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The Effects of Roundhouse Diagram Construction and Use on Meaningful Science Learning in the Middle School Classroom.

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THE EFFECTS OF ROUNDHOUSE DIAGRAM CONSTRUCTION AND USE ON MEANINGFUL SCIENCE LEARNING IN THE MIDDLE SCHOOL CLASSROOM

VOLUME I

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy in The Department of Curriculum and Instruction

by

Robin Eichel Ward
B.S., University of Tennessee, 1973
M.A., Louisiana State University, 1995
Ed.S., Louisiana State University, 1997
August, 1999
DEDICATION

This composition is dedicated to my parents, Florence and Al Eichel. I would like to thank them for all of the love and support they have given to me over the years. Time is the most precious gift one person can give another. Therefore, I dedicate this piece of work as a representation of time and devotion to the two people who created me. They raised me to understand the value of love and the meaning of family. They raised all three of their children with the ambition and motivation to reach high goals in their lives. They set an example for us to follow and we all followed. Their financial and emotional support throughout my lifetime provided me with the foundation which this research has built upon. Therefore, for the everlasting support of both of my parents, I dedicate this achievement to both of them.
ACKNOWLEDGMENTS

I would like to recognize those people in my life who contributed to this achievement. There were numerous professional colleagues, professional friends, and family members who not only supported me emotionally but encouraged me to accomplish this goal.

Seven years ago, I decided to resume my education when I became involved in the Louisiana Systemics Initiatives Program (LaSIP) at Louisiana State University under the guidance of Dr. Paul Lee, Dr. Sheila Pirkle, and Dr. Frank Cartledge. After taking eighteen hours of Physics and Chemistry classes with these professors, my mind was made up to major in Curriculum and Instruction with an emphasis on Science Education. Their incredible learning methods changed my way of teaching forever.

Dr. James Wandersee became my major professor at Louisiana State University. He not only taught me creative approaches to biology education, but he also supervised me and inspired me throughout my entire duration of coursework thereafter. I also became interested in Educational Leadership and was motivated to minor in that area under the direction of Dr. Richard Fossey. Dr. Fossey always made time for me and supported me in becoming my co-chair to my doctorate committee. My other committee members, Dr. Byron Launey and Dr. Earl Cheek were always there to assist me with an ear to listen as well as wise words for thought.

I would like to show deep appreciation to my dear friends, Brenda Ryder and Pauline Vidrine who helped me enormously with my study in the 6th-grade classroom. I am very grateful to have had Judy Land assist me with putting together this extensive
research study. I would also like to thank Dr. Rodney Johnson for his valuable input and helpful advice.

My deepest gratitude goes to my family members who have continued to support me throughout this past year, especially my sister-in-law, Gloria Grubbs, who always knew I would persevere. Last, but definitely not least, I want to thank my dear husband, Gene, who has always been there to comfort me throughout this dissertation process. He has listened to my frustrations as well as sacrificed his time and energy to make sure I had the resources necessary in order to complete this project. I could never have accomplished this piece of work without his love and deep consideration.
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ABSTRACT

This research explored the effects of Roundhouse diagram construction and use on meaningful learning of science concepts in a 6th-grade science classroom. This investigation examined the transformation of students' science concepts as they became more proficient in constructing Roundhouse diagrams, what problems students encountered while constructing Roundhouse diagrams, and how choices of iconic images affected their progress in meaningfully learning science concepts as they constructed a series of Roundhouse diagrams.

The process of constructing a Roundhouse diagram involved recognizing the learner's relevant existing concepts, evaluating the central concepts for a science lesson and breaking them down into their component parts, reconstructing the learner's conceptual framework by reducing the amount of detail efficiently, reviewing the reconstruction process, and linking each key concept to an iconic image.

The researcher collected and analyzed qualitative and quantitative data to determine the effectiveness of the Roundhouse diagram. Data included field notes, observations, students' responses to Roundhouse diagram worksheets, students' perceptions from evaluation sheets, students' mastery of technique sheets, tapes and transcripts of students' interviews, student-constructed Roundhouse diagrams, and documentation of science grades both pre- and post-Roundhouse diagramming. This multiple case study focused on six students although the whole class was used for statistical purposes. Stratified purposeful sampling was used to facilitate comparisons as well as week-by-week comparisons of students' science grades and Roundhouse
diagram scores to gain additional insight into the effectiveness of the Roundhouse
diagramming method.

Through participation in constructing a series of Roundhouse diagrams, middle
school students gained a greater understanding of science concepts. Roundhouse
diagram scores improved over time during the 10-week Roundhouse diagramming
session. Students’ science scores improved as they became more proficient in
constructing the Roundhouse diagrams. The major problems associated with
constructing Roundhouse diagrams were extracting the main ideas from the textbook,
understanding science concepts in terms of whole/part relationships, paraphrasing
sentences effectively, and sequencing events in an accurate order. A positive
relationship existed for the case study group based on students’ choices and drawings of
iconic images and the meaningful learning of science concepts.
INTRODUCTION

Why is Reform Necessary?

America’s crisis in education has been ongoing for several years now, and despite efforts being made to improve education in school districts across the land, American students, who should be able to rank high in achievement, are still found to rank near the bottom of many indicators of educational progress. Headlines may read: “One High School Student in Four Drops Out,” or “American High Schoolers Rank Near the Bottom in Math and Science Ability Internationally.” This situation constitutes a disaster of sorts, and if allowed to continue unchecked, could very well result in America’s downfall as a world leader. One must wonder if educational reform is simply an illusion that cannot actually be grasped—perhaps we have neglected the basic issues needed for change to occur.

“Corporate leaders are terrified of the mounting international economic competition we face with an undereducated work force and feel we are not equipped to fight back” (Robinson, 1993, p. 269). Hundreds of national reports have been published placing pressure on our society to transform education in some meaningful way (Berard, 1996; Fisher, 1999; Miller, 1995; U.S. Department of Labor, 1992). Many of these reports come from business groups who are aware new knowledge and technology are placing tremendous demands on the current work force. We exist in an information-rich, rapidly changing global society which requires an independent, competent work force (Louisiana Content Standards, 1997). The competitive position of any country today lies primarily in the knowledge generated from the education produced in the sciences and technology (Bybee, 1993).
There is another view which cannot be ignored. The book, *The Manufactured Crisis*, written by Berliner and Biddle (1995) makes the claim that many of these pressures to transform education, attacking the achievements of America’s public schools, began as a result of political propaganda. Many politicians, industrialists, business leaders, and members of the educational community criticize American schools and have restated these facts which are nothing more than distorted evidence used to benefit government officials. Berliner and Biddle (1995) state that American education faces three extraordinary problems: our traditional willingness to tolerate huge differences in funding for public schools; the dilemmas created by our radically expanded education system; and the fact that more and more disadvantaged children will be entering our schools. (p. 7)

Berliner and Biddle (1995) believe these problems must be addressed as a nation, and are social in nature, because poverty eventually leads to illiteracy. These authors, as well as others (Bracey, G. & Rothstein, R.), believe that it is strictly a myth to believe such statements as “student achievement has recently fallen across the nation” (p. 13), and that America’s public schools are in actuality doing much better than critics would have us to believe.

Nevertheless, it is not a matter of blame or who is at fault for the nation’s educational crisis. What is important is that our students are given our undivided attention as educators and our goal remains to better equip our students to live competitively in this ever-expanding populace. In order to do this, it is imperative that we continue to seek out the best instructional methods with which to teach our students.
The Nation's Report Card

The Department of Education publishes the results from a national assessment every four years in a series called The Nation's Report Card. The National Assessment of Educational Progress (NAEP) indicates that performance of American students is low in all subject areas and is not improving. Data from 20 years (1970-1990) of NAEP testing estimates that more than half the nation's elementary through high school students are unable to demonstrate competency in challenging subject matter. Fewer than half of all United States students appear to be able to think critically, creatively, or to solve problems which require interpretation (Mullis & Jenkins, 1990). Evidence from NAEP suggests that both the content and structure of our school science curricula are generally incongruent with the ideals of scientific enterprise. By neglecting the kinds of instructional activities that make purposeful connections between the study and practice of science, educators fail to help students understand the true spirit of science. NAEP reports have pointed out that United States students are, for the most part, incapable of answering higher-level questions on tests or of performing well on complex academic tasks (Mullis & Jenkins, 1988, 1990). The latest results (1997) summarizing the NAEP science performance for grades 4, 8, and 12 follow:

Three percent of students at grade levels 4, 8, and 12 performed at the advanced level indicating solid understanding of the content; 29% in grades 4 and 8, and 21% in grade 12 performed at or above the proficient level, demonstrating much of the knowledge essential for understanding; 67% in grade 4, 61% in grade 8, and 57% in grade 12 performed at or above the basic level demonstrating some knowledge required
for understanding; and 33% of students in grade 4, 39% in grade 8, and 43% in grade 12 performed below basic level.

Prevailing educational and instructional practices are failing to meet current demands. It is imperative that we change the way teachers interact with students—and these changes must be grounded in an understanding of how children learn (Bruer, 1993; Novak & Gowin, 1984).

**Goals of Science Education**

From society’s point of view, the first goal of education is to enable each individual to become a responsible citizen in our democratic system. Society’s second educational goal is for each citizen to be able to contribute economically as well as intellectually to the power of our nation (Connor, 1990). In order to achieve these goals, American public education must address issues related to the teaching and learning of the sciences and technology. The American Association for the Advancement of Science (AAAS) in 1993, in its *Project 2061: Benchmarks for Science Literacy*, defined scientifically literate persons as those “equipped with the knowledge and skills they need to make sense of how the world works, to think critically and independently, and to lead responsible and productive lives in a culture increasingly shaped by science and technology” (p. 6). Scientific thinking begins as children invent ideas and concepts through their experiences as they make sense of the world in which they live. “The purpose of science education is to provide a learning environment which builds on these experiences, as well as to provide opportunities for discussion and reflection that will lead to interconnected, coherent and articulated frameworks for understanding natural phenomena” (Howe, 1993, p. 225).
The Louisiana State Standards

A task force of the Louisiana State Standards for Curriculum Development (1997) has compiled a list of skills which apply to all students in all disciplines. These skills emphasize what cognitive scientists promote for students' educational well being in order to be productive lifelong learners. These skills provide connections between thinking, information processing, and visual representation. The fundamental skills involve using multiple pathways in order to solve problems, instructional techniques essential for all learning processes, and linking and generating knowledge. This process involves:

the effective use of cognitive processes to generate and link knowledge across disciplines in a variety of contexts. In order to engage in the principles of continued improvement, students must be able to transfer and elaborate on these processes. (The Louisiana Content Standards, 1997, p. 3)

The National Science Teachers Association's (NSTA) position statement on science teacher preparation places an emphasis on relationships and interconnections between grade levels and subject matter. At the middle school level, subject matter should stress in-depth understanding of meaningful themes as well as relationships to the "big picture," with less emphasis on lower-level skills such as memorization of facts (NSTA, 1999). By the end of the eighth grade, students should be able to analyze and interrelate parts of a system. "Thinking about things as systems means looking for how every part relates to others. The output from one part of a system (which can include material, energy, or information) can become the input to other parts" (AAAS, 1993, p. 265).
Textbooks

The primary educational tool in school is the textbook. In textbooks, information is presented in a linear fashion and does not promote connectivity or relationships among concepts. Within the school curriculum the textbook dominates what is learned. Research studies reveal that 75% of classroom instruction and 90% of homework time is structured around the textbook (Harms, 1981). In the science classroom the textbook dominates the curriculum and problems arise because many students do not have the skills and strategies necessary in order to comprehend science textbooks (Readence, Bean, & Baldwin, 1981). The skills that a student brings to the classroom greatly affect what is learned (Spiegel & Barufoldi, 1994).

The Project Synthesis report (Harms, 1981) reveals that 90% of all science teachers use a science textbook 90% of the time. The present science textbooks and methods of instruction emphasize learning of factual information and test primarily for recall (Novak, 1998). Often the information teachers disseminate to students is straight out of the textbook, providing only one point of view regarding complex issues (Brooks & Brooks, 1993; Langer, 1997). Rote memory is exercised rather than critical thinking and reflection. Isolated bits of information are taught rather than connectedness. Reading is practiced rather than doing. Reconstructing concepts is not encouraged and many topics are taught over and over again with needless detail (AAAS, 1989). "Textbooks are notoriously dull, poorly written, information-dense, and crammed with jargon" (Robinson, 1993, p. 59).

The long established tradition in education, especially in the sciences is the transmission of information from teacher and text to students of single-track, logically
organized knowledge (Carr, Barker, Bell, Biddulph, Jones, Kirkwood, Pearson, & Symington, 1994). Science textbooks are full of vocabulary that is difficult to comprehend (Barman, Johnson, Leyden & Rusch, 1982; Yager, 1983). Many teachers use the textbook religiously and plan to cover the entire book in the school year. They go through the material so rapidly they lose the students in the process (Barman et al., 1982). Research indicates that middle school science textbooks introduce as many as 2,500 technical terms in one single text (Hurd, 1983).

**Self-Esteem**

Classroom practices and the school environment formulate a student’s perception of his/her mental capabilities. Oftentimes, students get the wrong message which greatly affects their self-image, their motivation, and their success in school. As educators, we must create an environment where children can experience success and believe they can learn (Bruer, 1993). “Science has a reputation for being a tough subject due to the heavy vocabulary demands. Research indicates that self-concept is the most influential factor in predicting academic success of a student. This initial attitude is more important at the middle school level than at earlier levels” (Barman et al., 1982, p. 121). Research has repeatedly revealed that when instructional strategies do not lead students to grasp the meaning of a learning task, the learner’s confidence suffers greatly. “Schooling is too often an assault on students’ egos because the rote, arbitrary, verbatim instruction so common in classrooms has few intrinsic rewards” (Novak & Gowin, 1984, p. xii).
Oftentimes in the classroom the teacher has a single routine and a set of basics for each child. Information is often presented from a single perspective, and there is little room for disagreement or creativity. Students learn the basics in a rote unthinking manner. Langer (1997) refers to this automatic behavior as mindlessness. “Facts are taken as absolute truths to be learned as is, to be memorized, leaving little reason to think about them” (Langer, 1997, p. 71). David Ausubel (1963) makes a distinction between meaningful learning and rote learning. “Rote learning tasks can only be incorporated into cognitive structures in the form of self-contained entities organizationally isolated from the learners conceptual systems” (p. 43).

“Learners who develop well-organized knowledge structures are meaningful learners, and those who are learning primarily by rote are not developing these structures and/or their knowledge included many misconceptions” (Novak, 1998, p. 10). Students who rely on rote learning may know enough to pass but often do not understand the material enough to apply it outside of class. Teachers need to be selective about what they choose to teach and realize that teaching for meaningful learning of less material can be more beneficial, though it may be more time consuming. “The primary objective of school science is quality over quantity, meaning over memorizing, and understanding over awareness” (Mintzes & Wandersee, 1998 p. 56).

Students have long suffered under the dominance of Behaviorist principles which view learning as a change in behavior, not a change in the meaning of experience. Students need help learning how to construct knowledge from their experiences in the classroom (Novak & Gowin, 1984). The middle school student needs to learn facts but
should begin to assimilate and integrate them into conceptual frameworks. These frameworks need to be based on the learner’s prior knowledge. Ausubel’s (1968) assimilation theory of cognitive learning places emphasis on the importance of prior learning to provide the conceptual framework into which new knowledge may be assimilated. “The single most important factor influencing learning is what the learner already knows. Once that has been determined teach him [sic] accordingly” (Ausubel, Novak & Hanesian, 1978, epigraph; Mintzes & Wandersee, 1998, p. 39).

In 1956 a group of scientists and psychologists met at the Massachusetts Institute of Technology for a three-day symposium. This was the beginning of the cognitive revolution (Bruer, 1993). Cognitive scientists worked to discover relationships between thinking and information processing. Learning is ultimately the retention of useful knowledge, attitudes, and skills which are stored in the long-term memory. It is imperative that educators understand how the human memory operates in terms of making connections to learning and presenting information in such a way that it makes learning a powerful process. Educators who study cognition use terms such as “deep understanding” and “meaningful learning” which refer to how concepts are represented and connected by learners. Cognitive research is relevant to education because of the need to understand learning and what processes one utilizes in order to solve problems (Bruer, 1993).

The Working Memory

Research shows that meaningful learning benefits learners by increasing their ability to store and access information. Learners often create mental models—pictures or images of concepts in their mind, especially if the mind is organized. “Organizing
information means collecting information into groups or categories so that one can see
different patterns, connections, and relationships” (Robinson, 1993, p. 101).
Organizational techniques involve sorting out principal themes within the structure of a
text, and making clear the pattern and nature of the links within it, from one concept to
the next (White, 1988). These connections and patterns represent a person’s schema or
knowledge structure—“the central guidance system in the comprehension process”
(Readence, et al., 1981, p. 16). An individual searches existing schemata in order to
make sense of the environment. A schema is made up of similar bits of information
which forms a knowledge base (Readance et al., 1981; Solso, 1994).

Readance and associates (1981) refer to Rumelhart and Normal (1978) and their
outline of the essential ingredients in the comprehension process based on schema
theory. First, an individual must have prior knowledge or a knowledge base—termed a
schema. Second, assimilation occurs when new information enters into the existing
schema. Accommodation “involves adjusting the existing schemata to accept radically
new or discordant information. The third possibility—the learner can simply ignore or
reject information that fails to fit into the learner’s existing world” (p. 16). The
connection to prior knowledge and the types of inferences which are made are
influenced by our schemata. “Schemata help us decide how information should be
encoded, stored and retrieved” (Searleman & Herrmann, 1994, p. 141).

When meaningful learning takes place it implies that information has been well
represented and well connected. Our knowledge is represented in patterns due to neural
activation of the numerous interconnected brain cells. “The strength of these
connections is determined by experience and learning” (Solso, 1994, p. 262). The
greater the connections, the greater the understanding (White, 1988). When material is presented and never rehearsed or mentally pictured, it is soon forgotten. This may be due to the limited capacity of the short-term memory.

In 1956, George Miller wrote one of the most famous articles in the annals of psychology and gave it the title, “The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information.” In this article Miller wrote about the results of tests he performed on the human memory span. He repeatedly found that normal adults remembered about seven items. Miller coined the term “chunk” and claimed that organizing information into groups or clusters efficiently would increase the amount of information one could remember. Finding meaningful relationships between pieces of information reduces the amount to be remembered (Miller, 1956). When information is regrouped into integrated well-connected units, it is stored and retrieved more efficiently than are isolated bits of information. Chunking could be used to increase the normal memory span (Bruer, 1994; Readence, et al, 1981; Searleman & Herrmann, 1994). Searleman & Herrmann (1994) point out that “memory performance is usually enhanced when stimuli to be remembered are either familiar, frequent, related to each other, or concrete, and especially if these attributes are combined” (p. 30).

