and his findings. Experiment 2 asked the question: Does the size of a magnet affect the number of paper clips it picks up? His map showed the means for each magnet and the size of a paper clip. The 3 categories were supported by corresponding information from the data chart. In the final experiment he added a category of the problems his group faced.

Student 6

Bubble and Circle Maps were used to show his thinking. Both maps used magnets as its topic, but no other words were the same. He showed information about magnetized objects; 33 were not magnetized. The Bubble Map expressed 6 observations; all were mathematical statements. His first Bridge Map showed analogies using the type of magnet and the number of paper clips each held. While this is simple information the map was completed correctly. His final map used 4 science words, which were spelled correctly. The map contained information using electrical terms including magnet, protons, battery, notes, zapping, volts, ouch, nail, shock, coper [sic], and sizes. Three words expressed information about physical consequences, i e. shocked. He also used 3 science words: battery, nail, and copper.

Thinking Maps Questionnaire

Continued evidence of student use of Thinking Maps can be seen on the Thinking Maps Questionnaire. Table 19 shows that one hundred percent of the students defined and gave a purpose for Thinking Maps while only 50% gave examples. Three students placed above the mean of 19 words to define and to give a purpose for Thinking Maps. Two students used 23% of the 113 total words used to answer the first question. Students 2, 5, and 6 each used 14% fewer words than their counterparts.

The 2nd question had 50% fewer students explaining how they would use Thinking Maps; this was true of their use of examples as well. (See Table 20) Four students were above the mean of 15 words used to explain how they would use the maps; student 6 was one of these four. Using 1% fewer words than the highest ability student he outperformed 3 other students; one by 13%.

As seen on Table 21 one hundred percent of the students were able to explain how they might use the Thinking Maps in the future. All students except one of the two G/T students gave examples. Student 6 used eleven fewer words than student 1, but he used more words than either student 2 and 3. The other lower ability student used only seven fewer words in his explanation of how he would use the maps in the future. When Stanford complete battery scores and the number of words students used were compared, student 1 outperformed student 6 by 82.5 percentage points. Yet, she used only one more word on question 2. This dichotomy continued; student 2 used fewer words on all three questions. This pattern continued with student 5 as well. Both students 1 and 2 outperformed students 5 and 6 by over 83 percentage points in the area of science. In the area of thinking skills, students 1 and 2 again outperformed students 5 and 6, by 78 points. The correlation between test scores and word usage and concept about electricity did not hold true.

Table: 9: Thinking Maps Questionnaire: Question 1

1. What are Thinking Maps? What is the purpose for using them?

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Defines maps	Yes	Yes	Yes	Yes	Yes	Yes
Gives purpose	Yes	Yes	Yes	Yes	Yes	Yes
Gives example	No	No	Yes	No	No	Yes
Number of Words	26	11	22	24	14	16

Percentage of Words	23	10	21	23	12	14

Table: 10: Thinking Maps Questionnaire: Question 2

2. How do you use Thinking Maps?

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Explanation	Yes	No	No	Yes	Yes	Yes
Gives Example	No	No	Yes	No	Yes	Yes
Number of Words	19	7	13	18	12	18
Percentage of Words	22	8	15	21	14	21

Table: 11: Thinking Maps Questionnaire: Question 3

3. How might you use these in the future?

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Explanation	Yes	Yes	Yes	Yes	Yes	Yes
Gives Example	Yes	No	Yes	Yes	Yes	Yes
Number of Words	32	19	14	21	26	21
Percentage of Words	24	14	11	16	20	16

Science Unit Evaluation

Table 12: Student Comparison: Question 1

1. What do you know about electricity?

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Type of Thinking Map	Bubble	Bubble	Bubble	Bubble	Bubble	Bubble
Number of words	22	15	17	17	44	15
Number of Science words	17	3	3	2	4	6
Percentage of Science Words	77	20	18	9	9	40

Table 12 shows that all groups of students used a Bubble Map appropriate to the question with a mean score for the number of words each student used on their map of 22. Students 1 and 5 were at or above this mean; student 5 had the highest number of words, even surpassing student 1. The highest number of science words were used by student 1; 15 words higher than the minimum of 2 words. In the area of word usage, students 5 and 6 outperformed students 2, 3, and 4.

Table 13: Student Comparison: Question 2

2. Define electricity

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Type of Thinking Map	Circle	Circle	Circle	Circle	Circle	Circle
Number of words	6	7	5	8	8	5
Number of Science words	1	4	3	1	2	3
Percentage of Science Words	17	57	60	13	25	60

When defining electricity all of the students used a circle map, which correlated to the unit evaluation's question (see Table 13) Circle Maps are designed to show a learner's thinking as they define a topic. Lower ability students outperformed 2 others, including student 1. Student 6 used the highest percentage of science words, more than either student 1 or 2.

Table 14: Student Comparison: Question 3

3. Compare open and closed circuits.

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Type of Thinking Map	Double-Bubble	Double-Bubble	Double-Bubble	Double-Bubble	Double-Bubble	Double-Bubble
Number of words	8	14	28	24	25	21
Number of Science words	1	0	1	2	4	3
Percentage of Science Words	13	0	4	8	8	14

Table 14 shows that students 5 and 6 followed a pattern established in question 2; they outperformed their higher ability classmates by as much as 14 percentage points. Neither high ability students used as many words as any of their counterparts; they used fewer words than the mean by 12 and 6 respectively. There seems to be no correlation between the map and the number of words used; the comparison can only be made between the students' understanding of science concepts.

Table 15: Student Comparison: Question 4

4. What materials are attracted to magnets? Why?

	Student 1	Student 2	Student 3	Student 4	Student 5	Student
Type of Thinking Map	Circle	Multi-Flow Map	Circle	Tree	Tree	Tree
Number of words	9	14	11	54	32	12
Number of Science words	1	2	3	2	2	2
Percentage of Science Words	11	14	27	4	6	17

Students knew what materials were attracted to magnets which is shown in Table 15. Students 4 and 5 exceeded the group mean by 32 and 10 words, respectively. While student 6 used 10 words less than the group mean, he used more words than one of the G/T students. Student 3 outperformed student 1 by using two more science words; the 3 students using the Tree Map used a mean of 33 words.