Searleman & Herrmann (1994) refer to encoding which involves transforming information into a form which a person is able to retain. Organization is a way to enhance the encoding process. George Mandler, one of the earliest and strongest adherents of this view, wrote that “…to organize is to memorize…memory and organization are not only correlated, but organization is a necessary condition for
memory" (Searleman & Herrmann, 1994, p. 82). Organizational processes such as
"chunking" greatly enhance the ability to encode. Time is often limited in the
classroom and good organization is necessary. When meaningful chunks of information
are well connected to other important concepts, there are more possible ways to recall it
(Bruer, 1993). The more contexts, the easier it is to recall the information and its
meaning (White, 1988). "An integral part of answering a question is hunting for the
links between isolated bits of information" (Robinson, 1993, p. 104).

**A Hierarchy of Learning**

Novak & Gowin (1984) researched how students acquired science concepts and
were troubled over the fact that most paper-and-pencil tests did not capture the child’s
knowledge. "They become conscious of the fact that the meaning a child acquires for
any concept is evidenced not as all-or-none acquisition or failure to acquire, but rather a
growing set of propositional links between the concept of central concern and other
related concepts. It was also evident that some students acquired faulty linkages" (p. 95).
This acquiring of faulty linkages led to the devising of assessment tools that
would recognize these changes in students’ cognitive structures, which became known
as concept maps. Concept maps were used not only as evaluation tools but also as
organizational tools designed for meaningful learning. Learning involves decision
making about key concepts, reasoning, searching out related concepts, constructing
propositions, and using good linking words. Learning involves helping students build
concepts in a hierarchy of organization which go from general or more inclusive to
specific which is less inclusive (Ausubel, 1963, 1968; Mintzes & Wandersee, 1998;
Novak & Gowin, 1984).
"In an attempt to help learners organize, abstract, and reflect upon expository information, graphic organizers have emerged as a basis of some successful learning strategies" (Trowbridge & Wandersee, 1998, p. 98). There are various types of graphic organizers, among them Roundhouse diagrams and concept maps. Graphic organizers represent a way that students and teachers can communicate about thought processes which are put into a concrete form. Graphic organizers are used to make the mind's work visible (Clarke, 1990). The graphic organizer can be an excellent mechanism for defining related topics (Readence et al., 1981). One of the advantages of graphic organizers is that they help teachers to organize and clarify information for their own purposes. Graphic organizers can be used as either preteaching or postteaching strategies, or as evaluation tools (Novak & Gowin, 1984; Readence et al., 1988).

Graphic organizers serve as tools of metacognition. Metacognition is "awareness and self-control over one's own thought processes" (Wittrock, 1994; Gunstone & Mitchell, 1998). This strategy often increases transfer of science learning and facilitates conceptual change (Wittrock, 1994, p. 30). The primary goal of an educator is to teach students lessons in the classroom which can eventually be applied in the real world. Strategies which can help to enhance the learning of science in the classroom will increase confidence and decision making in real-life situations.

In graphic construction one must consider research on visual processing which involves the eye-brain system.

Much of what we call vision occurs not just in the eye, but in the cerebral cortex of the human brain. The visual primitives, which include such characteristics of the visual image as lines, edges, and shapes are later analyzed in terms of basic...
contours such as vertical and horizontal lines, angles, and curved lines. Ultimately, such features are compared with associations to prior knowledge and the cerebral cortex interprets what our eye detects. (Trowbridge & Wandersee, 1998, p. 109)

If graphic organizers are constructed well using simple lines which are clear and not too close together, they can serve to enhance the cognitive process, which will in turn enhance the ability to encode information, thus making it easier to recall.

Understanding the way the brain organizes the information from these incoming visual patterns is fundamental to the understanding of cognition. The German word “Prägnanz” means “pregnant with meaning” and can be applied to a well-shaped figure. Geometrically regular figures such as circles are referred to as stable figures. Our mind seeks out this type of two-dimensional figure in the environment. Solso (1994), claims that:

Presently cognitive psychologists are searching for universal laws and principles of how the mind perceives reality, stores information and reacts to environmental forces. The perception of simple forms is now seen as an important link in the chain of knowledge. (p. 99)

The Roundhouse Diagram

There is a great variety of graphic organizers which may serve as useful tools in the science education classroom. For the purpose of this study, I focused on the Roundhouse diagram, a new metacognitive strategy proposed by Wandersee (1994). “Roundhouse diagrams are named after the circular buildings with central turntables that are used by railroads for housing and switching locomotives” (Trowbridge & Wandersee, 1988, p. 105). Wandersee introduces the diagram with the center representing a conceptual turntable. The diagram contains seven outer sectors which is in line with George Miller’s psychological research on short-term memory capacity.
The student begins using the diagram at the 12 o'clock position and proceeds from segment to segment in a clockwise direction. The diagram is based on Constructivist principles. Students are asked to construct these diagrams in order to break down difficult concepts, to order a sequence of events, or to use for learning a list of steps for solving a problem. The diagram can even serve as a way to follow directions on how to use different scientific tools. An example of an author-made Roundhouse diagram has been provided for the reader depicting the advantages and features of the Roundhouse diagramming method (see p. 25). The center of the conceptual turntable has a line through it which is optional and can be used to divide a theme or topic or to place opposing ideas within a central area. Each sector should contain a “chunk” of information which, if efficiently constructed, could link several ideas in one diagram. Along with each chunk of knowledge, the students are asked to draw an icon which should link directly with that chunk of information. “The iconic features of the diagram can significantly improve science content recall, in comparison with other diagrams containing only text” (Trowbridge & Wandersee, 1998, p. 106).

The Roundhouse diagram is designed and based on research in neuroscience and visual cognition. The diagram links meaningful information and can be used as a way to construct knowledge as well as an evaluation tool. Reconstructing knowledge is an effective encoding strategy and enhances retrieval of information. The circular shape and simple lines used in this diagram make it pleasing to the mind and useful in the process of forming a mental picture.

Interview tasks were determined with students as a way to obtain information regarding the students’ work on the Roundhouse diagrams. The interview format was
highly flexible, depending on the student’s work as well as his or her answers to specific questions. The interviewer/researcher used the interview method in order to observe and gain knowledge regarding the students’ cognitive structure. The interviewer questioned concepts in the diagram in order to ascertain whether the learner held any misconceptions regarding the topic under study. The principal objective of an interview should be to determine what the learner knows about a given body of knowledge (Novak & Gowin, 1984).

The primary objective of the school environment is to transmit important subject matter to the learner effectively and meaningfully so that the learner eventually is able to apply this knowledge outside the classroom. Instruction should provide opportunities for creative endeavor rather than centering on memorizing facts (Barman et al., 1982). Learning is much more complicated than drilling facts accumulated in textbooks. Comprehension of the world around us requires deep understanding. Meaningful learning involves a study of how the mind works—how we encode, interpret, and acquire information. This present study reflects a concern for students’ conceptual difficulties. Wandersee’s research indicates that “students appear to benefit from this technique when they use it to represent procedures in their laboratory science reports” (Trowbridge & Wandersee, 1998, p. 106).

**Related Terms**

The purpose of the present research was to examine the use of Roundhouse diagrams on students’ learning in a middle-level science classroom context. For the purposes of this study, the following terms were defined:
Associations: According to Webster's Dictionary (1981), associations are connections of bits of knowledge. Associating is relating and using what we already know to make sense out of what we are trying to learn. Associations are often sensed by the learner as predecessors to meaningful learning.

Attention: Webster's Third New International Dictionary (1981) refers to attention as (1)[a] a condition of readiness, applying the mind to an object of sense or thought; [b] selective narrowing or focusing of consciousness and receptivity; (2) observation, notice, consideration with a view to action.

Chunking: According to Searleman and Herrmann (1994), “chunking is the process of combining information into meaningful clusters for storage in Short Term Memory” (p. 376). According to Readence and associates (1981), “chunking is a type of mental organization in which related bits of information are processed into a single unit” (p. 219).

Cognition: Webster’s Dictionary (1981) refers to cognition—(to become acquainted with, to know) as the act or process of knowing in the broadest sense: an intellectual process by which knowledge is gained about perceptions or ideas.

Concept Map: A concept map, according to Novak & Gowin (1984), “is a schematic device for representing a set of concept meanings embedded in a framework of propositions” (p. 15).

Concepts: According to Webster’s Dictionary (1981), concepts are abstract ideas, categories, classes of objects, events, or ideas that are illustrated by examples and defined by common characteristics. According to Novak and Gowin (1984) “a concept is defined as a regularity in events or objects designated by some label” (p. 4).
Conceptual change: According to Gunstone (1994), “Conceptual change as we currently conceive it, involves the learner recognizing his/her existing ideas and beliefs, evaluating these ideas and beliefs (preferably in terms of what is to be learned and how it is to be learned), and then personally deciding whether or not to reconstruct these existing ideas and beliefs. The reconstruction may lead to replacement or additions” (p. 132).

Constructivism: According to Tippins (1993), “constructivism refers to creating a classroom environment which maximizes social interaction between learners such that they can negotiate meaning, and provides a variety of sensory experiences from which learning is built” (Tobin, 1993, p. 7). According to Gunstone, (1994), “constructivism means that the learner constructs his/her own understanding from the totality of the experiences which he/she sees as relevant to the concept, belief, skill, etc., being considered” (p. 132).

Creativity: Webster's Dictionary (1981) defines creativity as the quality of being creative: ability to create. Creative: (1) having the power or quality of creating; given to creation; (2) Productive; (3) Having the quality of something created rather than imitated or assembled; imaginative as in art or writing. According to Novak and Gowin (1984), “creativity refers to new relationships, new meanings, and reconstruction of original work. Substantial, novel integrative reconciliations are the major product of creative minds” (p. 104).

Elaboration: According to Mintzes and Wandersee (1998), gradual elaboration and clarity of meaningful concepts occurs during the process of subsumption where less inclusive concepts are linked to more general parts of the learner’s cognitive structure.
Encode: According to Webser’s Third New International Dictionary (1981), encode means “to transfer (as a body of information) from one system of communication into another; to convert into code.” According to Hohn (1995), “encoding is the process of placing new information into the information processing system so that it is capable of storage in the long-term memory” (p. 203). According to Searleman and Herrmann (1994), encoding refers to “the phase of the memory process that involves transforming information into a form that can be retained” (p. 378).

Generation: According to Wittrock, (1994), generation is to “learn science with understanding, students generate a model or an explanation that organizes information into a coherent structure, and that relates the information to their knowledge and experience” (p. 33). “A generative learning model consists of four functional, cognitive processes: (1) knowledge, experience, and conceptions; (2) motivation and attribution; (3) generation; (4) metacognition” (p. 32).

Graphic Organizer: According to Readence and associates (1981), “a graphic organizer is a visual aid which defines hierarchical relationships among concepts and which lends itself to the teaching of technical vocabulary” (p. 221). According to Cassidy (1989), “a graphic organizer is a cognitive map in which important aspects of a concept, topic, or unit of study are identified and arranged in a visual pattern with appropriate verbal labels” (p. 34). Not all graphic organizers have labeled links, which shows that it is a broad term that includes everything from knowledge webs to concept maps to semantic networks.
**Imagery:** According to Hohn, (1995), “imagery is a process that contributes to encoding. Imagery consists of transforming verbal or written information into a visual form in which the mental image includes the information to be remembered” (p. 205).

**Information-processing/cognitive approach:** According to Searleman and Herrmann, information processing is “the theoretical view that assumes that cognitive processes (like memory) involve a series of interrelated mental operations and that people are actively manipulating and using strategies to process information” (p. 380).

**Integrative reconciliation:** According to Mintzes and Wandersee (1998), “this process occurs during meaningful learning where there is an explicit delineation of similarities and/or differences between related concepts. This forming of cross-connections between related concepts develops well-integrated knowledge structures” (p. 40).

**Metacognition:** According to Gunstone, (1994), metacognition is a multifaceted concept. “Learners are appropriately metacognitive if they consciously undertake an informed self-directed approach to recognizing, evaluating, and deciding whether to reconstruct their existing ideas and beliefs” (p. 133). “Metacognitive learning is awareness and control over one’s thought processes during learning. Metacognition increases transfer among students of different abilities and across subject matters, including science. These strategies increase the transfer of science learning; and they facilitate conceptual change” (p. 30). According to Trowbridge & Wandersee (1998), metacognition is “the process of conscious and intentional mental reflection upon and restructuring of one’s experiences” (p. 96).

**Metalearning:** According to Novak & Gowin (1984), “metalearning refers to learning that deals with the nature of learning, or learning about learning. Our experience with
metalearning began when the graduate students who were working with us recognized that the concepts and methods we were using in our research were helping them learn how to learn” (p. 9)

**Misconception**: (alternative conception or naïve conception) According to Novak & Gowin (1984), “misconception is the term commonly used to describe an unaccepted (and not necessarily wrong) interpretation of a concept illustrated in the statement in which the concept is embedded. The expressed meaning is not, however, a misconception to the person who holds it, but a functional meaning. Partly for this reason, misconceptions are remarkably stable and may persist for years. Research suggests that the best method for correcting a misconception is to identify one or more missing concepts that, when integrated into the individual’s conceptual framework, will obliterate the misconception” (p. 20). “Misconceptions are defined as paradigm-specific, limited or inappropriate propositional hierarchies” (Novak, 1984). Alternative conception dignifies the learner’s current knowledge by implying it works in some situations but not others and thus signals indirectly that it is not the current scientifically valid view. Alternative conception is the term most accepted today.

**Progressive differentiation**: According to Mintzes and Wandersee (1998), “progressive differentiation is the gradual elaboration and clarification of concepts meanings that occurs during subsumption and superordinate learning. Progressive differentiation typically results in increasing levels of hierarchy and branching of central concepts” (p. 40).
**Organization:** According to Hohn (1995), "organization consists of placing items into clusters or groups possessing a common characteristic. Organization is most effective in aiding memory when units are composed of easily identifiable elements" (p. 205).

**Propositions:** According to Novak & Gowin (1984), "Propositions are two or more concept labels linked by words in a semantic unit" (p. 15).

**Schema:** "Schemas are structured bodies of information that are stored in the long-term memory and allow inferences to be made about objects and events. The assumption is that these are so linked that potentially they can activate one another" (Hohn, 1995, p. 201). According to Searleman and Herrmann (1994), "schemas are mental representations of people, objects, situations, and events acquired through experience" (p. 140). Clark & Clark (1977) define schema as "a kind of mental framework based on cultural experience into which new facts are fitted" (p. 168). Schemata (the plural of schema) according to Readence and associates (1981), refer to a category system of the mind containing information about the surrounding environment.

**Schema Theory:** According to Readence and associates (1981), schema theory describes the process by which we add to (assimilate) or adjust (accommodate) our existing cognitive structure in the face of new or discordant information.

**Subsumption:** According to Mintzes and Wandersee (1998), "in the process of subsumption, new knowledge composed of more specific, less inclusive concepts, is linked to more general and inclusive concepts and propositions that are already a part of the learner's cognitive structure" (p. 40).
Transfer: According to the *Louisiana Science Content Standards* (1997), “transfer refers to the ability to apply a strategy or content knowledge effectively in a setting or context other than that in which it was originally learned” (p. 3).

**Overview of Dissertation Contents**

In summary, this Introduction presented the current need for reform in education, as well as the need for purposeful instructional activities in order to bridge the gap between how children learn and what is being practiced in the science classroom today. This process involved the effective use of cognitive processes in order to link what is learned in the science classroom to how students are using this knowledge in the real world. An emphasis was placed on meaningful learning to enhance greater understanding, which provides useful knowledge for problem solving in our complex society.

Graphic organizers have been introduced as metacognitive strategies which enable students to reconstruct knowledge, aiding in the encoding process so that information can be recalled more easily when needed to solve problems. The Roundhouse diagram, the focus of this study, has been established as an effective method for science teachers to use with middle school students as a way to visually access what the student already knows, as well as how the student connects this knowledge to other related areas.

The Review of Literature develops and provides a theoretical framework which supports the Roundhouse diagramming technique as a useful science teaching/learning strategy appropriate for the middle school science classroom. The literature research supports a Constructivist viewpoint for using this strategy as a successful method for
developing classroom instruction. The Methods section includes how the researcher determined that using Roundhouse diagrams does help middle school students better understand science concepts. The researcher collected and analyzed qualitative and quantitative data to determine the effectiveness of the Roundhouse diagram in a 6th-grade science classroom.

The Results and Discussion section presents a detailed examination of 11 Roundhouse diagrams and three wedges which were completed by the students in this 6th-grade science classroom. In-depth analysis is provided with a focus group of six students chosen for this study. This section includes tables based on student responses to evaluation checklists, as well as assessments given over science lessons based on the content in the Roundhouse diagrams. Statistical data and graphs are provided to show a comparison of students' science grades and Roundhouse diagram scores in order to gain insight into the effectiveness of the Roundhouse diagramming method of instruction.

The final section reveals conclusions based on the in-depth analysis provided in the previous section. Implications for teaching and learning science have been included, and suggestions have been made for future research.
Goals: To establish the advantages and features of using and constructing Roundhouse diagrams.

Figure 1. Advantages and Features of a Roundhouse Diagram
REVIEW OF LITERATURE

Introduction

In planning curriculum and instruction, objectives for middle school science should recognize the physical, intellectual, emotional, and social development of students. Students need to comprehend that science is part of our daily life, and it is imperative that they become acquainted with the contributions science can make to solving societal problems. It is the responsibility of every citizen to become scientifically literate so that effective laws and decisions can be made in relation to our society's values. Students need to be sensitized to the abuses as well as the contributions of science and technology (Voss, 1983; AAAS, 1993).

The 1996 Science Performance Standards (NAEP, 1997) were developed by educators, policy makers, curriculum experts, business persons, and members of the general public in an effort to assess what American students know. Results of these assessments of student achievement in the United States are reported annually in the NAEP report, known as "The Nation's Report Card." The NAEP is based on a framework consisting of two principles:

First, the framework recognizes that scientific knowledge should be organized to connect and create meaning for factual information and that the context in which knowledge is presented influences this organization. Second, the framework assumes that science performance depends on the ability to know and integrate facts into larger constructs and the ability to use scientific tools, procedures, and reasoning processes to develop an increased understanding of the natural world. (NAEP, 1997, p. 2)

These principles refer to organization, connectivity, meaningful learning, integration, reasoning processes, and the ability to see the parts of a whole. Learning involves mental organization. Learners develop schemas or structures of information.
which are stored in the long-term memory. These cognitive structures allow inferences to be drawn, making future learning possible. Roundhouse diagramming is a method for developing and organizing cognitive structures based on information learned in the classroom.

**Purpose of the Study**

The purpose of the present study was to examine the use of a metacognitive strategy, the Roundhouse diagram, to facilitate meaningful learning in the middle school science classroom. This research has focused on learner behavior while constructing Roundhouse diagrams as part of their science activities. Recent research in neuroscience, visual cognition, and psychology has generated many theories linking how the human memory uses encoding strategies which enhance retrieval of information.

The Roundhouse diagram is neurally inspired and based on psychological research and the processes in the visual information-processing system. The students constructed conceptual frameworks within the Roundhouse diagram and restructured information learned in class. Paraphrasing or chunking information into concise phrases was sequenced around the diagram and each concept was associated with an icon for encoding purposes.