Table 16: Student Comparison: Question 5

5. What are the parts of an electrical device?

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Type of Thinking Map	Not Used	Circle	Bubble	Tree	Brace	Brace
Number of words	10	9	8	11	16	8
Number of Science words	0	0	0	2	2	2
Percentage of Science Words	0	0	0	18	13	25

Table 16 shows that four different Thinking Maps were used to answer question 5, which was designed for students to use a Brace Map. Two students used the appropriate map; both were part of the lowest ability group. The number of word's means of 10 were matched or surpassed by three students: 1, 5, and 6. Only students 4, 5, and 6 used science words. The two students when used either a Circle Map or not any map at all did not use any science words to show the parts of an electrical device.

Table 17: Student Comparison: Question 6

6. If a flashlight is broken, what might you do to fix it?

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Type of Thinking Map	Bubble	Flow	-	Brace	Multi-Flow	Multi-Flow Map
Number of words	10	11	27	29	25	15
Number of Science words	0	0	0	0	1	1
Percentage of Science Words	0	0	0	0	4	6

Question 6 shows the mean number of words (20) was matched by or surpassed by two students. Students 5 and 6 used one science word each while no other student did so. Student 2 used a Flow Map, which was the correct map for this question. One student did not use a map but wrote information without the use of standard conventions. He did provide a possible way to fix a flashlight; however, he used no student-generated science words. Sixty-six percent of the students did not use any science words at all.

Table 18: Student Comparison: Question 7

7. What might cause a flashlight to fail?

	Student1	Student 2	Student 3	Student 4	Student 5	Student 6
Type of Thinking Map	-	-	Multi-Flow Map	-	Multi-Flow Map	Multi-Flow Map
Number of words	10	7	7	5	22	16
Number of Science words	0	0	0	0	1	1
Percentage of Science Words	0	0	0	0	5	6

The type of map and the number of words used in question 7 are shown in Table 18. Students 1, 2, and 4 did not use a Thinking Map; they also used no science words in their responses. Question 5 was designed for the use of a Multi-Flow map; 50% of the students used this map. Both student 5 and 6 used more words than their counterparts; they used the greatest number of words. While student 5 and 6 used only one science word, they were the only students to do so. The mean of 11 was surpassed by only students 5 and 6.

Table 19: Student Comparison: Question 8

8. Show how electricity is like other systems we use every day.

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Type of Thinking Map	Bubble	Bubble	Bridge	Bridge	Double Bubble	Bridge
Number of words	25	15	16	10	58	10
Number of Science words	2	2	1	3	2	4
Percentage of Science Words	8	13	6	30	3	40

As shown on Table 19 the data reveals how students used Thinking Maps and the number of words they used. Showing analogies is the purpose of a Bridge Map. Question 8 is designed to match this purpose; three students used the Bridge Map. All students used 10 or more words; student 5's maximum number of words was larger than the next highest of 25. Twenty percent of the students used more than the mean number of words, one from each of the highest and lowest ability students. This data

Question Two

How is inquiry science an effective instructional practice?

- Do students use inquiry science methods correctly?
- How do students show their understanding of science concepts?

The simple answer was, yes, they did use inquiry science methods correctly though that success varied; students across the spectrum included a research abstract, data, observations, and research findings. Using a subjective measure of their science notebooks revealed students who received language instruction in the resource room (5 and 6) did as well as the average student and better than one of the G/T students (student 2). (See Table 30)

Students' scores did not correspond with their abilities as first discussed (G/T, average, and special needs). Using scales similar to the MEA scoring rubric a score of 16 (MEA=Excel) was achieved by student 1; the remaining students received a Mastery score between 9-12 (MEA=Mastery).

Table 20

Science Notebook Rubric Scores

	1	2	3	4	5	6
Abstract	10	9	8	10	9	9
Data	12	9	10	11	11	9
Observations	12	9	9	11	9	7
Findings	12	8	5	8	7	8
Mean Score	15.3	11.6	10.6	13.3	12.0	11.0
Mean Scores	E	M	M	E	M	M

Student 1 (Gifted and Talented)

Within the scientist notebook entries, student 1 showed pre-instruction knowledge using a Bubble Map; 29 bubbles; 89 words; six science words; and phrases similar in length and number to her counterparts. “It can shock you”, “There is also static electricity,” “It’s made using power plants.” Her language skills were consistent with both her MEA and Stanford 10 scores. Her command of language became clear in her research abstracts and findings. “I believe that metals with magnetic materials will be attracted to magnets, because magnets are attracted to one another;” “As I had believed when we started our research, only magnetic materials were attracted to the magnet, but sometimes my prediction on whether the object was magnetic or not were wrong;” “I believe that the size of the magnet affects the number of paper clips it picks up. I will prove this by using different sized magnets to pick up as many paper clips as possible, using the magnets one by one. Each time, after the magnet has picked up a paper clip, I will take it off and record how many it picked up, along with the kind of magnet. How old the magnet is might affect the outcome.” She used a mean of 11 observations of which 82% were expressed in mathematical terms; and maintained additional notes for each experiment. On her after instruction science questionnaire, student 1 addressed procedures without flourish or fan-fair; her sentences did not elaborate. Question 2 asked what part of science worked well in learning science; her response revealed information to support the use of inquiry science methods. “The hands-on part of science works well for me because it gives a good sense of understanding.” In her response to the third question, she stated she believed inquiry science works better because it included hands-on parts.

Student 2 (Gifted and Talented)

Student 2's pre-instruction response regarding his knowledge about electricity contained five statements, all expressed as phrases: "Is a source of energy;" "Is created by friction," "Is conducted by neither the ground or rubber;" "We use it for all electricity;" and, "It can be blue or yellow (especially in the form of lightning)." Four science words were used. In each experiment, he included a research abstract, data, observations, and findings. His mean scores were: abstract-28; observations-12; findings-30.

In one of the experiments, he included notes. His Stanford 10 mean percentile score: 83.7, placed him well about the students' group mean of 42.2 and minimum individual mean of 11.3. This student briefly reported that he learned science making and abstract writing before he did an experiment. His response to the second question contained 6 words, "The experiment we actually get to try it." This response does not directly address the separate questions but it suggests the experiments worked well for him. The answer to question 3 supports the positive view he had about inquiry science. "Yes, because with text books it is boring so you forget with experiments it's fun so we remember."

Student 3 (Average Learner)

To this researcher, student 3 represented the "average" learner; this was based on classroom work, formative assessments, and student records. His testing scores revealed somewhat of a different view. His Stanford 10 scores of 24.4 were below the local mean of 51.5. His annual MEA assessment scores in reading, writing, and math were all Partially Meets. His written responses, evaluations, and questionnaire offered some insights into his thinking. While his pre-unit knowledge statements contained 153 words, only 20% were statements containing information about electricity; the remaining portion recalled his uncle's work establishing electrical service to rural areas. The first four statements showed accurate information about electricity: "Has a certain amount of volts;" "Is attracted to metal;" "Make lights, TVs, computers;" "Can be made by wind farms and water." His written work expressed ideas clearly, succinctly, and accurately. "All different kinds of metals put together will attract magnets," "I found that the compass had only two playses [sic] that it was attracked [sic] to, those were the screw on the tip of the compass and the pointed end," "How to prove this study: I will prove this study by takeing [sic] different sizes of magnets and see what happens." It is important to note that spelling was inconsistent and mistakes appeared throughout his work: sertain, atractid, aluminum, and takeing [sic] All of his mistakes were either ones from the One-Thousand Most Frequently Used Words list or were part of the science unit word wall. The unit evaluation responses are short, and had spelling, and English conventions mistakes. Seven of the eight questions contained accurate information. The final response: Show how electricity is like other systems we use to live better was neither accurate nor complete. The response to the science questionnaire's questions are simple enough, but effective. "By doing experiments." Question 2 asked, What part of science works well for you in learning about electricity? "The experiment, because we really got to know really what happens." Again, "Because we really got us to really what happens." This poorly composed sentence does imply that the experiments helped him learn about electricity.

Student 4 (Average Learner)

Again, previous to the beginning of this study, I viewed student 4 as an average learner. I also selected this student based on the same criteria as student 3. The MEA and Stanford 10s gave a different impression. The results of the MEA: reading-PM, writing-PM, and math-M suggested a lower than average ability learner. Stanford 10s showed percentile ranks of: reading-22.3; writing-37.4 (language); math 40.5 with a complete battery of 27.4. The complete battery included the subtests for reading, math, language, spelling, science, listening, and thinking skills. Local Stanford complete battery mean: 50. 7 percentile and the class mean 47.8 percentile placed him substantially below either of these percentile ranks. Stanford 10 scoring placed him 2.2 school grades behind the class mean of 8.7. However, his science notebook, questionnaire, and end of unit evaluation presented the abilities of an average student. The pre-instruction knowledge including these statements: 'It shocks you, powers stuff, is in outlets and colorless, and that you can be electrocuted by it.' His notebook work was evaluated with results closer to what an evaluator might consider average work. The rubric places him in the Excels category, which is 1.3 above the minimum score for that range (13.3). His abstract contained several well constructed sentences; a few sentences had spelling and grammar mistakes. "I believe that there are many thing [sic] that will attract magnets; but I believe metel [sic] will the most. I'll prove this by taking a magnet and put it on a variety of things.

The outcome of this project is if something is wet it could fall off easier." Several of his research findings included sentences with no errors. "Amazingly, the D battery got a higher mean than the six volt battery. The D got 31 as its average and the 6 volt got 14." His science questionnaire's description about how he learned about science included the use of and group discussions of science using Thinking Maps. The answer to the final question, Did you think learning science by conducting experiments helps you understand better than other ways? Why? supports the effectiveness of inquiry science. "Yes it did. Because it is fun and you learned all at the same time."

Student 5 (Special Needs)

Student 5 was one of the two students designated low ability; he received language and reading instruction in the resource room. He was first identified at eight years old with the special education teacher reporting, "Overall, he performed below average when compared to his peers in the area of reading. He was observed to read one or two words at a time in a slow, steady pattern." At that time he was placed in the Resource Room for instruction in reading and writing. Approximately 6 months after the conclusion of this study the academic tester noted, "He provided good effort during each testing challenge. This examiner views the present results as representative of his current level of intellectual functioning." Testing revealed his average ability in verbal and nonverbal domains; this marked a gain over the past year equal to more than a grade level in reading, spelling, and writing. For the purposes of this study he placed 5th of 6 students with a Stanford 10 percentile score of 15.2, 3.9 points above student 6. His science notebook score of 12.0 was at the top for the Mastery category (9-12 pts.)

His pre-unit knowledge contained five written sentences and included two science concepts: "Electricity is dangeruse" [sic]; "Electricity is transportable" His science notebook shows a variety of sentences, some compound. Throughout his writing there were a number of spelling and grammatical errors. He made a total of 32 observations for the 3 experiments. His notebook contained three maps in which his thinking was stated simply and contained accurate information. The first probe's Thinking Map contained seven statements; seven spelling errors with two science words. His data collection was neat, accurate. A Mastery score of 11 was achieved. On his unit evaluation, he used seven different Thinking Maps, marking each with the corresponding map he intended to use. When asked to show what he knew about electricity, he stated that electricity could do a lot of things including powering things. When comparing and contrasting open and closed circuits he used the appropriate map matching the design of the question. He indicated that both could have a lot of wires; the closed circuit worked. Questions six and seven used a Double Flow map stating accurate information. His description of how he learned about electricity addressed the use of, experiments [sic] and learning it in a hands on way." He also indicated his approval of inquiry science, "I like the hands on stuff because I understand it better. I also like it because I know what I'm doing."