To support this research, this chapter presents literature on (a) science learning, with an emphasis on meaningful learning, cognitive processes, constructivist principles and misconceptions; (b) metacognitive learning; (c) science instruction, specifically meaningful teaching, naïve science, and conceptual change; (d) metacognitive teaching strategies; (e) graphic organizers; (f) research studies using graphic organizers;

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(g) theories of learning; (h) the science of human cognition including the eye-brain system, the information-processing model, attention, the working memory, schemas, encoding, organization, imagery, elaboration, and conceptual models; (i) science and creativity; and (j) Roundhouse diagrams, the focus of this study.

**Research Questions**

The following research question and subquestions were used to guide this study:

1. Does constructing and using Roundhouse diagrams affect the meaningful learning of science concepts by middle school students?
   (a) How do students’ science concepts change as they become more proficient in constructing Roundhouse diagrams?
   (b) What problems do students encounter in mastering techniques associated with construction of Roundhouse diagrams?
   (c) How do students’ choices and drawings of iconic images affect their progress in meaningfully learning science concepts as they construct a series of Roundhouse diagrams?

**Science Learning**

“The single most important factor influencing learning is what the learner already knows. Ascertain this and teach him [sic] accordingly.”

(Ausubel, Novak & Hanesian, 1978, epigraph)

In our educational system today there are many ways to learn. There is rote learning, reception learning, and discovery or inquiry learning. The most powerful learning experiences are those which increase meaningful learning. New content becomes meaningful to the extent that it is substantively (non-arbitrarily) related to ideas...
already existing in the cognitive structure of the learner. For meaningful learning to occur, the material to be learned must have meaning, the learner must have relevant prior knowledge, and the learner must choose to incorporate new knowledge in a nonverbatim manner (Ausubel, 1963; Ausubel et al., 1978; Farmer, Farrell, & Lehman, 1991; Mintzes & Wandersee, 1998; Novak & Gowin, 1984; Wandersee, 1985).

In contrast, rote learning occurs when new content is arbitrarily (nonsubstantively) related to the existing cognitive structure of the learner (Ausubel, 1963; Ausubel et al., 1978; Farmer et al., 1991; Mintzes & Wandersee, 1998; Novak & Gowin, 1984; Wandersee, 1985). “Students who learn by rote tend to accumulate isolated propositions in cognitive structure rather than developing the strongly hierarchical frameworks of successively noninclusive concepts that are characteristic of meaningful learning. Rote learning does not require interacting with prior knowledge, it is simply obtained by verbatim memorization” (Novak & Gowin, 1984, p. 7). The limitations of rote learning are poor retention and the inability to use the knowledge for productive purposes such as problem solving (Mintzes & Wandersee, 1998). “Students who rely on rote learning may find themselves helpless. Memorizing is a strategy for taking in material that has no personal meaning” (Langer, 1997, p. 69). Students may know enough to pass with rote learning methods, but do not understand the material well enough to apply it outside of school. Teachers need to be selective about what they choose to teach and realize that teaching for meaningful learning of less material can be more beneficial, though it may be more time consuming (AAAS, 1989; Mintzes & Wandersee, 1998).
In the post-Sputnik era of curriculum reform, the two types of learning most represented in the educational system were reception learning and discovery learning. "Reception learning occurs when the intended learning is presented to the learner in the form of textbooks, lectures, etc. and the learner incorporates the content into his/her cognitive structure" (Farmer et al., 1991, p. 125). Meaningful learning is still possible with reception learning if the new content becomes substantively related to ideas existing in the learner's cognitive structure. The problem occurs when the learner has no prior knowledge related to the new content, or possesses misconceptions about the topic. At this point, the learner often resorts to rote learning which prevents meaningful learning from taking place (Wandersee, 1985; Smith, 1990).

Educators promoted discovery learning as a reform method by which meaningful learning could take place. Discovery learning, however, may be either meaningful or rote. In discovery learning "the learner must generate the desired content end-product or construct a missing interrelationship" (Farmer et al., 1991, p. 125). The end result depends on what kind of relationship was established between the new content and the prior knowledge structure of the learner. There are many times when a science lab is being conducted that the teacher tells the students what results they will obtain before they manipulate the experiments to find out the result. "In order for content to be meaningful the teacher must consider the characteristics of the content as well as the match between the new content and the student's existing mental structure" (Farmer et al., 1991, p. 126).

According to research of cognitive scientists, meaningful learning implies that information is well connected in the long-term memory. Cognitive processes, such as
memory, involve a series of interrelated mental operations. Richard Atkinson and Richard Shiffrin (1965; 1971) proposed that incoming information first enters the sensory register which contains information from the senses, and decays in a matter of seconds. Information which is further processed then goes to the short-term memory and finally to the long-term memory. Information encoded in terms of sound goes to the short-term memory and when encoded in terms of meaning, goes to the long-term memory (Mintzes & Wandersee, 1998; Searleman & Herrmann, 1994). This model of Atkinson and Shiffrin has been the most influential memory model.

George Miller's research on the short-term memory capacity revealed that the human memory could hold about seven "chunks" of information depending on the efficiency and organization of the information. If unrehearsed, this information decays within 30 seconds (Bruer, 1993; Mintzes & Wandersee, 1998; Searleman & Herrmann, 1994). In order for information to be processed in the long-term memory, there must be deliberate and conscious attempts to interpret, evaluate, compare and contrast new knowledge with existing knowledge and to establish connections between the two. It is this processing of information that invests new knowledge with its meaning and ultimately determines its idiosyncratic structure and potential usefulness to the learner.” (Mintzes & Wandersee, 1998, p. 43)

Cognitive science is the study of how the mind works and how we learn.

Research has revealed that students construct their own meanings from information regardless of how the teacher instructs. "The most important things students bring to science classes are their concepts" (Wandersee, 1985, p. 58). Students come into the classroom with a prior knowledge base which is often faulty (Connor, 1990; Smith, 1990; Wandersee, 1985). When the learner is exposed to new information, unless there exist multiple connections in cognitive structure to which it can be linked, the
information will more than likely not be remembered. Newly learned concepts need to be relayed to the learner in a variety of contexts because each student is unique in his/her existing cognitive structure. Varied teaching methods allow more opportunities for newly learned material to be connected to the student’s existing cognitive structure (AAAS, 1989). Effective learning could require the student totally to discard his or her previous concepts within a topic. “Research suggests that the best method for correcting a misconception is to identify one or more missing concepts that, when integrated into the individual’s conceptual framework, will obliterate the misconception” (Novak & Gowin, 1984, p. 20).

In order to identify missing concepts, a concept map or another type of graphic organizer, which shows a visual picture of what is in the learner’s mind, would be a suggested method to use. If misconceptions are not recognized and disproved visually, the learner may not be able to make sense of the new knowledge. Teachers can make use of a student’s misconceptions in class in order to see other perspectives, and the learner can correct the error. A graphic organizer can be used for this purpose.

“For many years science teaching has focused on ways to engage learners’ generative thought processes in the learning of scientific and mathematical concepts and principles that will transfer to facilitate related learning in science and to enhance problem solving in everyday situations” (Wittrock, 1994, p. 29). These thought processes connect to the learner’s experience, understanding, and metacognitive processes. Meaningful learning of concepts enhances the ability to transfer learning from the classroom to the real world. Students must be able to apply their knowledge as well as construct understanding in other areas. Recent cognitive research on science
teaching reveals the importance of “metacognitive learning, that is awareness and control over one’s thought processes during learning” (Wittrock, 1994, p. 30).

Traditional methods of learning what is in the textbook from the view of only one scientist do not effectively teach science to all students. Metacognitive strategies used in the science classroom increase the transfer of science learning and facilitate conceptual change (Wittrock, 1994).

**Metacognitive Learning**

“Metacognition may be defined as the knowledge and awareness of one’s own cognitive processes and the ability to regulate, evaluate, and monitor one’s thinking” (Bonds et al., 1992, p. 56). Learners who are metacognitive are involved with monitoring tasks in order to extend their own learning. Monitoring a task involves evaluating one’s work and asking questions such as: Does this make sense? What is the purpose of this task? Have I done what is necessary to achieve the purpose? Can I explain what I have done to another person? Extending one’s learning refers to linking what is being learned to previous knowledge about the topic (Gunstone & Mitchell, 1998; Novak & Gowin, 1984). Graphic organizers are an effective metacognitive tool a learner can use to visualize new connections which link to prior knowledge. The learner can ask questions such as: What specific changes can I link to my knowledge base? What have I learned? Have I answered what is needed to complete a new concept? Have I integrated new ideas properly?

Two behaviors must exist in the metacognitive process. First, the learner must have knowledge related to the subject matter under study or an understanding of the learning task. This knowledge can be ascertained by doing a graphic organizer or by
answering a series of questions regarding the topic. Second, the learner needs to know what is required to learn or understand the subject matter. "The learner may employ the following skills: checking, planning, selecting, self-questioning, introspection, and interpreting ongoing experiences" (Bonds et al., 1992, p. 56).

There are many metacognitive strategies that learners can use in the classroom such as:

1. Checking back—as a student reads, he/she can write questions about the material, then go back over the material and answer the questions.

2. Self-questioning—What is the main idea? What are the supporting details? What are the important names or terms being used?

3. Visual representation—Graphic organizers such as concept maps, story maps or Roundhouse diagrams can be used to break down important concepts into a visual picture.

4. "Acronymous Metacognitive Strategies"—(metacognitive strategies represented by acronyms). "One of the best known is the SQ3R approach developed by F. P. Robinson (1970)" S = Survey; Q = Question; R = Read; R = Recite; R = Review (Bonds et al., 1992, p. 57).

5. Re-reading—have the students read the material once, then have them re-read the material, but this time tell them they will be tested. (Bonds et al., 1992).

Students are often involved with learning tasks without questioning what they’ve been told to do. Educators are concerned with the fact that students do not remember what they have learned at school. There is much evidence, however, that students who think critically and can apply their skills outside the classroom are
students who have well-developed metacognitive skills (Costa, 1991). To develop these skills, students need to be guided and taught how to use metacognitive thinking tools.

**Science Instruction**

Teaching science usually begins with the child questioning observations about natural phenomena (AAAS, 1989). Teachers should begin with the child's reality, having them observe, describe, touch, question, and communicate about things in their environment. “We believe that human beings are meaning-makers; that the goal of education is to construct shared meanings and that this goal may be facilitated through the active intervention of well-prepared teachers” (Mintzes, Wandersee, & Novak, 1998, p. xviii).

Teachers use different strategies to teach science. Many teachers tend to lead away from subject matter by presenting numerous facts and definitions which are isolated and fail to give students deeper insight (Smith, 1990). Science teaching should not place an emphasis on accumulated knowledge and definitions of terms (AAAS, 1989). Teaching for understanding should be the goal for education, but developing understanding takes time. “The decision to encourage meaningful rather than rote learning is the most important decision a teacher can make” (Mintzes et al., 1998, p. xix). Viewing science learning as receiving and remembering information of individual facts to be recalled when needed is probably most common among teachers with weak science backgrounds (Smith, 1990).

Teaching strategies in most science classes involve a considerable amount of rote learning involving complicated definitions and an overabundance of material. Many times teachers place an emphasis on presenting large quantities of information
rather than quality of understanding (Conner, 1990; Mintzes & Wandersee, 1998). The result is ineffectual learning. This type of teaching approach does not facilitate the linking of concepts and very few students comprehend how an entire organism functions or how any parts of a whole operate.

In the late 1970s, research studies began involving students’ prior knowledge to instruction and how this affected the learning process. Since this prior knowledge was often not correct, it was referred to as misconceptions, alternate conceptions, or naïve science. Research has concluded that naïve science has the following characteristics:

1. starts early, before school begins, then continues lifelong;
2. subtle, and often missed by teachers unaware of it;
3. separable, that is, school answers are not merged with personal answers;
4. stable or robust, even after being disproved;
5. personal, each child has a different conclusion to the same experience;
6. incoherent and often contradictory. (Connor, 1990, p. 9)

“When students lack the relevant concepts necessary to link the new knowledge they encounter in classroom science lessons to their existing cognitive structure, meaningful learning cannot occur” (Wandersee, 1985, p. 554). Teachers need to realize that students come to class with naïve conceptions and need to consider how these students are thinking as well as how to change their thinking (Smith, 1990). “The difference between students’ ‘naïve’ conceptions and scientific alternatives represents what Hawkins (1980) calls ‘critical barriers’ to learning science, but they are also key to understanding. Teachers need to approach ‘naïve’ conceptions and teach for conceptual change” (Smith, 1990, p. 43). Many students who don’t understand science and don’t correct these misconceptions eventually resort to rote memory in order to keep up in class.
Teachers need to be able to construct questions that bring out alternative views and challenge what the student believes in. These students need to be directed through application, evidence, and argument. Teachers need topic-specific knowledge in order to be effective with this strategy. Research has found that many teachers possess naïve conceptions similar to their own students (Connor, 1990).

One of the best methods for detecting misconceptions is the interviewing process (Connor, 1990). Using graphic organizers as vehicles in the understanding of a child’s concept is a meaningful approach to learning science. Novak (1977) invented the concept map as an assessment tool to use with his audiotutorial science lessons. The concept map represented the child’s cognitive structure and has been proven useful for identifying alternative conceptions (Novak & Gowin, 1984; Trowbridge & Wandersee, 1998). Incorrect linkages, missing elements, or poor connections in the hierarchy can indicate a student’s lack of understanding. Graphic organizers such as concept maps or Roundhouse diagrams serve as a means for detecting misconceptions early on in the learning process. Teachers who teach for conceptual change place emphasis on identifying students’ misconceptions and breaking down barriers which block learning from occurring. This way of teaching requires knowledge of students’ naïve conceptions as well as useful teaching strategies to help promote the necessary changes (Smith, 1990).

There is a great amount of discrepancy found between what the science education community has advocated and what actually exists. For years, science educators have tried to educate students in hope of developing inquiry-based learning. "Within general inquiry are included strategies such as problem solving, uses of
evidence, logical and analogical reasoning, clarification of values, decision-making, and safeguards and customs of inquiry" (Welch, 1981, p. 54). Today, years later, the topic of inquiry-based learning continues to be addressed. “For students to learn science, the teaching of science should happen in the context of scientific inquiry” (Abrams, 1998, p. 307). The teacher would need to be highly trained in these methods and the school would need a well-equipped laboratory. The problem exists because many teachers are not prepared to teach inquiry-based learning methods and many students do not have the abilities to learn this way (Welch 1981).

Students are naturally curious and wonder about the world around them. Teachers need to encourage curiosity, creativity, and imagination when investigating scientific endeavors. It is vital to the learning process that students are allowed to make mistakes. Students need to be taught how to think first and then construct good questions to ask their teachers or peers. Teachers should encourage questions and should guide students in finding answers. “In the science classroom, wondering should be as highly valued as knowing” (AAAS, 1989, p. 204).

There are many current reform projects in science education, such as Project 2061, which claims that the only way lasting reform will occur is when the “people who operate the schools become part of the creative process” (AAAS, 1993, p. 379). If teachers are ready for these changes, we may avoid repeating mistakes of the past. It is the teachers who have the primary responsibility for implementing and planning the curriculum. New instructional methods as well as new resources must be employed because the traditional textbooks alone are not enough to make the changes. Because the public wants reform does not assure that reform will happen.
**Metacognitive Teaching Strategies**

The goal of every science teacher should be to engage learners in constructing meaning for concepts which will transfer, and help them to solve problems in everyday situations (AAAS, 1989). Research on cognition in science teaching reveals the critical importance of teaching comprehension and metacognitive strategies. Wittrock (1994) states the importance of metacognition in relation to conceptual change in science classes. "Metacognition increases transfer among students of different abilities and across different subject matters, including science. The strategies increase the transfer of science learning, and they facilitate conceptual change" (p. 30). Science teaching involves "(a) learning students’ alternative conceptions, beliefs, attributions, and related cognitive and affective thought processes, and (b) teaching students to use their knowledge, beliefs, and metacognitive thought processes to generate new, fruitful, and transferable concepts that have personal and everyday meaning and significance" (Wittrock, 1994, p. 31).

A "generative" teaching model for conceptual change focuses on cognitive and neural processes learners use to comprehend science. Students must themselves actively construct meaning from sensory input. "The model consists of five functional cognitive processes: (a) knowledge, experience and conceptions; (b) motivation; (c) attention; (d) generation, and (e) metacognition" (Fensham et al., 1994, p. 32).

1. Knowledge, experience, and conceptions—After learning the student’s conceptions and beliefs about science, it is important to teach students that generative learning is more than reading and memorizing and that it requires deep understanding. This can be done by constructing graphic organizers and structuring a visual picture of...
what we know about a topic. The teacher can then do an interview with the student and ask questions about the cognitive structure. Searleman and Herrmann (1994) refer to a person's knowledge base as being the foundation for future learning. "How well a person learns (or encodes) something often depends on how much the person already knows about it" (p. 85).

2. Motivation—If students are motivated toward a purpose, they become responsible for their own learning and experience frequent success with science concepts. Searleman & Herrmann (1994) support the idea of personal motivation as a factor in recall. At the same time people are motivated not to remember particular things. In the classroom, it is important to motivate students to become involved with their own interests and thus make learning a positive experience. This can be done by making learning relevant to the learner by using the student's personal experience in a learning situation.

3. Attention—students should learn to focus their attention on relating science to everyday situations. Searleman & Herrmann (1994) compare attention to the lens of a camera. If the camera is not focused, the details are blurred. "Because of a lack of proper attention to the task or information (such as information presented in a lecture), the person never really learned (encoded) the material in the first place" (p. 81).

4. Generation—Teach the students to generate useful scientific models that enhance understanding while they also relate to student knowledge and experience. Searleman & Herrmann (1994) speculate on what is called the generation effect. They point out that "People pay more attention to items that they generate themselves than items that are merely presented to them" (p. 90). If this is true, self-generated items are
processed at a deeper level and this is why they are easier to recall. In a classroom situation, students are often asked to recreate material in their own words because paraphrasing helps them process information at a deeper level. Organizational tools such as outlining, concept mapping, and Roundhouse diagrams are metacognitive tools that help students learn (encode) easier.

5. Metacognition—Teach students awareness and encourage their ability to use their knowledge to solve everyday problems (Wittrock, 1994).

Research shows it is possible to teach metacognitive skills. Basic metacognitive skills involve prediction of one’s problem-solving ability (Did it work?), reasonableness of one’s actions (Does it make sense?), and evaluating progress (How am I doing?) (Bruer 1993). Students use metacognitive skills when they play games by developing strategies for their next move as well as plans for a solution. These same skills can be transferred to a learning situation.

Using graphic organizers is a good way to visualize a learner’s thinking pattern. In problem-solving situations, the teacher can model metacognitive strategies for the learner. Eventually the student will be able to take over. With a graphic organizer such as the Roundhouse diagram, the teacher can visualize the students’ next step and guide the process (Bruer 1993).