Student 6 (Special Needs)

This student fit the criteria for inclusion in this group. He was first identified during the first grade. At that time it was noted that his strengths included: strong memory, gross motor skills, receptive language skills, and motivation. He was diagnosed as having Veliocardio Facial Syndrome. As a result he needed cosmetic surgery to correct his inward turning thumbs. His ongoing medical needs included insufficient breath support for speech volume, upper respiratory distress, sensory motor skills, and ear infections, which is positive for decreased hearing acuity. During the initial evaluation he was identified as being Other Health Impaired. His diagnosis warranted both resource room intervention and speech and language services, continuing throughout the study. Neither service occurred during the science or Thinking maps instruction period throughout the study. His Stanford 10 percentile score of 11.3 placed him at the lowest level. His highest subtest area was spelling followed by language skills. His science notebook revealed his mastery of writing abstracts, data, observations, and findings. He added some statements, which did not relate to the experiments. The changes in his knowledge were significant. His initial knowledge included single words including "inputs, extoion [sic] cords, everyday, and for light". On the unit evaluation his knowledge stated electricity was as a force, had static charges, charged by conduction. Using a Double Bubble map he compared and contrasted open and closed circuits. To answer what might he do to fix a broken flashlight, he suggested he could use duct tape, get a new light bulb, or be sure the battery connected. On question eight, his analogies included electricity:house::powerlines:transportation::power plants:store::coal:natural resources. His analogies show a relationship between systems and the sources to their beginning points. Throughout his science notebook, mistakes in spelling, punctuation, and grammar occurred. "I will prove this by putting the magnets by some metal;" "In my research my believe [sic] was right;" "I don't think anything [sic] going to effect." Each experiment contained an abstract, data, observations, and findings. His only note was not related to the experiment: *pencil is short. He listed a total of 33 observations for the experiments. He included illustrations and a percentage circle. Summing up his views on inquiry science methods, he responded to the 3rd questionnaire question by simply stating, "Yes, because you can see what the efect [sic] is and acually [sic] do the experiments."

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APPENDIX

A-1

Student # 1
Thinking Maps Questionnaire

How might you use these in the future?

I might use them as a guideline for a writing assigment, as a planner for the day, to remember important things, to help myself understand new subjects, and for other everyday needs.

A-2

Student # 1
Thinking Maps Questionnaire

What are Thinking Maps? What is the purpose of using them?

Thinking Maps are diagrams of your thoughts and ideas. The purpose of using them is to organize facts and show other people your opinions and thoughts.

26

How do you use Thinking Maps?

First you choose the best Thinking Map for the subject you are writing about, then you simply make it.

19

A-3

Student # 2
Thinking Maps Questionnaire

How might you use these in the future?

To list ideas for
just about anything
I do its hard to find
something you cant use
a thinking map for

A-4

Student # 2
Thinking Maps Questionnaire

What are Thinking Maps? What is the purpose of using them?

They are figures that you can use to show your thinking

A

How do you use Thinking Maps?

you write ideas in the space provided

1

Student # 3
Thinking Maps Questionnaire

How might you use these in the future?

In writen reports to help me, in scienee in reading, in writing, and more.

Student # 3
Thinking Maps Questionnaire

What are Thinking Maps? What is the purpose of using them?

A thinking map is a descriptional grid that help show your thinking, the purpose is to help show your thinking in detail.

27

How do you use Thinking Maps?

We use the the help us in writeing, and projects, science and reading reports.

13

A-7

Student # 4
Thinking Maps Questionnaire

How might you use these in the future?

I might use ~~these~~ these in the future by helping me rember books I'm reading and showing other people show my thoughts.

A-8

Student # 4
Thinking Maps Questionnaire

What are Thinking Maps? What is the purpose of using them?

Thinking maps are map that you right to show your thinking. To be able to show people the map and it to make sense.

24

How do you use Thinking Maps?

You use a thinking map to help you with rembering stuff and with showing you thougts on paper.

A-9

Student # 5
Thinking Maps Questionnaire

How might you use these in the future?

To help me at work like to wright things down. At collage to wright what the perfessor person talks about. In sports they might help like knowing what people do and where they are.

A-10

Student # 5
Thinking Maps Questionnaire

What are Thinking Maps? What is the purpose of using them?

The purpose of Thinking Maps is organize thinking or to remember things (on my behalf) and to even answewr questions. They are like tools to organize and help you "think".

How do you use Thinking Maps?

To help you with books or projects and you just wright them down

Student # 6
Thinking Maps Questionnaire

How might you use these in the future?

I might use them at my job or High school. I would use them because it would put my thoughts down.

Student # 6
Thinking Maps Questionnaire

What are Thinking Maps? What is the purpose of using them?

Thinking maps are suppose to help you think better.

How do you use Thinking Maps?

You just make the thinking Map and you think about whats happening in a story or a book.

Student # 1
Science Questionnaire

Describe how you learned about electricity.

We did experiments: Mr. M-J would give us a probe, we would write a research abstract, we would gather our data, record it, then do our research findings and observations. We had to make a certain number of observations math-related. We rarely used a textbook.

Student # 1
Science Questionnaire

What part of science works well for you in learning about electricity? Why?

The hands-on part of science works well for me because it gives a good sense of understanding.

Did you think learning science by conducting experiments helps you understand better than other ways? Why?

Yes, because it includes hands-on parts in it.

Student # 2
Science Questionnaire

Describe how you learned about electricity.

I made an abstract
then did an expirment
to

What part of science works well for you in learning about electricity? Why?

The expiriment we actually get to try it

Did you think learning science by conducting experiments helps you understand better than other ways? Why?

yes because with text book its boring so you forget with expirements it easy so we remember

B-5

Student # 3
Science Questionnaire

Describe how you learned about electricity.

By doing experiments and by doing a little bit of stofe in a text book.

B-6

Student # 3
Science Questionnaire

What part of science works well for you in learning about electricity? Why?

the experiment, becuase we really got to known really what happens.

Did you think learning science by conducting experiments helps you understand better than other ways? Why?

because we really got us to really what happens

B-7

Student # 4
Science Questionnaire

Describe how you learned about electricity.

We learned about electricty from a book and then we would make a thinking map. After that we would get in a grow and desuse our thinking maps and make one big one.

B-8

Student # 4
Science Questionnaire

What part of science works well for you in learning about electricity? Why?

the experiment, becvase we really got to known really what happens.

Did you think learning science by conducting experiments helps you understand better than other ways? Why?

because we really got us to really what happens

B-9

Student # 5
Science Questionnaire

Describe how you learned about electricity.

We all did exsperaments on electricity. A man from CMP came to talk about electricity and dangerous it is. We learnded about it in a hands on way. But we did read one book.

B-10

Student # 5
Science Questionnaire

What part of science works well for you in learning about electricity? Why?

I like the hands on stuff because I understand it better. I also like it because I know what I'm doing.

Did you think learning science by conducting experiments helps you understand better than other ways? Why?

Yes. I understand it better and I get to work on it with my group that can exsplain it to me.

B-11

Student # 6
Science Questionnaire

Describe how you learned about electricity.

I did experiments. Some of them are water, wind, solar.

C-1

1-2-08 1:02pm

Electricity

Probe: What is attracted to magnets?

Research Abstract:

I believe that magnets are attracted to metal. I will prove this by puting the magnets by some metal. What might affect is that there might be to much metal around it.

Materials
various objects, magnets

C-2

√=Yes / X=No

Object	Prediction	Y-N	Outcome
tin foil	NO	NO	√
spoon	No	NO	√
tack	Yes	Y	√
battery	Yes	Y	√
tack	Yes	Y	√
sort pencils)	No	Y	X
(pencil) grip	NO	N	√
light bulb	Yes	N	X
paper rings	Yes	Y	√
Staples	Yes	y	√
brac. facuer	Yes	y	√
Clothing	Yes	y	√
fork screw	Yes	y	√
big screw	Yes	y	√
nail	NO	y	X
pipe cleaner	Yes	y	√
Paper clip	Yes	y	√
dice	NO	N	√

C-3

Research findings:
In my research my believe was right. My believe was, that I believed magnets were attracted to metal. I proved this by puting the magnet to something metal. I found out that 20 out of the 33 were not attracted. I also found out that 60% were not metal.

The science unit assessment (Table 21) provided information of student understanding of electrical concepts. For analysis purposes, a numeric value was assigned: Exceeds = 24-32; Mastery = 16-23; Partially Meets = 9-15; Does Not Meet = 1-8. Scores were not assigned based on the use of Thinking Maps or whether they corresponded to the evaluation design, but on the concepts that the question attempted to elicit. Responses followed no pattern, as all students received a range between PM and E; 4 received PM-Es; 1 student received DM-M scores; the final student received Partially Meets for all questions. Two students were below the mean of 20.5, while students 1, 4, 5, and 6 were above; both low ability students (5, 6) were above this mean score.

Table 21:

Science Unit Assessment Scoring

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
What do you know about electricity?	E	M	PM	M	M	M
Define electricity.	M	M	PM	PM	M	PM
Compare open and closed circuits.	PM	PM	PM	M	M	PM
What materials are attracted to a magnet?	E	PM	PM	M	PM	M
What are the parts of an electrical device?	PM	PM	PM	M	M	PM
If a flashlight is broken, what might you do to fix it?	PM	DM	PM	PM	PM	M
What might cause a flashlight to fail?	M	DM	PM	M	PM	M
Show how electricity is like other systems we use to live better.	M	E	PM	E	E	M

Student 1 received 2 Exceeds; 3 Masters; 3 Partially Meets, which resulted in her 7-point margin over the lowest score. She received the same number of PMs (3) as did students 2, 4, 5, and 6. Student 2 also did not meet the mean score, falling below by 2.5 percentage points; having the same number of Partially Meets as students 5 and 6. As with students 4 and 5, he also received a single E.

Student 2 was the only student to receive a Did Not Meet score: 2.5 points below the mean. Two of his 8 responses were assigned the DM score, the only student to do so. Of the two students scoring below the study group mean he was the only student to receive an E, thus having the full range of possible scores.

Student 3 received the lowest score, 5.5 percentage points below the study group mean. He was the only student to receive all Partially Meets. On questions 2, 3, 4, 5, 6, and 7, all other students received a PM as well. He was 7 points behind the other student labeled as an average learner and 6 points behind student 5. Student 4 received one E as did student 5. He received the same number of Ms as student 6 (5). He had the same answer as the other students 44% of the time. On question 1 he had the greatest number of fellow students with the same answer. Seventy-five percent of his thinking Maps were correlated to the unit evaluation questions. Fifty percent of his maps were the same as the other students.

Student 5 used 7 of the 8 maps correctly. Though the map for question 6 did not use the corresponding map for which the test was constructed, his showed appropriate thinking to answer the question. Student 5 had a higher score than 3 other students; his score was .5 percentage points greater than the mean. His thinking corresponded to the question mean 70% of the time.

Student 6 used seven different maps. Question 6 was designed to use a Flow Map rather than the Multi-Flow Map that he used. However, the information did show appropriate ways for him to fix a flashlight. He was .5 above the group mean; 50 % of the time his answers were at or above the mean scores. On the evaluation questions he had the same answer as the other students.

Chapter Five

Discussion of Findings

As a practitioner I have spent more than 30 years honing my craft. It is my desire to ensure students learn meaningful information in meaningful ways. I have come to believe that children learn best by doing; we can see this everyday in the work they do, constructing new knowledge as they make sense of their world. On a very practical level, this meaning-making is thinking. Educational theorists John Dewey and Jerome Bruner; as well as researcher Robert Marzano, and equity advocates Jonathan Kozol and Alfie Cohn press educators to use strategies to think. As a practitioner, I search for teaching strategies that increase student achievement; therefore, throughout this study students have been at its center.