**Graphic Organizers**

Too often students are unable to master the individual elements of a topic without truly grasping the “big picture.” If students fail to understand how the elements relate to one another, they cannot truly comprehend the topic. Educators many times expect students to perform, but fail to provide them with strategies they need to succeed.
Graphic organizers are effective tools for helping students see how individual ideas or elements connect to form a larger whole. A graphic organizer provides a structure to help students read and learn effectively from their textbooks, especially in a science classroom where the amount of information to be learned can be overwhelming.

Many studies have investigated the graphic organizer as a means of facilitating understanding (Bean, Singer, Sorter & Frazee, 1986; Griffin, Malone, & Kameenui, 1995; Novak & Gowin, 1984; Simmons, Griffin, & Kameenui, 1988; Trowbridge & Wandersee, 1998). The graphic organizer was originally called a structured overview and was developed as a method to teach Ausubel's theory of meaningful learning. Ausubel called this method an advance organizer because the teacher used it to organize a lesson and presented it in advance. Ausubel (1963) promoted the use of advance organizers as a way to access a student's prior knowledge. Ausubel believed that if existing knowledge is well organized, new knowledge can more easily be related to the existing structure (Griffin et al., 1995). The advance organizer was an introductory prose passage that included the most important content and was originally intended as a device teachers used to help students. Years later, in 1974, Barron and Stone developed what came to be known as a graphic postorganizer and hypothesized that student participation in construction of the organizer would be the best method of integrating new information with prior knowledge (Griffin et al., 1995).

Readence and associates (1981) introduced five dominant visual organization patterns which exist in the graphic organizer and were used as a basis for this study.

1. Cause/Effect: The interrelationship of two or more events, objects, or ideas (connects reasons with results);
2. **Comparison/Contrast**: The similarities and differences among two or more events, objects, or ideas (can be advantages or disadvantages);

3. **Time/Order**: The chronological ordering of two or more events, objects, or ideas (can be a sequence of events);

4. **Simple Listing**: Two or more objects, events, or ideas are listed sequentially according to the author’s criteria for organization (can be directions for a lab experiment);

5. **Problem/Solution**: The interaction of two or more factors, one citing a problem and another providing a potential answer to that problem (can answer a question). (p. 136)

Graphic organizers are tools which can aid in perceiving the student’s knowledge base, but the main goal is to have students generate these organizers from their own knowledge base as they become familiar with material being learned. Student-constructed organizers contribute more to comprehension than teacher-devised organizers (Moore & Readence, 1984; Readence et al., 1981; Robinson, 1993). Graphic organizers “make use of established knowledge to increase familiarity and learnability of new material” (Ausubel, 1963, p. 82). Organizers emphasize main ideas and omit less important information. Organizers increase the difference between newly learned material and conflicting ideas or misconceptions which may exist (Ausubel, 1963; Novak & Gowin, 1984).

Graphic organizers can help teachers to visualize how students think as they struggle with information in the textbook and try to work through problems. Graphic organizers can be created using lines, circles, pictures, and text. Using different patterns, teachers and students can organize and manipulate the subject in different ways in order to better understand relationships within the context (Clark, 1991).

There are many different kinds of graphic organizers to fit different patterns of thinking. Frames for inductive thinking help students organize and analyze facts.
Frames for deductive thinking help students relate, predict, plan, and solve problems. When students internalize information and gain confidence in their ability to organize concepts, they may eventually dispense with creating graphic organizers (Clarke, 1991; Trowbridge & Wandersee, 1998). The goal for teaching graphic organizers is not just to teach students to think, but to enhance their problem-solving skills. Designing graphic organizers should help students become strategic thinkers. We improve our thinking abilities by restructuring information over and over again, changing the pattern and constructing new results (Clarke, 1991; Robinson, 1993).

Using graphic organizers allows students to be responsible for their own learning and to become independent thinkers (Novak & Gowin, 1984; Trowbridge & Wandersee, 1998). Much of what has been researched about graphic organizers involves strategies to help students learn and to aid educators in organization of material in textbooks. The learner becomes responsible and is able to see that questions can be answered in more ways than one (Fensham, Gunstone & White, 1994).

Novak & Gowin's (1984) research on graphic organizers consisted of the development of the concept map and the Vee diagram. The Vee heuristic, developed by Gowin in 1977, was first used with students in 1978 as a way to construct meanings from knowledge. The elements of the Vee diagram interact with each other in the production of knowledge. Concept mapping is usually introduced before the Vee diagram so that the students will already be familiar with the concepts to be used in the diagram itself (Novak & Gowin, 1984). The concept map was first constructed by Novak in 1977 and was used as a way to evaluate clinical interviews in his science education research group. "Gradually, these researchers came to understand that a
concept map was equally valuable as a metacognitive device when constructed by science learners themselves" (Trowbridge & Wandersee, 1998, p. 96).

Concept maps represent relationships between concepts in the form of propositions. "Propositions are two or more concept labels linked by words in a semantic unit" (Novak & Gowin, 1984, p. 15). Concept maps focus on main ideas within a topic which go from general to more specific in a hierarchy of concepts. They are used as learning tools but are also powerful evaluation tools. When a learner constructs a concept map, misconceptions become evident when connecting two concepts. Concept maps, as other graphic organizers, present relationships between concepts in a visible fashion. When concepts are put into a concrete form, meaning can be reconstructed by the learner. "A concept map becomes a schematic device which summarizes what has been learned" (Novak & Gowin, 1984, p. 15).

"As students create strategies for complex thinking, they may also see that thinking is in a circular form" (Clarke, 1991, p. 227). Our visual field is circular and our mind seeks out stable figures of which the circle is the most perfect (Solso, 1994). Circle diagrams provide a basis for many sophisticated techniques such as Venn diagrams developed by John Venn and used by Gunstone (1980), concept circle diagramming proposed by Wandersee (1987), and Roundhouse diagrams proposed by Wandersee (1994).

Science education research has shown a concern for the processes of science learning and evaluation techniques used to test student understanding of difficult concepts. Graphic organizers present a method which will help students become scientifically literate (AAAS, 1993) and help students think critically and
independently. The Louisiana Content Standards (1997) stress the importance of generating and linking knowledge so that students will be able to transfer knowledge outside the classroom environment. Based on the complexity of scientific information, heavy vocabulary demands, and the dominance of complex textual information, graphic organizers present a way to restructure and organize knowledge so that it can be understood and made meaningful to the learner.

Research Studies Using Graphic Organizers

The use of graphic organizers to facilitate comprehension has been a research topic of many investigations. The research articles reviewed for this summary involve all grade and content areas. All the studies reviewed are from the past two decades. Improvement of comprehension and learning has been the focus since Ausubel developed his advance organizers in the 1960s. More than 20 different graphic organizers have emerged since then, most of these rooted in Ausubel's theory of meaningful learning.

Research conducted by Hawk (1982) has shown graphic organizers to be significantly beneficial to student achievement in a middle school life science classroom. The graphic organizers examined in this study used pictures and visual graphics. The purpose of the study was to determine the efficiency of graphic organizers in facilitating learning of above average students in heterogeneously grouped 6th- and 7th-grade life science classes. The results revealed that the 213 students in the classes which used the organizers had an adjusted mean difference between the pretest and posttest of 21.38, while the 177 students who did not use the organizers had an
adjusted mean difference of 12.07. Thus the 9.31 difference between the two treatments was statistically significant.

Hawk (1986) gave five reasons why she believed this study enhanced learning:

1. the organizer provided an overview of the material to be learned,
2. the organizer provided a framework to help the learner assimilate and organize new information,
3. the organizer cued the student of what to look for in terms of cause and effect and sequence of events,
4. as a review instrument the organizer strengthened what was learned, and
5. the organizer provided visual aids and helped construct concepts for learners. (p. 86)

Thomas Bean and others (1986) were interested in comparing the effects of outlining as a method of instruction versus the graphic organizer on 10-grade students' reading comprehension in world history. They also wanted to compare attitudes since attitude often determines success (Barman et al., 1982, Bean et al., 1986, Bruer, 1993). This 14-week study found that students who used graphic organizers and who received training in summarization and question generation scored significantly higher than groups instructed in outlining or graphic organizers alone. Students in the graphic organizer group displayed a significantly more positive attitude toward the method of instruction than the outline groups. These students were average to above average and were eager to expand the metacognitive strategy. Some of the students reported that they were able to transfer the use of the graphic organizer method to complex strategies in their biology classes. Dunston (1992) critiqued this particular study by citing that the 14-week instructional time was very lengthy and there may be problems with generalizability since that length of time may not be available in other secondary school
settings. She also criticized the fact that students with the highest level of achievement had previous instruction time for 14 weeks in summarization techniques (p. 61).

Deborah C. Simmons (1988) and others investigated the effectiveness of three instructional procedures for facilitating 6th-graders' comprehension and retention of science content. Teacher-constructed graphic organizers were used before text reading, after text reading, and traditional instruction was used before and after text reading. The results of this experimental study involving 49 students suggested that teacher-constructed graphic organizers, regardless of position, are no more effective than traditional instruction in increasing comprehension and retention of science content area information. Other studies have also indicated that student-constructed organizers are much more effective in contributing to a student's comprehension than teacher-constructed organizers (Readence & Moore, 1980; Readence et al., 1981).

Spiegel and Barufaldi (1994) proposed a research study to determine the effects of text structure awareness and graphic postorganizer on recall and retention of science knowledge. Community college anatomy and physiology students took part in an eight-week study skills class. The class used graphic postorganizers to construct five science textbook text structures; cause and effect, classification, enumeration, generalization, and sequence. As previously stated, most science classrooms are dominated by textbooks which are usually complex and difficult to comprehend (Barman et al., 1982; Fensham et al., 1994; Harms & Yager, 1981; Hurd, 1983; Readence et al., 1981). Constructivist theories of learning view the learner as one who actively constructs knowledge based on prior conceptual frameworks and who is dependent on metacognitive processes (Gunstone, 1994; Gunstone & Mitchell, 1998; Novak &
This study actively involved students who participated in combined strategies rather than just postorganizers. The results revealed gains in recall and retention due to training in recognition of text structures plus generating the graphic postorganizers. Using both strategies increased recall and retention over other techniques such as underlining, re-reading, or highlighting used by untrained students.

Gunstone & White (1986) assessed students' understanding of science content using Venn diagrams. This study revealed students' perceptions of connections between concepts by having them drawing Venn diagram which "represented relations between particular classes of concepts" (Gunstone & White, 1986, p. 151). Gunstone (1980) used Venn diagram questions to determine comprehension of senior high school physics students studying kinematics and dynamics concepts. These Venn diagram questions are useful as powerful probing tools in interviews to assess understanding. In interviews one can ask students directly why they constructed the diagram in a particular way, to help detect misconceptions. The task was expressed in this form: "draw a diagram to show the relations you see between these concepts/ideas" (p. 155).

In conclusion, Venn diagrams work best when used for purposes of syllogistic reasoning in order to create a meaningful relationship. In this study Venn diagrams were found to be powerful devices to prove understanding and provide stimuli for class discussion. They also took only a short time to complete, and were best used with students from mid-elementary levels and up.

Griffin and associates (1995) researched the effects of graphic organizer instruction on average 5th-grade students. This study involved two questions: (a) Does graphic organizer instruction facilitate comprehension, recall, and transfer of
information contained in an expository textbook? and (b) To what degree is explicit instruction necessary for independent generation and use of graphic organizers by students?" (p. 98). The study used nine graphic organizers based on the hierarchical relationships of main ideas within the passage. After four teacher-made organizers were presented, the students began constructing organizers independently. Scripts were written to the students with explicit instructions. After three days the scripts contained only critical procedures. There were five treatment conditions: (a) explicit graphic organizer instruction, (b) explicit instruction but no graphic organizers, (c) implicit graphic organizer instruction but no graphic organizer, (d) implicit instruction but no graphic organizer, (e) traditional basis instruction. After all the instructional sessions, free recalls were given to students to assess their immediate and delayed recall of the chapter. The results of the study revealed that explicitness and presence of graphic organizers best facilitated information retrieval for both immediate and delayed recall.

**Implications**

"Most research on graphic organizers has failed to simulate actual classroom learning. Typically, studies have used short, poorly organized text, single graphic organizers, and immediate tests measuring only factual knowledge" (Robinson & Kiewra, 1995, p. 455). A critique of graphic organizer research by Dunston (1992) raises questions about results of prior studies. One question she raises is that in many instances the "teacher/researcher-constructed organizers are designed to match the schema of the teacher/researcher and not that of the student" (p. 63). This idea brings up the question, of whether the appropriate graphic organizer is being introduced to the student in relation to the activity being performed by the student. Other factors to be
considered are the extent of the students' prior knowledge about the topic as well as how to evaluate student-constructed graphic organizers. The evaluation technique must be appropriate for the graphic organizer being used in the study. Another point is that whether a reasonable time period has been used to train students properly to use the graphic organizers (Dunston, 1992). Research in these problem areas is necessary to provide reliable information for future investigations using the graphic organizers.

**Theories of Learning**

The role of the teacher has changed to meet increasing demands, but the purpose of education is still the same—to impart new knowledge to the learner. Before there were textbooks, teachers used stories and pictures to communicate important concepts. Methods and resources have continued to undergo transformation over the ages. As educators, we can make use of the past and utilize past experiences with positive results. Teachers are crucial for this transformation to take place.

**Plato**

The idea of the importance of prior knowledge actually dates back all the way to Plato's time. Four hundred years before Christ, the Greek philosopher Plato was concerned with the same questions researchers are asking today—How do people learn? Plato had a "recollection" theory that the learner must have some prior knowledge in order to comprehend what is being presented. Plato believed that knowledge is innate and in place from birth. He believed the learner is an observer of reality. Learning was a process of remembering what the mind had already experienced. Teaching was helping another to recall past experiences. According to Plato, one must already know something in order to accumulate new knowledge (Phillips & Soltis, 1985).
Two thousand years later, at the end of the seventeenth century, the British philosopher John Locke tried to answer the same question—How do people learn? He developed a theory that greatly influenced the field of psychology. Contrary to Plato’s theory, Locke believed the mind was a blank tablet at birth but possessed the ability to learn. After one began to experience the environment with the senses, the mind retained the experience in the memory. Knowledge depended on prior experience. As one experienced life, ideas began to form. If one missed out on experiences, ideas lacked complexity. This may be why underprivileged children are low achievers in many instances (Phillips & Soltis, 1985).

Plato and Locke were philosophers, not psychologists, and their methods were not scientific. It was not until 1870 that modern experimental psychology developed. After the writing of Darwin’s Theory of Evolution in 1859, it became recognized that human behavior was similar in many ways to animal behavior. Research into how animals learn became the background for Behaviorism (Phillips & Soltis, 1985).

Behaviorism

John B. Watson wrote a famous article in The Psychological Review in 1913, “Psychology as the Behaviorist Views It,” which gave birth to the Behaviorist movement. Similar to Locke, Behaviorists believed that as humans interacted with the environment, they gained experience. Unlike Locke and Plato, Behaviorists were not interested in the origin of ideas. Their question was not how do humans learn, but instead how do humans behave? How do students behave so that they can learn? The mind was not observable so it was avoided, and instead, behaviors were observed. At
this time in Russia, Ivan Pavlov studied digestion in dogs and noticed that each time he fed them, they produced saliva. If he rang a bell at the same time, the dogs associated the bell with food and salivated. He discovered a certain stimulus produces a particular response. Watson believed this classical conditioning was the key to human learning. He called these behaviors "built in" natural responses (Phillips & Soltis, 1985).

E. L. Thorndike (1874-1949) studied the behavior of cats by trapping them in a box equipped with a device which allowed them to escape by touch. He developed his "law of exercise" which stated that the stimulus opened a nerve pathway to the brain which connected to the organ producing the response. His "law of effect" stated that because the response was pleasing to the animal, the animal continued to perform. This was called operant conditioning. In contrast, B. F. Skinner discovered that laboratory rats, repetitiously rewarded each time they performed, eventually stopped responding to the reward and no longer performed. He developed a way of shaping behavior with pigeons and applied it to the learning process of humans by using a teaching machine that rewarded students for correct answers and allowed them to move on to new material. Skinner believed that one could learn only from observable behavior, and that the inner workings of the mind could not be dealt with by scientists (Phillips & Soltis, 1985).

**Gestalt Psychologists**

A variety of theoretical perspectives in the field of memory began to emerge at this time. Largely because of the Gestalt psychologists, society came to accept the view that "context, organization, and meaning were very important factors for both learning and memory" (Searleman & Herrmann, 1994, p. 17).
One of the early Gestalt psychologists, Wolfgang Köhler (1887-1967), and others, discovered flaws in the experiments of Thorndike, who was known for his studies with cats. Thorndike’s methods of trapping the cats did not allow the animals to think intellectually in order to break out of the box. His conclusions were based solely on a mechanical response. He merely imprisoned the animal and consequently the animal was not allowed the use of reasoning to escape. Köhler performed similar experiments and found that learning takes place through acts of insight which require the learner to become familiar with the problem in order for it to be solved. For these Gestalt psychologists, meaningful patterns existed from within. For them, the key to learning was connected to our senses and our nervous system (Phillips & Soltis, 1985). The Gestalt psychologist, whose name came from the German word close to the English word “configuration,” believed that “the key to understanding perception was to be found by studying the way the brain organizes basic stimuli (Solso, 1994, p. 89).

John Dewey

Throughout the history of America, the transformation of science education has centered around societal issues. Developments in technology increased and as a result scientific knowledge and literacy became necessary. As the population multiplied and a greater number of people migrated to the city, many new jobs opened and industry flourished in the nation. The world changed, the workplace changed, jobs changed, and the need for education changed.

In the late 1800s, a knowledge-oriented model referred to as “elementary science” was taught at the elementary school level and reflected an interest in technological advances. Another model existed as well, which represented more of a
personal interest in nature, the environment and the enrichment of life. At the secondary level of education, the knowledge model of science became the most widespread. In 1938, a leader and scholar in the educational field emerged named John Dewey. He highly criticized the knowledge model and advocated that science should be functional, related to solving problems within society, and centered on the student (Bybee, 1993). As early as 1916, Dewey advocated the experimental method of teaching science which required that the learner be mentally and physically engaged in the learning process. This widely contrasted with the present Behaviorist point of view. Dewey stressed the connection between learning and doing.

Jean Piaget

Toward the end of the twentieth century, Jean Piaget (1896-1980) came forward in the educational movement as a developmental psychologist. Like Dewey, he believed that the human capacity to think and to learn was an adaptive feature. “Its biological function was to aid the individual in dealing fruitfully with the surrounding environment” (Phillips & Soltis, 1985, p. 41). Piaget was best known for his developmental theory that claimed that a child’s thinking develops in stages. “Piaget viewed learning as a biological process characterized by successive periods of assimilation, accommodation, and equilibration” (Mintzes & Wandersee, 1998, p. 36). Piaget’s work placed importance on cognitive functions but failed to take into account the learner’s prior knowledge of a topic (Mintzes & Wandersee, 1998). Many cognitive scientists since the mid 1970s disagree with Piaget’s developmental stages, and have found that even infants understand counting and numbers. Cognitive scientists state that oftentimes Piaget’s tasks required more knowledge than was purported to exist at
particular Piagetian developmental stages, such as understanding counting (Bruer, 1993).