If you will remember with me a day some twenty years ago, the kernel for this dissertation was planted. At the beginning of my first year of teaching 5th grade I posed a question to my students about why birds could fly and cows could not, so I bought beef bones and I bought chicken bones. Students worked in small groups. I suppose we were a bit noisy because the principal stood at the doorway. She asked, “And where is your teacher?” I was in a corner, on the floor, working with a small group of fifth graders who had difficulty concentrating. She walked over and asked what I was doing. How does one explain the presence of beef bones and chicken bones? “We’re experimenting.” She came a bit closer, watched us for a short time and then told us to get back to work. We did. And this single event sent me on a quest to learn instructional techniques that excited my students while they made sense of the world around them.

It is this researcher’s belief that we can, nay, must, find ways to employ teaching methods that tap into a learner’s sense of wonder and the innate wish to understand one’s world. Inquiry science taps into a learner’s curiosity and offers students a way to extend their thinking. This study’s focus was Thinking Maps and on electrical energy. Inquiry science is constructivism in action. Students work to form an understanding of concepts, in this situation, electricity. Students construct new learning based on previous knowledge. Both practices percolated from the theoretical work of Skinner, Vygotsky, and Bruner. Their theoretical beliefs had one common theme: learners must be active before thinking can be solidified. Further research suggests learning is social and developmental; it can only occur when there is a sense of safety. And finally, it is unique and organized and adaptive as it builds on previous knowledge. Marzano, and colleagues, brought theory and our knowledge about brain functioning together. Their work focused on nine strategies that research showed would increase student achievement. They are practices that combine theory, knowledge and research. Inquiry science is active; it builds on previous knowledge, and is developmental. Thinking Maps are designed to represent the eight thinking processes learners use to make sense of the world. Thinking is the sharing of ideas and sharing is necessary in a complex world. It is essential to form a civilized society and for ensuring success in the global economy.

Marzano's publication, Classroom Instruction that Works, Research-Based Strategies for Increasing Student Achievement. (1999) included the use of inquiry science and Thinking Maps. Marzano focused on nine strategies, six of which are at the center of this research. Identifying similarities and differences; summarizing and note taking; and nonlinguistic representations are three of the strategies. Cooperative Learning is part of inquiry science methods because students work in small groups. Finally, generating and testing hypotheses, and providing cues, questions, and advanced organizers are closely related to the use of both .

Inquiry science activities consist of forming theories, testing hypotheses, collecting data, and postulating results. In this study student work was analyzed using students' science notebooks, unit evaluations, and questionnaires. The analysis suggested they are both effective practices.

In conclusion, the data revealed several important facts. Preliminary findings included: differences in student understanding in science concepts and use of Thinking Maps. Student work revealed unanticipated data; students receiving instruction in reading and writing skills in the school's resource room used Thinking

Maps more effectively. While there was a difference between student language skills there was no evidence students' concepts of electricity were different. The Stanford 10 results suggest students with lower reading scores would be less capable of using inquiry science methods to learn new concepts. A comparison between student's test scores and ability to use inquiry science methods showed no relationship. The analysis revealed that the group needing additional reading instruction was at least as capable, if not better, at showing their thinking using Thinking Maps. These students were able to form hypotheses, write clear abstracts, collect appropriate data, and express their findings. Increases in student achievement in science, math, and language skills became evident in this study. The effectiveness of Thinking Maps was also evident, as students used a variety of maps to show their thinking.

The results of this study suggest the importance of active learning and that by structuring classroom activities there exists an opportunity to enhance student learning, to increase student achievement. Students that we traditionally label as learning disabled can increase and more importantly demonstrate their understanding about complex topics. Both students 5 and 6 demonstrate this through their Thinking Maps and inquiry science questionnaires, and scientist's notebooks,. The implication is that we need to restructure the learning process.

Additionally, this study offers evidence that instruction across the curriculum is effective, easily structured, and results in significant gains in knowledge. One premise of this study is there are effective alternatives to federally required testing. Students can engage in the rich discourse as they share their knowledge through Thinking Maps and learn through experiences rather than textbooks.

Research begets more research; this is the nature of study, whether it is qualitative or quantitative. The use of Thinking Maps and inquiry science techniques by six 5th grade students was central to this study. The analysis of students' science notebooks and questionnaires are effective strategies.

Research in the use of Thinking Maps in other curriculum areas would be appropriate, as would research into how students at different grade levels use them. It would be appropriate to replicate this qualitative study by collecting data from a larger group of students. Analyzing a larger sample could confirm the studies' findings. The larger sample could lend itself to a quantitative study, giving the study information from a different perspective. Such a study may clarify and verify this researcher's findings. Additional studies regarding the possible correlation between learning styles and use could extend this study and provide additional information in the effort to ensure teachers use methods to increase student achievement.

It is important to note that the follow up studies are important to add, extend, and apply. Thus far I have discussed the importance of research; however, the goal of all studies is the application of the new knowledge. Unless any new research stemming from this study is not applied then I believe it is all for not. So it behooves practitioners to use its findings to increase student achievement, to understand that curiosity leads to deep understanding, and to be aware of the importance of meaning making.

Data

Science Notebooks

Table 22

Experiment 1: What materials are attracted to magnets?

Language

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Abstract Number of words	19	12	32	48	27	32

Number of observations	12	14	12	12	4	7
Research findings words	93	17	36	66	Missing	49

Table 23

Experiment 1

Thinking Maps Use

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Type	Brace	Flow	Brace	Brace	Bubble	Brace
Number of	1	0	3	2	2	7
Number of Words	30	16	67	37	19	20

Table 24

Experiment 2: Does the size of the magnet affect the number of paper clips it can pick up?

Language

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Abstract	79	32	39	61	14	24
Number of observations	12	12	19	12	15	12
Research Findings	91	82	43	93	19	47

Table 25

Thinking Map Use

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Type	Bubble	Flow	Brace	Bubble	Bubble	Bubble; Circle
Number of	5	0	5	5	3	6
Number of	15	0	5	7	4	0
Number of Words	96	31	72	39	52	36; 17

Table 26

Experiment 3: Does the size of the battery create a stronger electromagnet?

Language

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Abstract	63	32	52	69	13	26
Observations	7	5	0	8	1	8
Research Findings	60	16	0	72	31	29

Table 27

Thinking Map Use

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Type	Bubble	Flow		Brace	Bubble	Circle
Number of	2	0	0	4	4	0
Number of	2	0	0	4	4	0
Number of Words	35	26	0	18	65	13

Thinking Maps Questionnaire

Table 28

1. What are Thinking Maps? What is the purpose for using them?

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Defines maps	Yes	Yes	Yes	Yes	Yes	Yes
Gives purpose	Yes	Yes	Yes	Yes	Yes	Yes
Gives example	No	No	Yes	No	No	Yes
Number of Words	26	11	22	24	14	

Table 29

2. How do you use Thinking Maps?

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Explanation	Yes	No	No	Yes	Yes	Yes
Gives Example	No	No	Yes	No	Yes	1
Number of Words	19	7	13	18	12	18

Table 30

3. How might you use these in the future?

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Explanation	Yes	Yes	Yes	Yes	Yes	Yes
Gives Example	Yes	No	Yes	Yes	Yes	Yes
Number of Words	32	19	14	21	26	21

Science Unit Evaluation

Table 31

1. What do you know about electricity?

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Type of Thinking Map	Bubble	Bubble	Bubble	Bubble	Bubble	Bubble
Number of primary	7	3	4	5	2	6
Number of words	21	17	17	5	10	15
Number of secondary	19	0	0	2	2	0
Number of words	12	-	-	11	20	-
Number if 3rd	3	-	-	-	-	-
Number of words	22	-	-	-	-	-
Number of Science words	17	2	1	2	2	4

Table 32

2. Define electricity

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Type of Thinking Map	Circle	Circle	Circle	Circle	Circle	Circle
Number of words	6	7	5	8	0	
Number of Science words	1	4	3	1	0	4

Table 33

3. Compare open and closed circuits.

		Student 1	Student 2	Student 3	Student 4	Student 5
Type of Thinking Map	Double Bubble	Double Bubble	Double Bubble	Double Bubble	Double Bubble	Double Bubble
Number of words	8	14	28	24	28	21
Number of Science words	1	0	1	2	1	3

Table 34

4. What materials are attracted to magnets? Why?

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Type of Thinking Map	Circle	Multi-Flow Map	Circle	Tree	Bubble Map	Tree
Number of words	9	14	11	54	14	12
Number of Science words	1	2	3	2	3	2

Table 35

5. What are the parts of an electrical device?

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Type of Thinking Map	Not Used	Circle	Bubble	Tree	Brace	Brace
Number of words	10	9	8	11	14	8
Number of Science words	0	0	0	2	0	1

Table 36

6. If a flashlight is broken, what might you do to fix it?

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Type of Thinking Map	Bubble	Flow	-	Brace	-	Multi-Flow Map
Number of words	10	11	27	29	12	15
Number of Science words	0	0	0	0	0	0

Table 37

7. What might cause a flashlight to fail?

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Type of Thinking Map	-	-	Multi-Flow Map	-	Multi-Flow Map	Multi-Flow Map
Number of words	10	7	7	5	13	16
Number of Science words	0	0	0	0	0	0

Table 38

8. Show how electricity is like other systems we use every day.

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
Type of Thinking Map	Bubble	Bubble	Bubble	Bubble	-	Bubble
Number of words	25	15	10	10	0	9
Number of Science words	?	?	?	?	?	?

Table 39

Assessment Scores

	Reading	Writing	Math	Science	Thinking Skills
MEA Scores	E	M	E	NA	NA
Stanford 10 Percentile Scores	89.9	93.9	98.9	94.9	95.8

Table 40

Science Experiment Data

	Experiment 1	Experiment 2	Experiment 3	Mean Score
Abstract: Number of words	19	79	63	54
Observations:	12	12	7	10
Research Findings: Number of Words	93	91	60	81
<u>Thinking Map</u>				
Type	Bubble	Brace	Bubble	
Number of Words	96	30	35	53

Table 41

Assessment Scores

	Reading	Writing	Math	Science	Thinking Skills
MEA Scores	P	P	M	NA	NA
Stanford 10 Percentile Scores	7.2	5.2	8.2	3.1	11.3

Table 42

Science Experiment Data

	Experiment 1	Experiment 2	Experiment 3	Mean Score	
<u>Language</u>					
Abstract: Number of words	32	24	26	27	
Observations:	7	12	8	9	
Research Findings: Number of Words	49	47	29	41	
<u>Thinking Map</u>					
Type	Bubble	Brace	Circle		
Number of Words	36	20	13	26	

Table 43

MEA & Stanford 10 Comparison

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
MEA reading	E	M	P	P	P	P
MEA writing	M	M	P	P	P	P
MEA math	E	E	P	M	P	M
Stanford reading	89.9	89.8	22.3	22.3	8.2	7.2
Stanford writing	93.9	88.7	22.3	37.4	15.3	5.2
Stanford math	98.9	65.6	21.3	40.5	13.3	8.2
Stanford science	94.9	94.8	42.5	37.4	11.3	3.1
Stanford thinking	95.8	86.7	21.3	23.4	4.2	11.3

Maine Education Assessment Scores

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
	1	2	3	4	5	6
Reading	E		PM	PM	PM	PM
Writing	M	M	PM	PM	PM	PM
Math	E	E	PM	M	PM	M

D-1

Informed Consent

Study: An Examination of Thinking Maps in the Context of Inquiry-Based Science Education for Fifth-Grade Students.

C. Morgan-Janes, doctoral candidate at Franklin Pierce University is conducting a research study to examine the affects Thinking Maps and inquiry science have on student understanding of electricity. There will be approximately 40 test participants know as 5th graders at Marshwood Middle School, MSAD35, South Berwick-Eliot, Maine.

<u>Process</u>

Parent agreement of their child's participation in this study will allow the researcher to:

1. Analyze the participants records, MEA test scores, and other relevant information.

2. Assess the participants' use of science concepts.

3. Assess the participants' use of Thinking Maps.

4. Obtain, digitally photographs, photo copy, and publish said information in the dissertation.

5. Video-tape the student's participation in standard science curriculum for the purpose of completing doctoral work and in professional development.