**Jerome Bruner**

In the early 1960s, science education became immersed in new energy and several well-funded programs due to the curriculum reform movement triggered by the Sputnik space race with the Soviet Union. This reform movement adopted a new model of science inspired by Jerome Bruner (1960) in the *Process of Education*. Bruner addressed how learning science could be made more meaningful in relation to how students could be prepared for future problems in the real world (Phillips & Soltis, 1985). This model instigated a movement which brought children into direct contact with science materials. Children were allowed to manipulate objects, as well as to ask questions freely related to science activities in the Elementary Science Study (ESS) Project. Teachers with weak science backgrounds were not confident with this movement away from the traditional textbook (Howe, 1993).

Another project called Science Curriculum Improvement Study (SCIS) emerged which was based on Piaget’s developmental findings on cognitive processes. In this study, each lesson began with discovery methods and ended with a concept which could be used for prediction purposes. Bruner supported Piaget’s work in the educational field although they held differences of opinion. Bruner believed that “any subject could be taught to any child at any stage of development” (Mintzes & Wandersee, 1998, p. 37). In Bruner’s model, “knowledge consisted of science concepts forming a structure of a discipline” (Bybee, 1993, p. 12). “Jerome Bruner extended the cognitive approach by emphasizing that incoming stimuli are stored and interpreted according to
past learning, whereupon they are placed into loosely structured categories” (Hohn, 1995, p. 189). Bruner emphasized the idea that learning is most meaningful and best remembered when learners discover relationships among concepts on their own.

Influenced greatly by Piaget and Bruner in 1964, the National Science Teachers Association (NSTA) publication, Theory Into Action, made it clear to the science education community that the present goals for science were “the conceptual schemes of science” and “the process of science” (Bybee, 1993, p. 12).

**Robert Gagne**

The aims of science were used in the Science--A Process Approach (SAPA) which was influenced by Robert Gagne (1965), a psychologist who advocated the understanding of science process skills. The thinking behind this program, aligned with behavioral objectives, was that a child’s inability to learn a task was not related to cognitive development but to the lack of prior knowledge. “He added to and modified the theories of Thorndike and Skinner and selected aspects of the theory proposed by the Gestalt school of psychology” (Farmer et al., 1991, p. 126). Gagne (1970) classified all human learning into eight main types, placing an emphasis on learning as a process of successive complex skills in a hierarchy of knowledge (Farmer et al., 1991). Gagne greatly influenced the curriculum reform efforts in Science For All Americans (AAAS) which centered its development and goals around the integration of process skills and inquiry methods (Bybee, 1993; Howe, 1993; Mintzes & Wandersee, 1998). The major criticism to Gagne’s work was that there were no connections made to scientific concepts, and as a result, hands-on lessons lacked the necessary depth for understanding and reflection (Mintzes & Wandersee, 1998).
Joseph Schwab

“In the United States, Joseph Schwab wrote that the structure of a discipline could be analyzed in two parts: the substantive structure (or conceptual structure) and the syntactical structure” (Phillips & Soltis, 1985, p. 57). Schwab was one of the driving forces behind the Biology Teachers Handbook (1963) and much of the hands-on learning movement was influenced by him (Mintzes & Wandersee, 1998). “Schwab treats a discipline as a living entity, as a body of knowledge that is in constant flux, growing and changing, and with which the student has to learn to work. He views knowledge as a human construction designed to make sense of experience” (Phillips & Soltis, 1985, p. 59).

David Ausubel

In 1963, David Ausubel wrote The Psychology of Meaningful Verbal Learning, which reveals a theory of how individuals comprehend, learn, organize, and remember the large volume of meaningful verbal materials which are presented to them by an educational agency such as school” (Ausubel, 1963, p. xi). In this book, Ausubel makes a distinction between rote and meaningful learning processes. In 1968, Ausubel wrote another book called Educational Psychology: A Cognitive View, which portrays his theory “the single most important factor influencing learning is what the learner already knows. Ascertain this and teach him [sic] accordingly” (Mintzes & Wandersee, 1998, p. 37). Ausubel believed that learning is facilitated by presenting students with “advance organizers” or “anchoring ideas.” The advance organizer can be a visual way to relate new information to existing knowledge (Phillips & Soltis, 1985). Students need guidance in making these “mental connections.”
Ausubel differed from Bruner because he did not believe that students need to rediscover things that others have already discovered. Ausubel believed that students need to be guided during discovery. Instead he said that students need to learn the principles behind the discoveries in a meaningful manner. This led Ausubel to advocate a “general to specific approach in teaching expository lessons” (Hohn, 1995, p. 189).

David Ausubel is known for making a substantial contribution to our understanding of the psychological character of meaningful learning” (Farmer et al., 1991, p. 124).

Allan Paivio

In the early 1970s, Allan Paivio and others presented a dual-coding theory as a general framework for educational psychology. Paivio stated:

Human cognition is unique in that it has become specialized for dealing simultaneously with language and with nonverbal objects and events. Moreover, the language system is peculiar in that it deals directly with linguistic input and output, while at the same time serving a symbolic function with respect to nonverbal objects, events, and behaviors. Any representational theory must accommodate this dual functionality. (p. 53)

Paivio’s Dual-Coding Theory assumes there are two cognitive subsystems, one for processing images, and the other, language. Paivio assumes two representational units called “imagens” (mental images based on part-whole relationships) and “logogens” (verbal entities based on links and hierarchies) for verbal organizations similar to George Miller’s “chunks.”

Paivio’s Dual-Coding Theory identifies three kinds of processes: (a) representational—activating verbal and nonverbal representations, (b) referential—activating the verbal system by the nonverbal system, and (c) associative processing—the activation of representations within the same verbal and nonverbal system. Paivio’s
experiments based on these processes concluded that human response times were faster to recall pictures over language. Paivio's Dual-Coding Theory explains that recall is enhanced when information is presented in both a verbal and visual fashion.

**D. Bob Gowin**

D. Bob Gowin's Theory of Educating developed as a method to help students understand the structure of knowledge as well as how humans produce knowledge in any particular field. The Vee diagram is based on Gowin's original five questions: “What is the telling question? What are the key concepts? What methods of inquiry are used? What are the major knowledge claims? What are the value claims?” (Novak & Gowin, 1984, p.3).

The Vee heuristic was developed by Gowin (1981) based on the assumption that knowledge is dependent on concepts, theories, and methodologies. The Vee diagram is a metacognitive tool which helps students make connections between prior knowledge and newly learned information. The purpose of the Vee diagram is to represent how knowledge in science is constructed and to show how that knowledge was obtained.

**Joseph D. Novak**

Joseph D. Novak's Human Constructivist Theory (1998) "offers the heuristic and predictive power of a psychological model of human learning together with the analytical and explanatory potential embodied in a unique philosophical perspective on conceptual change" (Mintzes & Wandersee, 1998, p. 47). The Constructivist perspective bases its rationale on understanding and conceptual change. This process involves constructing knowledge metacognitively, restructuring this knowledge, evaluating the knowledge, and reviewing the knowledge (Gunstone, 1994). Novak's
theory involves the construction of meanings by forming connections between interrelated concepts linking previously learned material to newly learned material. This type of learning is meaningful and generally takes time for most people. Learning of this kind is hierarchical and emphasizes that no two people construct knowledge in exactly the same way. "Knowledge is an idiosyncratic, hierarchically organized framework of interrelated concepts that is 'built up' by scientists and science students over time" (Mintzes & Wandersee, 1998, p. 52).

The study of children's naïve ideas and misconceptions has been the center for extensive research in science education in the past decade. Most programs do not recognize the fact that children formulate their own ideas and develop concepts which last their lifetime if not corrected. The study of science concept learning has been developed by Joseph Novak (1977) who, with D. Bob Gowin, wrote the book Learning How to Learn (1984). This book was written as a way to help students construct new, more powerful meanings. Novak and Gowin used concept maps to help identify students' misconceptions as well as a way to visually encounter what a child is thinking about a topic. Concept maps act as a graphic of a person's mental representation and represent knowledge structures. The absence of associations can prove to be essential tools for learning. Interviewing and using concept maps have proven to be useful tools for many learners (Novak & Gowin, 1984; Mintzes & Wandersee, 1998).

Dr. Novak was a professor at Cornell University and developed what he calls a Human Constructivist perspective. Ausubel's idea, "the most important single factor influencing learning is what the learner already knows," became the inspiration for Novak's work. "Human Constructivists believe that individuals construct meanings by
forming connections between new concepts and those that are part of an existing framework of prior knowledge" (Mintzes & Wandersee, 1998, p. 47). This view concludes that no two people construct identical meanings when presented with the same information. Novak's Human Constructivist model includes meaningful learning, the use of cognitive theory, the restructuring of knowledge from multiple perspectives, and ultimately conceptual change.

**Human Constructivism**

The book *Teaching Science for Understanding: A Human Constructivist View* edited by Mintzes, Wandersee, & Novak (1998), incorporates all of the learning theories forming the foundation which supports this research study. The essence of this book reveals the theoretical and empirical principles of Human Constructivism. This book is dedicated to the improvement of science teaching and learning. I have used its content as a source of theory as well as inspiration for this study.

Ausubel's (1968) Theory of Meaningful Learning and his famous quotation, "Ascertain what the learner already knows and teach him [sic] accordingly" (Mintzes, Wandersee, & Novak, 1998, p. 329) lays the groundwork for using graphic organization and the basis of effective instruction in the science classroom. This emphasis on metacognition rather than rote learning is the stimulus for conceptual change as well as creative opportunity. This process of seeking meaning and understanding related to science concepts provides opportunities for learners to reconstruct, evaluate and review their own ideas. Relating prior knowledge to new information encourages significant changes in the cognitive structure which will in turn aid in the ability to learn and recall
knowledge. Grasping the fundamental principles of meaningful learning provides a structural framework as a basis from which to build from for the rest of our lives.

**The Science Of Human Cognition**

To understand the nature of thinking and how students learn is necessary for effective teaching and learning to take place. Cognitive scientists and educational researchers have joined forces to improve educational reform efforts. Cognitive scientists began to research the similarities and inner workings between thinking, information processing, and the working memory. Cognitive science is beginning to learn “what knowledge processes and skills distinguish more effective from less effective teaching performances” (Bruer, 1993, p. 17).

There exists a dual concept of seeing involving the visual stimulation of the eye and the interpretation of sensory signals by the brain (Solso, 1994; Trowbridge & Wandersee, 1998). The brain is, in fact, a very large part of the visual process, of how we interpret what we see with our eyes. Cognitive scientists explain that visual impressions are not limited to sensory experiences that involve neural energy, but involve the observer’s cognitive background which gives experience meaning. This is why no two people share the exact interpretations. Each of us possesses unique emotional and intellectual reactions when we encounter images or events.

“Bruner and Ausubel emphasized the interaction of the individual’s organized learning structures with new stimuli in performing cognitive tasks such as solving problems. Both men noted the existence of prior structures but neither provided details about the perception of new input, its relation to existing structures, and how it is processed” (Hohn, 1995, p. 189). A model emerged in the late 1960s and has become
the dominant cognitive position today, the cognitive information-processing model of learning. Visual processing of information involves the eye-brain system as light energy enters the eye, is transmitted to the visual cortex in the brain, and finally is interpreted in the associative cortex. The information received by the eye is meaningfully organized in the brain, passing along numerous neural networks in the process. It is in the final stage where one’s emotional and intellectual capacities are linked to prior knowledge and experience in the world that the object or event is ultimately interpreted (Hohn, 1995; Searleman & Herrmann, 1994; Solso, 1994).

The information-processing model portrays the learner attending to a selection of stimuli from a multitude of surrounding events, translating the physical stimuli into meaningful mental forms, then processing the forms to a greater or lesser extent so that they are more or less integrated with older knowledge. The act of processing is equivalent to the construction of meaning. (White, 1988, p. 116)

This model describes what happens from the moment information is perceived until the moment it is interpreted. Each step of the process can be simulated by a computer in the form of storage and retrieval operations. The significance of this research is that it led eventually to the development of different memory models.

**Memory**

Our memory is a highly organized structure which is capable of instantly searching for and analyzing information effectively. There has been a long debate over how many memory systems are present. Until the late 1950s, the dominant view was that we had a single memory system, because psychologists were greatly influenced by the principles of associationism. Most learning was thought to have occurred due to stimulus-response pairings. If forgetting occurred, it was may have been that initial
learning was weak or because too much information was learned, and interference of similar pairings took place (Searleman & Herrmann, 1994).

In the early 1960s, the computer age changed traditional views regarding the memory system, and psychologists began to adopt the information-processing approach. Flowcharting became a popular technique used to represent stages in the computer program. In 1958, John Brown and Lloyd and Margaret Peterson developed the Brown-Peterson Distracter Technique, which was based on evidence that if subjects were distracted from learning new information, that information would be completely forgotten in a couple of seconds. Based on their evidence, Brown and Peterson concluded that there must be two memory systems. The short-term memory system was very small and was used for rehearsal purposes while the long-term memory was much greater and was not affected by rehearsal procedures. Brown and Peterson attributed forgetting to what they called “trace decay” which means unless material is substantially rehearsed, it will fade away quickly (Searleman & Herrmann, 1994).

**Memory Models**

The first memory model to use the information-processing system was the Atkinson and Shiffrin model (1965). This model proposed that incoming information first enters the sensory register which stores information from each of the senses. Most information never gets beyond this point, but some is processed and selected to enter the short-term memory. The last stage in information processing is the long-term memory which has a large capacity. Information alternates between the short-term memory and the long-term memory. Information in the short-term memory is encoded acoustically whereas in the long-term memory information is encoded in terms of meaning. In other
words, information that is presented meaningfully to the learner is more likely to become encoded in the long-term memory. According to the Atkinson-Shiffrin model, the decision of what information and what amount of information to be processed is a voluntary one, determined by the individual according to what is of interest to that particular person (Hohn, 1995; Searleman & Herrmann, 1994).

Many studies were performed on human subjects at this time as to how much capacity our memory systems processed. George Sperling (1960) presented subjects with letters for a matter of seconds. The ability to remember these unrelated letters was poor and the decay was very rapid. His work proved that there was a form of memory that decayed very rapidly. A memory trace, if unrehearsed, was thought to last about 30 seconds in the short-term memory, but it could last an indefinite time in the long-term memory. In 1956, George Miller wrote an article, “The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information.” Miller also tested people on their recall abilities, with various letters and words, and found that most people could remember seven items, give two or take two. Miller coined the term “chunk” and used it to refer to a unit of information stored in the short-term memory. A chunk can represent a group of words which are meaningfully grouped. Combining these chunks in the short-term memory is called chunking. Chunking can be used to greatly increase the amount of information that can be remembered (Hohn, 1995; Searleman & Herrmann, 1994). “Miller suggested that learning may involve constantly recoding knowledge into different symbol structures in an attempt to discover the most efficient chunks” (Bruer, 1993, p. 10).
In 1976, J. R. Anderson provided a theory called the adaptive control of thought (ACT) process. "Cognitive units can be either propositions, images, or strings of words. A proposition is the smallest unit of knowledge of which a true or false judgment can be made" (Hohn, 1995, p. 192). The proposition containing subject, verb, and an object is the form that is most meaningful to learners. "Research evidence suggests that we retrieve information more in propositional form than in the form of the original input" (Hohn, 1995, p. 193). Propositions encoded in the working memory are linked to the long-term memory by what is called a trace. As we rehearse propositions, we strengthen the traces enhancing recall ability for that proposition. Teachers need to attempt to activate as many associated units in the neural network as possible. This is why it is important for teachers to ask questions in different ways in order to activate and trigger the proposition that was learned. Also, teachers need to provide several different examples, because the more associations that exist, the better the recall abilities.

Some computers retrieve information in a serial fashion, but the brain does not work that way. Alternate models have been proposed based on the parallel distributed processing qualities of the brain which act simultaneously. Like the ACT model, encoded information is more easily retrieved if the connections between associations are strong. However, cognitive processes are complex because activation occurs across several networks concurrently. Connections within the neural network are established at the synapses in the brain between neighboring neurons. "Knowledge is learned and processed according to the strength of the connections between units. Because of the similarities to the way the brain functions, connectionist models are often referred to as
Attention

If attention is not complete, information is often not encoded. Many times people do not remember because they never learned the material in the first place (Searleman & Herrmann, 1994). Recent cognitive research indicates the brain is a model builder with short- and long-term attention mechanisms which react to different events. It is a challenge for most students to direct long-term attention to scientific conceptions and meaningful explanations (Wittrock, 1994). There are things that teachers can do to enhance attention. Sitting up straight in an alert posture will increase the visual and auditory senses, but will not ensure learning. It is always helpful not to overwork any one teaching method and to use a variety of strategies such as visual stimulation, auditory stimulation, reading, etc. Any change in stimuli breaks up boredom. Changing voice patterns and volume, and having great speakers is also effective. Another factor is novelty--using stimuli which has not been encountered. Intensity is also an attention attracter, using either loudness or drama. It is important that learning tasks not be too easy or too difficult. Overly criticizing teachers can create the loss of confidence as well as lose a child's attention (Hohn, 1995; White, 1988).

Once information has been selected, attention is activated and enters the working memory. In order for learning to occur, information must be processed while it is active, through rehearsal techniques such as repetition or forming an image of the material (Hohn, 1995; Searleman & Herrmann, 1994). Re-reading material and extended practice of activities is necessary for learning material. Reconstruction of parallel distributed processing (PDP) models or neural networks" (Searleman & Herrmann, 1994, p. 72).
knowledge by placing important terms and facts into concept maps has proven to be a powerful learning device (Novak & Gowin, 1984).

**Schemas**

"Schemas are mental representations of people, objects, situations, and events acquired through experience" (Searleman & Herrmann, 1994, p. 140). When information is integrated with previous knowledge, the kinds of inferences one makes can greatly influence our schemas. Schemas help us decide which information should receive attention and processing. Schemas are interrelated bits of knowledge which are context specific and are stored in the long-term memory which allow us to make decisions as well as inferences about information. "Schemas are important to learning because they provide a structure into which new content must be placed before it can be comprehended" (Hohn, 1995, p. 202). The development of schemas is a major purpose of education, and teachers need to be trained in how to help students develop, activate, and refine their schemas (Hohn, 1995).

**Encoding**

Encoding involves transforming information into a form that a person can comprehend and retain. People have control and choice over the encoding process. Encoding information often depends on how that information will be used. If a test is expected, then the effort put into encoding the information will be greater. Personal motivation has a great deal to do with the encoding process. Connecting new information to prior knowledge in the information-processing system increases the potential for information to be stored in the long-term memory. Types of encoding include the following:
1. Organizing or reorganizing separate instances into a single unit (such as creating a Roundhouse diagram);
2. Imagery, a visual form of organization in which verbal content is transformed to an easily visualized image (such as a Roundhouse diagram or concept map);
3. Elaboration, in which new information is expanded on by adding it to what one already knows (such as Roundhouse diagrams or concept mapping).