New Findings

Each participant's guardian will receive information after the study regaring the findings, which will not be part of their trimester evaluations in any area. At any time information, which affects the subject whether positively or negatively will be shared with the child's guardian. At this time the guardian will have the right to terminate the child's inclusion in this study.

Risks

At the start of this study there are minimal perceived risks to either child's health or cognitive abilities.

Benefits

The researcher believes the students will benefit from the instruction part of this study. No promises of increased ability to problem solve in any academic area is implied at this time or at the conclusion of this study. Additionally, the researcher and supervisory members of MSAD35 may use the information to adjust instructional practices.

Explanations

All aspects of this study will be explained to guardians prior to its start. At any time the researcher will answer any and all questions asked by the guardian.

Costs

There will be no costs to either the guardian or student at any time during or at the conclusion of the study. Information found as a result will be offered to the guardian without cost as well.

Voluntary Participation

Each subject or his/her guardian may withdraw their concent at any time and no further analysis of their work will occur and there will be no consequences on their academic records.

Confidentiality

To guard the subjects' indentity numbers will be assigned and at no tme will these be shared with anyone including but not limited to any professional organization or instructor/advisor at Franklin Pierce University. Research records will be kept confidential as stated in state and federal regulations.

IRB Approval

The Institutional Review Board of Franklin Pierce University has reviewed and approved this research project.

Consent Information

Guardians will receive copies of this informed consent and all materials associated with the study's consent forms.

Research Statement

I agree to my child's participation in this study and understand that this research study will be used for no other purpose than that which is connected to the doctoral studies of C. Morgan-Janes. Each guardian understands the risks and benefits; nature and purpose of this study.

Signatures

Guardian: ________________________________ Date: September, 2008

Student: _________________________________ Date: September, 2008

Researcher: _______________________________ Date: September, 200

E-1

Unit Lessons

Electricity: Lesson One

Probe: What objects are attracted to magnets?

Words we might use during this unit include:

I wonder statements: students put these into their notebooks before sharing them with the class.

Research Abstract includes: an I believe statement; how I'll prove my hypothesis; and what factors might affect the outcome of this.

Materials: various objects include both metal and non-metal objects: nails (ex. pencil erasers, bottle caps, string).; different strength magnets

Procedures: a) place objects on a tray or any non-electromagnetic surface; b) have students predict which objects will be attracted to the magnets; test their predictions.

Data

Observations: (these are based on the data).

Research Findings includes: a statement regarding the student's hypothesis; the observation expresses in sentence form; and what factors did or did not affect the outcome of the experiment.

E-2

Electricity: Lesson Two

Probe: Does the size of a battery create stronger electromagnets?

Words we might use during this unit include:

I wonder statements: students put these into their notebooks before sharing them with the class.

Research Abstract includes: an I believe statement; how I'll prove my hypothesis; and what factors might affect the outcome of this experiment.

Materials: several sized batteries; magnet wire (enameled); two different sized nails; paper clips.

Procedures: a) wrap the wire tightly around one nail; b) place the wires to both ends of the battery; c) place the paper clips onto any non-magnetized surface; d) place the electromagnet near the paper clips.

Data

Object	Prediction	Outcome

Observations: (these are based on the data).

Research Findings includes: a statement regarding the student's hypothesis; the observation expresses in sentence form; and what factors did or did not affect the outcome of the experiment.

E-3

Electricity: Lesson Three

Probe: What combinations of battery, bulb, and wire will make the bulb light up?

Words we might use during this unit include: circuit; closed circuit; electrical current; open circuit; prediction; source; switch.

I wonder statements: students put these into their notebooks before sharing them with the class.

Research Abstract includes: an I believe statement; how I'll prove my hypothesis; and what factors might affect the outcome of this experiment.

Materials: battery; flashlight bulb; light bulbs; wire (both ends are stripped).

Procedures: a) blow up the balloon; b) tie the string to the balloon; c) mark one side of the balloon with the marker; d) rub the marked spot with the wool.

Data:

Observations: (these are based on the data).

Research Findings includes: a statement regarding the student's hypothesis; the observation expresses in sentence form; and what factors did or did not affect the outcome of the experiment.

Extensions:

To make a wet cell battery: cut 12 penny-size circles (oak-tag); soak the paper in a solution of vinegar and salt; starting with a zinc washer alternately stack a washer, paper circles, and copper pennies. Connect a wire from a low-voltage electric receiver (travel alarm clock) to the zinc washer and the top penny.

F-1

Unit Evaluation

Classroom Number _______

Unit Evaluation

Directions: Use any method you can think of to answer these eight questions.

1. What do you know about electricity? (Circle Map: defining in context)
2. Define electricity. (Bubble Map: describing qualities)
3. Compare open circuit and a closed circuit. (Double Bubble Map: compare and contrast)
4. What things are attracted to a magnet? (Tree Map: classifying)
5. What are the parts of an electrical appliance? (Brace Map: part-whole)
6. If a flash light is broken, what might you do to fix it? (Flow Map: sequencing
7. What might cause a flash light to fail? What can happen when it doesn't work? (Multi-Flow Map: cause and sequence)

8. How is electricity like other electrical things? (Bridge Map: seeing analogies)

Thinking Maps and Science Inquiry cci

Maine Education Assessment Scores

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6
	1	2	3	4	5	6
Reading	E		PM	PM	PM	PM
Writing	M	M	PM	PM	PM	PM
Math	E	E	PM	M	PM	M

5th Grade Percentage Scores

	Excel	Mastery	Partially Meets	Does Not Meet
Reading	20%	60%	15%	5%
Writing	20%	70%	10%	0
Math	10%	80%	10%	0

Thinking Map Use

	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6

Type	Bubble	Flow	Brace	Bubble	Bubble	Bubble; Circle
Number of	5	0	5	5	3	6
Number of	15	0	5	7	4	0
Number of Words	96	31	72	39	52	36; 17