(Hohn, 1995, p. 203)

Simply rehearsing material does not ensure that it becomes part of the long-term memory. Encoding usually occurs as a result of existing schemas becoming activated. Thinking about a particular title to a familiar story is enough to activate a schema of encoded material. Reorganizing and restructuring content from the text to a graphic organizer is also an effective encoding activity (Bruer, 1993).

One of the most effective ways to promote encoding is organization. There are several ways to organize material such as classifying according to color or shape, by putting information into columns according to meaning, by the use of chunking, or by using a variety of graphic organizers. Roundhouse diagrams not only organize material according to meaning but chunking is used as well which restructures information by reducing the amount of material that needs to be processed. When recall is required, most learners automatically try to organize information into some form which is easy to memorize (Hohn, 1995).

**Imagery**

Imagery is another process which stimulates encoding. Imagery is the act of transforming verbal or written material from the text into a visual form for purposes of promoting a mental image to be recalled. Research suggests that images enhance the memory. Concepts which involve imagery are encoded better because the concept is
encountered not only in a verbal or written form, but also in a visual form, which adds another dimension. Whenever an abstract concept is made into a concrete visual form, it is easier to grasp and retrieve (Hohn, 1995). This is another reason why the Roundhouse diagram is effective. Many times scientific concepts are abstract. By organizing this information into chunks, and then reducing the amount of material to be processed, the learner will encode the information easier. When the reduced material is reorganized and linked to a visual image with an icon, another dimension is added to the encoding process, enhancing the recall of the material even more. Concepts which can be visualized are encoded verbally and visually. Recall and recognition are enhanced by presenting information in both visual and verbal forms (Paivio, 1986). Paivio’s Dual-Coding Theory supports the importance of imagery-based material in cognitive operations.

Conceptual Models

An instructional technique for improving students’ understanding of scientific concepts is the use of conceptual models or graphic organizers which build on students’ mental representations and build schemas based on related material. The use of concept maps was presented by Novak & Gowin (1984) in their book *Learning How to Learn*. There are many uses for conceptual models as instructional strategies as well as for evaluation purposes. Conceptual models are excellent tools to help inform students who have little prior knowledge about a particular subject. There are many graphic organizers to choose from in order to promote understanding as well as to promote encoding. Conceptual models are most beneficial when students are asked to construct them for purposes of better understanding material.
Implications

The developments in science education reform which involve psychology and the science of human cognition offer the possibility of better understanding specific content material for the majority of students, particularly the at-risk students. Providing teachers with a better understanding of the human mind will give support in teaching practices which involve methods to promote encoding as well as memory retrieval (Bruer, 1993).

In a grade-seeking classroom climate where memorization of facts makes one a good student, anxiety exists for many students who are so unchallenged that their inattention to classroom procedures hinders their response on tests. Over a period of time, their grades fall and their self-confidence is hindered to the point that they are no longer interested in trying. Involving students in meaningful learning experiences generates interest as well as helps them process information at a deeper level which results in transfer of more complex learning tasks. The effect of anxiety in science classrooms is an important factor to consider. High fear of failure has a detrimental effect on the ability to organize information and to use knowledge for problem-solving purposes. Testing procedures which merely probe for factual information often do not accurately measure the learner’s knowledge or capabilities (Langer, 1997).

Pupils motivated to learn by restructuring information enhance their working memory and are able to activate existing schemas. The organization and imagery strategies provided by the teacher must be based on what the learner already knows because if misconceptions exist, future learning cannot take place (Mintzes & Wandersee, 1998). Teachers must have a method by which they are able to visualize
their students' mental representations based on what the students know about particular subject matter. In any learning situation, the quality of the relationship between the learner and the teacher can greatly influence student motivation and achievement.

The cognitive view of learning is based on the thought that perceptual reorganization is necessary for learning to occur. Ausubel (1963) believes meaningful learning occurs when new information is related to information that is already in the cognitive structure. This new information is selected for the working memory according to factors such as novelty or intensity which activates attention. The items which are selected must be organized, visualized, or elaborated on in some manner so that encoding can take place. Conceptual models such as Roundhouse diagrams provide the organization and visualization needed to enhance the encoding process.

Retrieval of information for complex learning tasks such as problem solving, depends on the availability of cues. The teacher needs to be trained to recognize appropriate strategies for cueing the learner and activating information which has been encoded. Teachers must be able to encourage this type of associative learning by teaching students how to connect and relate ideas, thereby building schemas. Graphic organizers and various conceptual models help to generate related associations. Teachers as well as students need guidance in utilizing these skills (Hohn, 1995).

Science and Creativity

The physical structure of the eye and brain are alike in most human beings across the species. However, the way individuals perceive the external world is quite unique. The way in which we visualize the external world is detected by the eye but
understood in the brain. "The brain sees what the eye detects and has stored knowledge about forms, colors, shapes, juxtapositions, and the meaning of life" (Solso, 1994, p. 45).

What started out to be "a cluster of photosensitive cells connected to locomotive devices" (Solso, 1994, p. 16) evolved into the structure of the human eye as we know it today. "Only within the past three million years have the humanoid eye and brain graced the earth; an eye and brain not unlike the ones reading these words and understanding the message" (Solso, 1994, p. 17). This sensory instrument evolved as a biological function of survival. The evolutionary process has enabled man throughout the ages to answer three basic questions: "What is an object? Where is it? What is it doing?" (Solso, 1994, p. 49). This original function of survival is clear but somehow in all of this complex evolutionary process, man began to appreciate the aesthetics of art and to seek order and truth in his environment.

Humankind's need to seek knowledge developed into philosophy, a Greek word meaning love of wisdom. Philosophers diverged into groups, some of which studied nature and others studying the human soul. Natural philosophers changed their name to scientists, which comes from the Latin word scientia meaning "knowledge." Science developed into a way of thinking about the world and answering questions in the curious minds and the imagination of mankind. The creative act consists of a combination of unrelated experiences in such a way that one gets more out of the emergent whole than one has put in (Koestler, 1981). Science developed into a creative field, much like that of the artist. By the middle of the twentieth century, many people
felt as if the arts and sciences had formed separate cultures in society, but in many basic ways, they were quite alike (Henning, 1987).

Science and Art

When primitive creatures were roaming the earth, art and science did not exist as concepts. Then one day, prehistoric man began to draw pictures in his cave, as an effort to communicate and understand his environment. Those images hold aesthetic value even today. In essence, man became both artist and scientist at the same time.

“Creative artists and scientists both develop forms (theories, models, and works of art) to articulate the inner experiences in response to their observations of the world, or to certain ideas about the world” (Henning, 1987, p. xiv). Both artist and scientist create forms and create beauty based on their experiences within the world. Science aims at truth, art at beauty. The qualities of truth and beauty exist in the one who beholds the experience. Both truth and beauty are interpreted uniquely by each individual because they reflect the inner structures and perceptions of the mind (Koestler, 1981). “Art appeals to universal principles of perception and cognitive organization, and resonates sympathetically to the inner neurological structures of the brain—we can discover the salient facts necessary to formulate general laws of the mind and the often elusive relationship of the mind with the external world” (Solso, 1994, p. 49).

The scientist searches for truth by submitting a theory to controlled testing and strict observation, whereas the artist depends on the response of other people. For both the artist and the scientist, beauty requires a balance synonymous with truth. Forms developed by artists and scientists result from their effort to meaningfully arrange their experience in response to the world. The structure of each form is dependent on outside
variables such as mathematics and physics for the scientist, and line, shape, and color for the artist. “Beautiful scientific forms affirm the beauty of nature” (Henning, 1987, p. xv). The artistic form recreates the essence of this beauty. In actuality the result is one and the same. “Creative activity occurs when an artist or scientist invents a new form as he pushes into what John Livingston Lowes called the surging chaos of the unexpressed” (Henning, 1987, p. 2)

The primary purpose of scientific theory is to provide knowledge, while in art the purpose is to delight or perturb the senses. Art provides knowledge because satisfaction derived from beauty plays an important role in all scientific endeavors. Each person perceiving a work of art brings unique experiences and cognitive structures to the experience, resulting in differences in interpretation and opinion. Nevertheless, as one experiences a work of art or a scientific model, both knowledge and delight/perturbation are stimulated.

The way in which the eye and brain process art is generally the same for all human beings. Robert Solso introduces the interactive model of artistic perception and cognition in his book, Cognition and the Visual Arts. Visual information in the form of light wave particles is detected by the eye and transformed into neural energy. This energy is transferred to the visual cortex of the brain where primitive shapes and forms are detected. These forms are analyzed in terms of contours, angles, curves, and vertical and horizontal lines. Information is further processed and transferred into the cerebral cortex. Signals are activated in a parallel fashion and neural impulses are spread to the brain. This activation occurs simultaneously which leads to the interpretation of visual signals as these signals are associated with prior knowledge and experience. The
preference of aesthetic values is prominent during this last stage and is based on our
taste and intellectual makeup. (Solso, 1994).

"Scientists and artists alike depend on inferences from sensory experience to tell
them what they are experiencing, and both use imagination to develop their pictures of
reality" (Henning, 1987, p. 5). “On the testimony of the greatest thinkers who have
taken the trouble to record their methods of work, not only verbal thinking but
conscious thinking in general plays only a subordinate part in the brief, decisive phase
of the creative act itself” (Koestler, 1981, p. 13).

Emphasis has been placed on spontaneity and ideas sparked from unknown
origins, which no one can explain, not only in the creative processes of art, but in the
exact sciences as well. Oftentimes scientists have to remove themselves from rational
processes in order to think clearly. “Creativeness is not encouraged under a pattern of
strict routine or exhaustive regimentation” (Cobb, 1967, p. 52). The greatest scientists
have admitted that just prior to great discoveries they were not guided by logic but
rather by a sense of beauty which is unexplainable. This is why true creativity cannot
be replicated through conventional techniques. It is not a process with logical steps and
rules to follow (Bybee, 1983; Cobb, 1967; Koestler, 1981). Einstein describes his own
creative process in remarkably similar notion, “Strenuous intellectual effort and the
contemplation of God’s creation are the angels which will guide me, reconciling,
strengthening, and yet with uncompromising rigor, through all the disquiet and conflicts
of this life” (Forman, 1981, p. 23).

In addition to relying on intuition and imagination in striving after beauty and
knowledge, creative artists and scientists share a respect for, and take aesthetic
pleasure in, craftsmanship. If the artist and the scientist are successful, each
emerges from the creative act with a form, a work of art or a scientific model or theory that articulates in appropriate terms its creator’s experience. (Henning, 1987, p. 10)

The knowledge the form provides is obtained in appreciation and as a result, adds a new dimension to the creative process and to the culmination of principles acquired by mankind. “The most important factor of the creative process is that strange spontaneous power variously designated as intuition, the unconscious, the subconscious, the inspirational” (Cobb, 1967, p. 55).

For some scientists and artists, the creative act is a personal process and represents a kind of miracle of thinking. Based on the information-processing model and the interactive model of artistic perception and memory, there exists a biological need for interaction with the environment, which is involuntary, to maintain this information-processing system.

The Creative Process

Using this model, there also exist characteristics of the creative process which have been collected by Brewster Ghiselin in the book The Creative Process:

1. The creative idea is born in a gray area which is not clearly defined but exists in a chaotic state of mixed emotions. A transformation from chaos takes place automatically and is basically an unconscious act. Logical reasoning before the creative idea occurs is not present, although the result is clear and orderly. Creative thinking is a process of random scanning through stored neural networks in search of properties which match those suggested in the initial problem to be solved. These networks are stored and coded in the central nervous system. The grey, undefined area comes from scanning the stored neural networks. When matching properties are found, the answer
becomes clear. The insight occurs in the regions of the associated cortex which causes the process to be unconscious.

2. The creative idea or insight has three characteristics: the idea is initially trivial in content; the central nervous system becomes stimulated and excited due to a deep feeling of satisfaction; when the insight becomes clear, thinking returns to a state of consciousness.

3. It is important not to rush the creative process. A person's will and persistence is only meaningful when following up the creative insight once it has been obtained.

4. Creative people often exhibit an uninhibited attitude toward intellectual restraints, causing a feeling of restlessness.

5. Creativity builds upon but goes beyond prior experience. The creative individual has a built-in variability existing within the central nervous system which is much greater than conventional people. His/her stores of experience may have a greater memory storage, so he/she is capable of storing more information.

6. The creative effort of an individual requires a great deal of self-discipline. True understanding is not possible without training. Creative people must concentrate their energy extensively. The insight of the creative endeavor is only a small part of the final solution. (Crutchfield, 1973; Golovin, 1963; Koestler, 1981).

It is important for psychologists, cognitive scientists, and educators to learn about the creative process for the sake of our survival. General concern for the creative process in science is an important element of responsible citizenship. All of us are made aware on a daily basis of the imperative importance of knowledge in science and
technology, especially in terms of our nation’s military and space development. It is of
the utmost important that our nation provide opportunities for the necessary training and
education needed to produce creative workers and thinkers in all fields (Golovin, 1963).
There are other reasons to inquire about creativity beyond that of practicality. “The
reason is the ancient search of the humanist for the excellence of man; the next creative
act may bring man to a new dignity” (Bruner, 1962, p. 2).

The Creative Individual

It may be that the creative individual is largely gene determined and it makes
little difference what social, cultural, or educational conditions bear influence on this
person. Nevertheless, the effective ability of an individual in any particular field must
involve training and rich experience. In the information-processing model, this relates
to the importance of stored experience and the strength of the interconnectedness of the
neural network. The process of the unconscious random scanning will be more efficient
based on the associations within the stored experience. “Such conscious interrelation is
probably responsible for building, through use, the strong synaptic connections required
for the rapid and consistent associative reactions probably so useful in allowing
effective random scanning” (Golovin, 1963, p. 19).

In our competitive world, even the creative individual must be extremely
motivated. “It is clear that without strong motivation to ensure the necessary
persistence in acquiring the interrelating experience, creativeness in the basic physical
sciences is today essentially impossible no matter how initially gifted the individual
may be” (Golovin, 1963, p. 19). A good example of this perseverance, this tenacity,
and above all, this thorough independence in the pursuit of understanding, is Einstein's achievement of the theory of relativity (Forman, 1981).

"True creativity, it is alleged, is not the exclusive property of the rare genius among us, but a tender bud that resides in some measure within every child, requiring only the gentle, catalytic influence of sensitive, imaginative teaching to coax it into glorious bloom" (Ausubel, 1963, p. 102). If we accept the notion that intellect is identifiable by representation of cognitive abilities, all children have the potential to be creative individuals in a conducive educational environment. The educational process can increase creative potential by providing opportunities for spontaneity and individualized expression. Teachers should challenge students as well as reward creative achievement. Teaching techniques may not make a difference but creative potential and creative accomplishments of students must be stimulated as well as appreciated (Ausubel, 1963).

**Creative Potential**

Professor J. P. Guilford defines creative potential "as a collection of abilities and other traits that contribute toward successful creative thinking" (Guilford, 1965, p. 6). Creative thinking is usually associated with productive thinking, but when it is distinguished from other types of thinking, there is usually something novel about it. Production can exist in terms of things which are tangible or products which are socially worthy and not tangible, such as thought.

Within Guilford's Structure-of-Intelllect (SOI) Model, products of thought come in six varieties; "units, classes, relations, systems, transformations, and implications"
Schemata or groupings of thought usually refer to most of the varieties, especially systems and relations. Intellectual abilities include the cognition of semantic relationships and the importance of schemata (Guilford, 1965; Starko, 1995; Koestler, 1981). Guilford's research on components of divergent production formed the basis of much of the assessment available today on creativity. The assessments include "fluency (generating many ideas), flexibility (generating different types of ideas from different perspectives), originality (generating unusual ideas), and elaboration (adding to ideas to improve them)" (Starko, 1995, p. 42). Guilford as well as other contemporary psychologists do not view creativity as a mysterious force, but rather as a pattern of cognitive strengths which underlie other factors of intellectual experiences.

**Models of Creativity**

One of the earliest models of creativity can be found in John Dewey's (1920) model for problem solving. Dewey recognized five stages: (a) recognizing the problem, (b) analyzing the problem, (c) suggesting possible solutions to the problem, (d) testing the consequences of the problem, and (e) judging and deciding on a selected solution to the problem (Guilford, 1965; Starko, 1995).

Dewey's contemporary, Graham Wallas (1926) takes the sequencing one step further including unconscious processing and the experience of "Aha." The "Aha" reaction refers to the moment of truth described by Gestalt psychologists, when the bits of the puzzle suddenly fit into place. This moment of truth occurs on a truly emotional level described as "a feeling of participation in an experience which transcends the boundaries of the self" (Koestler, 1981, p. 8). Freud refers to this moment as an "oceanic feeling." Piaget called the condition "protoplasmic consciousness." This is
the moment when the artist surges to a higher level of consciousness and inwardly evolves to a euphoric state of mind (Koestler, 1981).

Wallas refers to illumination to describe the “Aha” moment, where clarity is found in the solution. Verification soon follows which is the step where the solution is tested for effectiveness. Elaboration occurs as the last stage where the fine tuning takes place (Starko, 1995). Research indicates that there are deep psychological connections between creative thinking, problem solving, and learning.

The product of thinking is related to the discovery of relations within the system. There may exist common properties, connections or complex interactions. This process involves the ability to order and arrange details and carry out the steps in a reasonable sequence in order to achieve a final product. There must exist motivational reasons for solving the problem. This motivation may be a drive to satisfy and fulfill the individual, simply by solving the problem. The thrill of being able to triumph over difficult situations and satisfy intellectual achievement should be the motivation. (Guilford, 1965; Starko, 1995; Koestler, 1981).

**Creative Characteristics**

The 1990s have been a time for curriculum reform with content teaching. In considering the review of literature and research in the field of creativity, the following identified characteristics have been suggested to educators by Starko (1995):

1. Content learning in any field should be directed toward allowing students to interact with the content in significant ways which relate to real problems.
2. Assessment procedures should be aligned with significant application and reflect similar procedures.
3. Inquiry-based learning should be applied where students explore significant problems and draw conclusions rather than the traditional single-track method with teacher-centered lectures and textbook memorization and recitation.
4. Students should be active participants in meaningful learning activities rather than passive receptors of learning.
5. Creative and critical thinking strategies should be incorporated where students are taught to think instead of memorize. 
6. Metacognitive skills should be implemented in both teaching and learning strategies.
7. Students should be taught to use technology across disciplines.
8. Values, attitudes, and skills should be taught as habits of mind as they relate to an individual’s knowledge and learning as well as ways of thinking and acting.
9. Conceptual models should be taught where content is organized around key concepts and principles rather than isolated bits of information.
10. Students should be taught to use content across all disciplines. (p. 172)

**Creative Teaching**

Teaching which supports creativity must allow students to find and solve problems based on real-life situations. Students must first gain an understanding of the subject matter in order to be able to ask questions so that they can explore. Teachers should consider preparation, presentation, and application. Teachers must first find out what the student knows and connect prior knowledge with the subject matter. Providing graphic organizers is a great way to spur interest, curiosity, and connect prior knowledge to new knowledge. Next, allow the students to express their ideas and ask questions relevant to what is being taught. Challenge students to present information organized into conceptual frameworks such as Roundhouse diagrams, present their conclusions, and compare the results with the ideas expressed by other students. Students should then be allowed to practice strategies which are creative such as role playing or simulation in which students must use information in a different way than that in which it was learned (Starko, 1995).

A child does not have to be gifted in order to exhibit creative traits. The potential for creativity can exist in any child, but often the educational process stifles its
development. Rote memorization of textbooks is a task most people can accomplish if the desire is there. This is no indication that understanding has taken place or that a problem can be solved as a result of memorizing. It would make much more sense if issues could be discussed and if students were allowed to differ in opinion as well as with the teacher. What message is sent to students when they are not allowed to express their opinions? Most students are not allowed the time to think much less express themselves or reflect upon an idea (Cobb, 1967).

From the earliest age possible, appreciation of the arts and sciences should be developed along with practical intelligence. "Psychologists are beginning to believe that the child's intelligence can be increased by perceptual training" (Cobb, 1967, p. 21). The chief goal of the education process should be to stimulate creative potential and encourage creative imagination in youth. The greatest achievers in the world are those who have allowed their imaginations to explore undiscovered realms. Creativity, appreciation, and imagination are internal processes which are personal, intangible, and very rarely nurtured in the educational process (Cobb, 1967; Jones & McEwin, 1983; Koestler, 1981).

Implications

The identification of creative abilities in young children has been a subject of research for a long time. In order to predict creative ability, one would have to anticipate that this individual would display those characteristics in adulthood. It is probably impractical to predict that an individual has creative abilities. Instead it would be much more useful to wait until the individual has been productive and has demonstrated creative ability (Guilford, 1965).
Creative ability in science must be associated with prior rigorous conditioning. It is impractical to say in advance which individuals may display this ability without having this training. Only after acquiring the necessary educational training can those creative individual's performance be evaluated, as having the capacity for creative productivity. Creative effectiveness in any field requires a great amount of interrelated stored prior experiences, strong connections within the central nervous system and the probability of genes which determine creative potential (Guilford, 1965).

Some of the creative potential may be gene determined, but richness of experience also plays an important factor. Effective interconnections in the central nervous system greatly depend on acquiring experience and associations useful in allowing effective problem solving. There must also exist strong motivation in acquiring this interrelated experience. Strong motives and effective persistence are likely to result in creative contributions (Starko, 1995).

There is a great challenge to educators as well as exciting possibilities in teaching for creativity. Effective teaching must foster creativity, develop problem-solving skills, encourage self-fulfillment and satisfaction for acquiring knowledge, and direct classroom tasks based on prior learning experiences.

Research suggests the use of meaningful learning tasks which promote associations from prior learning to new learning, to relationships interconnected within the cognitive structure. Productive thinking employs the activation of creative processes and abilities which range from cognition and memory through methods which promote creative thinking. From an educational viewpoint, there are a number of teacher-structured skills involving active learning which engage the intellect, the
capacity to form meaningful concepts, and practice in storage, retrieval, and organization of conceptual frameworks.

This view of mental development encourages inventiveness and competence. The classroom teacher must be imaginative and at the same time use sound judgment in determining what activities to use in the classroom. Teachers must remain flexible and open when discussions could lead into a new lesson for the day, which may have been totally unplanned. Allowing the students to lead the way motivates them to participate at all levels of the experience. The teacher needs to generate ideas which recall information from storage in the memory and connect this data to new information learned in the classroom. In doing so, the student will be more likely to connect this new knowledge to real life situations and transfer this knowledge to the real world (Starko, 1995).

The Roundhouse Diagram

Research indicates that graphic organizers serve as useful tools for science learning, instruction, and evaluation in the science classroom (Trowbridge & Wandersee, 1998). A Gowin’s Vee diagram of the overall research study on Roundhouse diagrams is an example of a graphic organizer used as a presentation tool for science instruction (see Appendix A). A flow chart was also designed for the purpose of providing the reader with a total view of this research preparation, data collection, and results on the use and construction of the Roundhouse diagram (see Appendix B). For the purposes of this study, I focused on the Roundhouse diagram. Wandersee (1994) developed the Roundhouse diagram and introduced it to the science education community at Louisiana State University (Trowbridge & Wandersee, 1998).
Professor Wandersee assigned this diagram to teachers in a science lab lesson, asking them to represent the different facets encompassing their teaching experience. "People use concepts both to provide a taxonomy of objects or events in the world and to formulate relationships between concepts in that taxonomy" (Wandersee, 1987, p. 9).

The Roundhouse diagram is a newly developed metacognitive strategy proposed by Wandersee (1994) for the purposes of concise, holistic, graphic representation of a science topic, process, or activity. It also creates a simple, targeted, low-resolution visual model on the learner's current conceptual understanding. Permission to use the Roundhouse diagram for the purposes of this study was granted by Dr. Jim Wandersee (see Appendix C).

My experience with the Roundhouse diagram initially involved attending Wandersee's biology education classroom in 1994. At the time, I was teaching 4th-grade science and math and was asked to display this curriculum in a Roundhouse diagram. My Roundhouse diagram centered on the exploration and discovery of science and math (see Appendix D). I divided the conceptual framework into the seven sectors provided in the diagram. The initial sector, at the 12 o'clock position, then rotating clockwise, began with time and space relationships and ended with inquiry and hands-on application. In each sector, I drew pictures and glued icons, which represented the concept which was paraphrased or "chunked" in each section. The greatest benefit I received in learning this technique is that today, over three years later, I can still remember what is on that diagram. It was then that I became interested in graphic organizers and started using them in my classroom with my students.
Design

This basic configuration was adapted from a syllabus designed for a class Professor Wandersee attended at Michigan State University, prepared by Dr. Edwin Kashy. Due to Wandersee's years of studying the learning theory of David Ausubel at Cornell University, as well as teaching concept mapping and Vee diagramming at Louisiana State University, he applied the construction of this diagram to what he knew about graphic organization.

Using basic constructivist principles, students have been asked to construct their own Roundhouse diagrams, based on information learned in the science classroom, serving as a metacognitive tool in learning and instruction. The Roundhouse diagram serves as a basis for reconstructing knowledge which in cognitive science has proven to be helpful with encoding information for retrieval purposes. The iconic features and images connected to efficient chunks of information also enhance the learning and recall of scientific concepts.

The seven sections of the Roundhouse diagram are based on the psychological research of George Miller (1956) who studied the human memory span and determined that most people can effectively recall seven items, give or take two. If this information is chunked efficiently by reducing the amount of detail, the learner can increase the amount that is learned and retrieved effectively.

A Roundhouse diagram is a two-dimensional geometric figure which is circular. The conceptual structure exists within the seven sectors around the circular turntable, existing in the middle of this design. Geometric regular figures, such as circles, are referred to as stable figures. Our field of vision using both eyes is circular as well. Our
mind seeks out these types of two-dimensional figures in the environment because they are easy to process by human observers. If graphic organizers are constructed using simple lines, which are clear and not too close together, they serve to enhance the cognitive process, which will, in turn, enhance the ability to encode information and to retrieve it more easily (Searleman & Herrmann, 1994; Solso, 1994). Research indicates that students benefit from the Roundhouse diagram technique when it is used to represent procedures in the science laboratory (Trowbridge & Wandersee, 1998).

**Visual Imagery**

Empirical evidence based on Levin, Bender, and Pressley (1979) concludes that children who are shown pictures while being read a story will recall 40% more information than children who weren’t shown pictures at all. In other cases, when students generated their own visual representations of the same content, similar results were found. “Thus, both story-relevant illustrations and visual imagery have been found to facilitate children’s recall of story information” (Levin et al., 1979, p. 92). The study concluded that the illustrations directed student’s attention, which cognitive scientists say is the first step in the encoding process (Hohn, 1995; Searleman & Herrmann, 1994; Wittrock, 1994). Educators have also discovered that pictures improve children’s ability to retrieve curriculum-related and nonfunctional content as well (Levin and Berry, 1980).

Imagery contributes greatly to the encoding process (Hohn, 1995; Searleman & Herrmann, 1994). Whenever verbal information is transformed into a visual form the mental image includes things which are remembered. If someone were to ask you what kind of curtains you had on your window when you were a child, you would attempt to
visualize your room based on your long-term memory. The visual representation provided by your memory would help you to answer the question. Research indicates that images enhance the memory (Hohn, 1995). A study presented by Paivio and Foth (1970) asked several college students to link pairs of nouns with a picture. Those who did not use the pictures did not have as good a recall as those who used pictures with the nouns. Paivio discovered that concrete information is remembered more easily than abstract information. A person will remember the word "chair" more easily than the word "behavior" (Paivio, 1986). Why does imagery enhance recall? Because ideas are encoded using two dimensions, verbal and visual. Dual encoding is easier to remember than singular encoding (Hohn, 1995).

Illustrations which have the same function as a keyword are called pictorial mnemonics. The terminology is transformed into a key word that sounds similar and is then related to a picture representing the linking characteristic. For example, in a study by Rosenheck, Levin, and Levin (1989), a group of plants in a biology classroom, such as angiosperm and dicotyledon, were related to the keywords angel and dinosaur, and then related to the pictures of the angel and the dinosaur. On both immediate and delayed recall tests, the students who used the pictorial mnemonics outperformed the other students (Hohn, 1995).

"Visual literacy is a real issue both in the classroom and in the textbook. We are expanding the visual information base; however, if that base is to have the desired cognitive effect, we must expand our visual literacy" (Blystone and Dettling, 1990, p.20). A teacher can bring the importance of visual literacy to a productive position in the classroom. Blystone (1990) developed a study with college students asking them to
draw pictures of cells they saw under a microscope. Based on the student’s drawing, the teacher can determine if understanding has taken place. This use of drawing pictures and linking them to concepts helps to develop visual thinking abilities and can produce interesting possibilities for learning (Launey, 1995).

**Naïve Science**

The Roundhouse diagram is based on David Ausubel’s (1963) Theory of Meaningful Learning as opposed to rote memorization. The Roundhouse diagram is a way to link new information to prior knowledge, and since it is a visual representation of a mental model, it may be easier to determine if the learner has misconceptions about the subject matter. “Learners construct their own meanings through cognitive assimilation of the phenomenon into their existing notions or by accommodating the existing notions to make more powerful assimilating frameworks” (Nussbaum & Sharoni-Dagan, 1983, p. 99). There is a growing number of studies about misconceptions, also called naïve science or alternative conceptions (Connor, 1990; Mintzes & Wandersee, 1998; Rowe & Holland, 1990; Smith, 1990; Wandersee, 1985).

**Possible Misconceptions or Alternative Conceptions**

In the pilot study, Carl’s objective in his Roundhouse diagram was to see chlorophyll fall out of a leaf. We discussed this misconception. He thought chlorophyll just fell out since the season was called fall. So I took some fingernail polish remover (acetone) and put a leaf in it. The next day the solution was green. Then I allowed the liquid to dry out of the leaf which was without the green color. He saw the green color extracted from the leaf. I explained to him that deciduous leaves fall as a result of a chemical change in which the hormone auxin plays a considerable part. As the auxin
decreases, a layer of cells called the abscission layer blocks the flow of water and nutrients to the leaves. As the leaves dry out, the chlorophyll ceases to be produced and the green color fades. As a result, the leaves dry out with no chlorophyll in them any longer, and eventually fall to the ground. Collin was delighted by this explanation and simple procedure, and admitted that he never understood the concept and had been confused. Most of the time, teachers are not aware of what exists in the thinking of a child because the concepts are not visual. The Roundhouse diagram provides teachers with the opportunity not only to see what the child is thinking, but to reteach the misconception and address the confusion with the questions and valid information. Is this not what teaching is about? Unfortunately, many teachers just remain accountable by having students read from the textbook, memorize for testing purposes, and assign grades.

If misconceptions go undetected and unchallenged, it is likely they will become more deep rooted over time. As children grow up in their environment, they develop their own explanations as to how things work. It happens so naturally that it is not recognized until someone else confronts us with a different interpretation. Some of these explanations are hard to relinquish and many are never recognized. Students need much more than active discussion to get rid of these misconceptions (Rowe & Holland, 1990). Instruction should be designed in such a way that the teacher is able to discover misconceptions, and this is one area where Roundhouse diagrams are useful. "It yields an approximation of what the learner knows about a prescribed subject and can also reveal conceptual difficulties, misconceptions, and alternative explanations students harbor" (Wandersee, 1987, p. 17).
**Meaningful Learning**

The Roundhouse diagram was used in the science classroom to enhance meaningful learning. This effective learning strategy is metacognitive in nature because it involves the awareness of the learner and includes the learner's decisions and actions which result in the development of a learning experience (Gunstone & Mitchell, 1998). The learner reconstructs content derived from the text or the learning environment and constructs a Roundhouse diagram by using a specific worksheet (see Appendix E). After the initial planning and practice is finished, the information is then placed on the diagram (see Appendix F). Upon completion of the task, a Roundhouse diagram checklist is issued to the learner, to be sure all steps have been completed (see Appendix G). Next, the researcher/interviewer set up a time with the learner to be interviewed, based on the information in the diagram. The learner was then asked questions in relation to sequence of events, iconic relationships to the conceptual framework, and the efficiency of chunking. The questions varied from student to student depending on the construction and conceptual information in the diagram.

**Connections and Relationships**

Students need help learning how to make connections, especially in science education due to the intricate web of relationships and the vast amounts of information to be consumed. When relationships can be established, learners create their own useful procedures and strategies. Roundhouse diagrams serve as a heuristic for understanding knowledge. If a student is studying the parts of a plant and soon understands the process of reproduction and how this process relates to photosynthesis, he/she will in turn relate the idea to the food chain which connects to other ideas, such as why trees

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are important for human survival. Meaningful relationships based on connectivity of concepts is the key to how our neural networks function and how we relate to the world from the inside out. These relationships represent the essence of life because today’s students are the future and their ideas may answer questions which may lead to the survival of the human species.

**Roundhouse Diagram Reflections**

Presenting information in meaningful and useful contexts and relating new learning to prior learning assists in connecting new information. It is important that teachers continue to find out what students already know about the subject matter, and placing the learner’s thoughts within a diagram is an excellent way to assess their thinking. Students are more likely to remember more factual content when instruction focuses on higher order processes and meaningful learning than when it emphasizes low-level mechanical learning such as rote memorization (Mintzes & Wandersee, 1998).

Roundhouse diagrams provide the learner with a variety of ways to use, structure, restructure, organize, and integrate their ideas. Students have a difficult time when asked to break down whole ideas into parts because many learners have not been challenged with this experience before. Students need guidance and direction in learning how to think for themselves. Metacognitive activities are difficult for many students. The Roundhouse diagram provides step by step instructions within the worksheet and helps them to formulate their own priorities about what is most important. Teachers need to realize that metacognitive learning takes time as well as practice and it is important for teachers to remain patient.
The Roundhouse diagram provides opportunities to involve students in thinking about associations by encouraging them to analyze, discuss, compare, and contrast their diagram with those of other students. The activity is individually constructed but the finished product should be presented and involve other opinions. It is imperative to present a risk-free environment, free from criticism. Some students do not draw as well as others, and the students need not be intimidated by that fact. Providing the clip art books for tracing purposes aims at solving that problem.

Roundhouse diagrams are an effective way to present an order or sequence of events. Students need to recognize conceptual hierarchies and ordering of events which go from general to specific. Constructing a sequence of this nature within a Roundhouse diagram allows the learner to promote this kind of conceptual framework.

As learners develop and encounter new concepts, a major goal of educators is for the student to be able to connect new knowledge to what is already known. It is important for the learner to be able to differentiate the new concept from similar concepts. Complex thinking is a restructuring process. Creating Roundhouse diagrams is an eminently useful method for constructing conceptual building blocks and creating mental models (Trowbridge & Wandersee, 1998).

The Pilot Study

Three students from a regular- to low-achievement 6th-grade classroom were chosen by the science teacher for the Roundhouse diagram pilot study. There were two girls and one boy who participated. They were chosen because they had good communication skills, ability, and needed help with study and learning methods. I sent home a letter to their parents explaining to them what would be done in the pilot study.
and received permission to work with them one hour after school every afternoon. The 
teacher gave me her lesson plans for the month so that I was aware of the subject matter 
in advance. We worked in life science with Chapter Four in their textbook, which was 
on plant response. We covered four lessons in that chapter:

   Lesson 1. How do plants respond to their environment?
   Lesson 2. What are some stimuli to which plants respond?
   Lesson 3. Why do different plants flower at different times?
   Lesson 4. What effects do light and temperature have on leaves?

We began Chapter 5 on Ecosystems and Biomes. We were only able to cover the water 
cycle.

Preliminary Motivational Activities

   I started the study by asking the children, “What is a Roundhouse diagram?” I 
used an overhead projector and showed them a transparency of a Roundhouse diagram. 
(see Appendix F) We talked about graphic organizers, and I found out that they had 
some previous experience using Venn diagrams and concept mapping in some of their 
lessons this year. I told them that “Roundhouse diagrams were named after circular 
bruildings with central turntables that were used by railroads for housing and switching 
locomotives” (Trowbridge & Wandersee, 1998, p. 104). I showed them a transparency 
of the Roundhouse diagram I had created, and I explained to them that I took one whole 
concept (see Appendix D), “The Exploration and Discovery of Science and Math” and I 
broke it down into seven of the most important parts. I explained that this diagram was 
an assignment in my class. I showed them how to look at the diagram like a clock and 
begin at the sector in the 12 o’clock position and go around clockwise with the parts.
This particular diagram did not have an order to the parts, but I explained to them that some ideas do have an order that must be kept in each sector. I asked them to count how many sections there were, and I explained to them why psychologists use seven items, give two or take two, for purposes of remembering (George Miller). I showed them how I used the “and” and “of” and the line down the middle circle to represent two main parts of the title.

Before we actually began using the diagrams, I took the children to the library where we used some encyclopedias to look up “Railroads” (Withuhn, 1998) The children were curious about the traffic control of the locomotives, so I had them look it up and write down some important facts that were discovered. We wrote some facts on the blackboard as they found them, and then we discussed how this could be used as an analogy to conceptual frameworks in the Roundhouse diagram.

The students enjoyed this initial activity and learned a lot about trains as well as Roundhouse diagrams. Before beginning their first diagram with science material, I wanted the students to relate the Roundhouse diagram to their favorite activity or hobby. One student constructed hers on riding bicycles and going shopping. The boy constructed his on hunting, and the other girl did her diagram on drawing. The last girl could obviously draw very well, and did a very detailed diagram (see Appendix H). I also did a diagram on horses, and I made a transparency of mine and showed it to the children. Each child stood up and explained his or her diagram. Before the children put their ideas on the actual diagram, I had them use notebook paper to write out their main concept with the seven parts. Then I had them think up the pictures or icons they wanted to use and sketch them out on a practice sheet first. I feel this extra practice
helped them formulate their ideas and also helped them encode information when dealing with scientific material. Each time the student restructured the material, he or she learned it better because of the extra exposure.

**Constructing the Roundhouse Diagram**

I created several books for the classroom composed of clipart containing drawings of different objects the students may be interested in tracing. The books contain over 3,000 laminated color clipart drawings useful for ideas as well as tracing purposes to help children who have trouble drawing. Each book is lettered A through G. There were seven of the books with approximately 30 pages in each book. Each book was complete with an index which was laminated and inserted in the front of the book so that students could look up the subjects inside the book, rather than having to look through all of the pictures in each book.

Each time the students finished their Roundhouse diagrams, I had them fill out a checklist sheet so they could be sure not to have left anything out (see Appendix G). I introduced the students to the enlarged wedge diagram (see Appendix I) and explained its purpose. The enlarged wedge was used when a student was having problems with a particular section. The extra area of planning was helpful in developing an idea. The enlarged wedge was also used for elaboration purposes, since the space was limited on the Roundhouse diagram. The student had the option of adding more details to a particular section if it was needed.

I decided to incorporate an example of a Roundhouse diagram which was used to break down an abstract idea the students were familiar with—photosynthesis (see Appendix J). I placed the diagram on a transparency and went through the example
Roundhouse diagram worksheet with them step by step (see Appendix K). A blank worksheet was given to each student before they were allowed to put their ideas on the Roundhouse diagram (see Appendix E). This way, each student would have a plan written and drawn out before placing the information on the Roundhouse diagram.

Lesson One introduced four new definitions: response, stimuli, hormone, and tropism. Three pages in their textbook referred to these terms regarding how plants respond to their environments. I allowed the students to work together, but they had to do their own individual Roundhouse diagrams and break down the parts. They did their worksheet practice and found stimuli and responses for seven different plants, which they drew and put into their diagram. Although there was no particular order, I had the students examine their results and I asked them to see if there were any similarities and differences. They decided the bean and ivy plants responded the same way to sunlight. They also noticed that the Venus flytrap and the sundew plants both responded to insects. Both students made up pictures from their mind and used the pictures in the textbook to link to their concepts. Both students explained their diagrams well and seemed confident in their work.

Lesson Two referred to the stimuli to which plants respond. Both students immediately began their work and only worked together on the title. They read through their material in the textbook and outlined their practice work in their notebooks. When their planning was sufficient, they both completed the diagrams. Wendy wrote words on the outside of her diagram which represented what was inside each section. I thought this was very creative and unique.
Working through the rest of the lessons remained a positive experience. The students did not lose interest and they did not mind doing this work at the end of the long school day. The last day I gave the two children present an unannounced quiz. I gave them two blank Roundhouse diagrams and I had them reproduce from memory ones that they had previously done. Brenda reproduced a Roundhouse diagram in full from memory after one day. Carl was able to almost complete his diagram after one week. On the back of the test pages, I had the children write out an explanation of their topic in an essay form, as if it were a question on a test. They both did well. I wanted to be sure they connected the ideas in the diagram and could transfer this knowledge to a different context.

**Peer Tutoring**

I decided to allow Wendy to teach Brenda how to do the Roundhouse diagram. She used the overhead projector and told Brenda, “You start at the top like a clock.” Wendy told Brenda how to do the title. She said, “You can use the ‘and’ and ‘of’ if you want to or you can use liquid paper and erase it.” Wendy did a diagram on shopping for Brenda to show her how it was done. It took her about twenty minutes to draw it out and explain it to Brenda. She was very enthusiastic and Brenda listened to every word. Wendy gave Brenda a blank Roundhouse diagram and said, “Now, what do you like to do? Brenda said, “Draw.” Brenda was able to finish her own diagram in about fifteen minutes and seemed very confident.

**Evaluation**

I asked the children a number of questions orally and wrote down their responses. I asked if the students thought the Roundhouse diagram was an effective
method for learning. Carl said, "Yes, I studied the diagrams before my tests." Wendy said, "I remembered what I had written because of all the practice work." She also said, "It helped me to re-read the material again." Brenda said, "It helps to take it all apart and put it back together again. Carl said, "The pictures help you to learn. It helps you to see what the book is talking about because I have reading problems." Carl said, "The diagram tells me what to do. It helps me when I study." Wendy said, "I like it better than taking notes and it's fun drawing." Brenda said, "The diagram helps me to talk and picture it in my mind. Once you draw a picture, you can remember it. It helps me to answer my homework questions." Wendy said, "It's like pictionary." Carl said, "I'd like to take a test this way. I can remember it."

I decided to write up a student evaluation checklist based on the children's responses (see Appendix L). I thought the students should have some voice about the work they had created. They felt responsible when they evaluated their own work.

**Problems**

The first problem I encountered was that students needed initial practice in constructing Roundhouse diagrams. That was why I decided to make the Roundhouse diagram worksheet. It would give the students time to formulate, plan, and organize ideas before they did their diagram. The second problem I encountered was that students who could not figure out how to draw something looked in the books and took up too much time that could have been used constructing knowledge. That was why I decided to make the index sheets, so the students would not have to look through each and every picture in order to find what they needed. The index saved time.
The students found it very difficult when asked to take an entire concept and divide it into seven parts. When we first started with the favorite hobby, I had the students close their eyes and actually imagine that hobby. Then I asked them to list what they saw. Imagery exercises helped them in the beginning. Students need to be taught how to think because too many times they are just asked to repeat information. Restructuring information required thinking. Thinking produces knowledge and knowledge produces more thinking.

Benefits

The greatest benefit of all was being able to see what the student was thinking. If their thinking was erroneous, I was able to help them understand the correct answer before they were tested. Many times teachers are not able to discover what the child is really thinking.

Students get experience re-reading the material in order to get additional practice with the Roundhouse diagram worksheet. The students are reinforced once again when they reorganize the information from the worksheet to the diagram. The students are able to connect new information with prior knowledge in a visual manner which can be presented and evaluated by the teacher to determine whether any misconceptions exist. The learners must restructure material and attend to important parts. By restructuring the material, the information is processed at a deeper level, so that it can be used in more complex learning tasks, such as generating new ideas. All learning involves thinking. Information which is processed at deeper levels is learned better. Integrating thinking skills with content instruction helps students broaden conceptual understanding, and at the same time use that knowledge in problem solving, creative
thinking, and acquiring new knowledge. By helping students acquire and use thinking
skills, teachers are able to improve the self-confidence and achievement of students.

The Classroom Connection

The pilot study was an invaluable experience and provided me with extensive
insight into data collection and analysis for the forthcoming research study. The main
problem which occurred in the pilot study centered around the fact that the students
needed more structure for construction of the Roundhouse diagram. During the pilot
study I had to create step by step instructions for the students on the board, which led to
the creation of the Roundhouse diagram worksheet (see Appendix E) which was used in
the actual study. This worksheet became the blueprint for the diagram itself. Although
it was time consuming for the students to fill out, the restructuring process which took
place in filling it out proved to be most valuable. In the analysis for the pilot study, I
discovered that the students who carefully worked through these initial stages were the
students who benefited most from the Roundhouse diagramming method.

The process consisted of reading the material in the textbook, then re-reading the
material to locate the main ideas. Next, the main ideas had to be paraphrased or
chunked. In this part, the students put the information into their own words, thus
recreating the ideas and therefore owning them. Then the restructured concepts were
once again addressed and linked to an icon which represented what was being said. In
actuality the students were actively studying the lesson. I discovered these students
were able to recreate these diagrams, for the most part, from memory.

There were a number of common characteristics I noticed in the pilot study,
which became predictions for the actual study. I observed there was an increase in
concentration levels when students were working on the diagrams. The diagrams improved as students gained more experience and practice. I noticed an increase in the students' self-esteem and confidence levels. I noticed all of the students enjoyed constructing the diagrams. They took their time and made a concerted effort to write and draw neatly. They helped each other by having mature discussions about the subject matter.

The pilot study helped me to make other instructional decisions. I thought the students needed to write paragraphs explaining what they wrote in their diagrams, in order for successful transfer to occur, so I bought them each a writing journal. Through journaling, I could also hear their voices about what they were learning, as well as problems they were having. This idea led to creating the student evaluation checklist (see Appendix L). I thought the students would own the diagrams even more if they could evaluate their own work on them.

**Overview of Review of Literature**

The topics covered in this chapter reviewed some significant ideas and practices involved in pursuing the improvement of science teaching and learning. Research studies using graphic organizers, metacognitive learning and teaching disciplines, cognitive science, creativity, and the research involving the Roundhouse diagram support teaching and learning practices which depart widely from traditional expository pedagogy, which focuses on rote memorization practices still used in many science classrooms today. The emergent theme, a Human Constructivist perspective, is based on historical exploration and the present analysis and focuses on meaningful learning, reconstruction of knowledge, and ultimately, conceptual change.
METHODS

Research Design

Case Study Approach

As a research design, the case study is characterized by interest in individual cases, not by the type of methods used for inquiry (Stake, 1995, 1998). Some researchers focus on a single case because of intrinsic interests. Other researchers use the case study as an instrument to accomplish understanding or insight into how or why a phenomenon occurs (Yin, 1994). The instrumental case study is used to develop understanding of an interest, rather than focusing only on the case. Another type of case study has a combined purpose, using a number of cases to investigate a phenomenon. This multiple case report investigates a common characteristic, a variety of different characteristics, or repeated patterns of interest. Multiple case studies often lead to an understanding, which in turn leads to even a greater understanding, perhaps creating a theory about a still larger group of cases (Stake, 1998, 1995).

The case study strategy, selected for this research proposal was based on the multiple case report, using a combination of intrinsic and instrumental interests in order to gain insight into a particular phenomenon (Yin, 1994). The multiple case approach best facilitates achieving the purpose of this research endeavor due to its emphasis on an integrated system. The case study is a system with boundaries, purpose, and working parts. Achieving balance and variety is important, but learning is the primary objective to evaluating and analyzing outcomes (Stake, 1995).

Case studies integrate processes, people, and things of interest within a given situation (Gall et al., 1996). The processes, events, and people make up the phenomenon.
of interest. In this case study, the phenomenon of interest was the 6th-grade students within the classroom learning environment. A phenomenon has many aspects and thus a narrower focus was needed. The focus of this case study, from which data collection and analysis flowed, was based on the effects of the Roundhouse diagramming method of learning and the students who participated in the research study. The unit of analysis was the aspect of the phenomenon that was sampled. In this case study, the unit of analysis was the student, six of which were selected for study (Gall et al., 1996).

In-depth information from a small number of participants was valuable in exploring the construction of the Roundhouse diagram and its effectiveness in understanding science concepts. Six students were selected for detailed investigation. Stratified purposeful sampling was used—a sample of two above average, two average, and two below average cases in this 6th-grade classroom population of 19 students was sampled (see Appendix M). This type of sampling was used to facilitate comparisons (Patton, 1990). The qualitative researcher takes into account the entire organization, but out of necessity reduces the subject matter for purposes of manageability (Bodgan & Biklen, 1998). “The validity, meaningfulness, and insights generated from qualitative inquiry have more to do with the information-richness of the cases selected and the observational/analytical capabilities of the researcher than with sample size” (Patton, 1990, p. 185). The findings of this multiple case study were considered in terms of their implications for effective instruction in the middle school science classroom.

Contextual relations are highly pertinent to the phenomenon of study. “With its own unique history, the case study is a complex entity operating within a number of contexts, including the physical, economic, ethical, and aesthetic” (Stake, 1998, p. 91).
Qualitative research methods of inquiry possess qualities which are holistic, naturalistic, and dominated with phenomenological interests (Patton, 1990). Holistic case studies examine these social complexities using descriptive and interpretative techniques such as direct observation, participant observation, and interviewing. Participants will interact and share some characteristics, but many traits will not be common. The interview approach is used to gather data which cannot be observed (Bogdan & Biklen, 1998; Stake, 1998). A substantial amount of data was collected to represent the phenomenon. The data collected was in the form of field notes, transcripts, interviews, images, and documentation. Some quantitative data was collected as well (Gall et al., 1996; Yin, 1994).

Case studies involve field work so as to interact with participants in their natural settings. It is best to study a phenomenon in its natural context. "A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 1994, p. 13). The case study allows a thorough investigation of real-life experiences and the investigator has little control over the events. It is important that the investigator ensure rigor so that flawed evidence or biased views do not influence findings (Yin, 1994). A good case study is naturalistic and parallels real-life experiences, which is fundamental in enhancing the processes of awareness and understanding (Stake, 1998).

One of the major goals of a case study is to develop understanding through the eyes of the participants. The emic perspective is the viewpoint of the participant (Gall et
The case study is a comprehensive research strategy integrating purposes of data collection and data analysis.

The case study inquiry copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result benefits from the prior development of theoretical propositions to guide data collection and analysis. (Yin, 1994, p. 13)

Discipline is a quality of good case study research. One needs to be insightful enough to design good research questions which will be structured around the phenomenon being investigated. “The design of all research requires conceptual organization, ideas to express needed understanding, conceptual bridges from what is already known, cognitive structures to guide data gathering, and outlines for representing interpretations to others” (Stake, 1995, p. 15). Good research questions are important because they add structure to the case study which is an intricate web of complexities (Stake, 1995).

In a social process, experiences are all blended together, but the human constructivist claims knowledge is, in part, socially constructed. Researchers compare their case studies with others. A case study researcher constructs knowledge from others’ experience. Comparison description is also referred to as thick description and actually defines the uniqueness of the case study. As stated in the beginning, the case study is a system. The researcher observes its functions, describes and interprets its realities.

The conceptions of most naturalistic, holistic, ethnographic, phenomenonological case studies emphasize objective description and personalistic interpretation, a respect and curiosity for culturally different perceptions of phenomena, and empathetic representation of local settings—all blending (perhaps clumped) within a constructivist epistemology. (Stake, 1995, p. 98)
According to Yin (1994), there are six types of case study validation: documentation, archival records, interviews, participant observation, direct observation, and physical artifacts. No one source has an advantage over another and all are important in gathering data. The case study research fundamental to this design relied on (a) multiple case sources studied as single cases and then cross-analyzed, (b) interviews as an essential source of case study information, (c) documentation such as worksheets and evaluations under study, administrative documents, transcripts, and all other evidence collected from field notes and observations. (d) direct observation from the case study site, (e) participant observation involving introduction of activities, informal interviewing, and conversation with participants, and (f) physical artifacts such as Roundhouse diagrams and computer printouts.

Case study evidence can be collected, analyzed, and reported using qualitative, quantitative, or mixed methodologies (Patton, 1990; Stake, 1995; Yin, 1994). For the purposes of this research study, Yin's structured approach was followed in answering the major research question: Does constructing and using Roundhouse diagrams affect the meaningful learning of science concepts by middle school students?

**Qualitative Methodology**

Qualitative research does not have a distinct set of methods. Qualitative researchers use narrative, content, discourse, and even statistics to add insight to a study. A combination of techniques are used, such as participant observation, interviewing, survey research, cultural studies, methods of phenomenology, hermeneutics, feminism, ethnographies and many others. All of these research practices provide insight (Denzin & Lincoln, 1998). Bogdan & Biklen (1998) describe five features of qualitative research:
1. Naturalistic—The researcher collects data in the natural setting due to the concern for contextual cues to understanding the population under observation.

2. Descriptive—Qualitative research is illustrative. Data includes direct quotations, field notes, photographs, videotapes, transcripts, interview tapes, and documents, all in search of understanding. Qualitative researchers note gestures, facial expressions, conversation, cultural expressions, slang, and details which would normally be unnoticed in the environment. Information is rich and full of clues where all details are considered.

3. Concern with process—Qualitative researchers are not only concerned with products and outcomes, but with processes of how and why the conclusion was reached. Quantitative techniques will be combined by means of pre- and post-grading due to the introduction of the Roundhouse diagram. Qualitative strategies will be used to show how the activities, procedures, and interactions produce changes in cognition.

4. Inductive—Research emerges when integrated pieces of data take shape as the researcher collects and analyzes its parts. Data analysis goes from broad to specific in content.

5. Meaning—Participant perspectives are important to the researcher. Accuracy is imperative.

A Mixed Methodology

There are three major approaches to research in the field of education: quantitative, qualitative, and mixed methodology or hybrid studies. The quantitative approach is based on a positivist paradigm focusing on numerical data, while the qualitative approach is based on a phenomenological paradigm concentrating on
description and interpretation (Gall et al., 1996; Patton, 1990). Quantitative researchers
direct their attention toward explanation and control; qualitative researchers center on
understanding complex interrelationships (Stake, 1995). Qualitative methods permit the
researcher to evaluate issues in-depth and rich in detail due to the absence of
predetermined categories. Quantitative methods require predetermined categories to
which numbers are assigned (Patton, 1990).

Positivist research (quantitative) assumes an objective social reality which is
constant across time and setting and generates numerical data to represent the social
environment. Post-positivist research (qualitative) assumes that knowledge is socially
constructed and interpreted by the participants within that structure. Knowledge is
primarily developed through intensive study and collection of verbal data (Gall et al.,
1996).

Qualitative/quantitative differences are usually linked to the various kinds of
research questions to be answered. In quantitative studies, the research question is based
on a small number of variables. Qualitative research questions are based on cases or
phenomena which involve searching for patterns and relationships (Stake, 1995).
Both approaches have helped educational researchers discover understanding. This case
study used both approaches to investigate the effects of the Roundhouse diagram on
meaningful learning in the middle school classroom.

A mixed methodology was used in this research study. Qualitative methods were
employed which depended on researcher-subject interaction as well as intense
observation and interviewing. As a participant observer, the researcher worked
individually with students and also instructed the class activities. The classroom
teacher continued teaching the subject matter. The researcher aided in instruction, interviewing, answering questions, and making suggestions. The classroom teacher selected the sample based on information-rich cases, since she was familiar with the students' abilities. A quantitative component was used as additional evidence in triangulating methods. Students' science grade-point averages were recorded prior to the exposure to the Roundhouse diagramming method and were compared to their post-exposure grade-point averages at the end of the study. This quasi-experimental repeated-measures design required the use of a paired t-test to analyze gain scores. Effect-sizes were also computed. Additionally, descriptive statistics were used to provide depth to the qualitative data analysis.

**Participants and Setting**

The participants selected for this multiple case study were members of one 6th-grade science classroom containing 19 students, located at an urban elementary school in a south central Louisiana city with a population of approximately 20,000. The chosen school had approximately 700 students in grades K-6. The population was comprised of 51% African American students and 49% Caucasian students. There were seven Asian-American students, two Hispanic-American students, and one Native-American student in the school. In addition, about 85% of the entire school participated in the free lunch program.

The 19 students in this classroom were heterogeneously grouped ranging from low to high achievement levels, and they were representative of the school in terms of race and socioeconomic diversity. There were 10 females and nine males in the class.
Seventeen of the 19 students were in the free lunch program. There were 11 African-American students and eight Caucasian students.

The chosen sample for the multiple case study contained six students, two above average, two average, and two below average achievement levels. This researcher did an in-depth case study on each child and then a cross-reference was made as a comparative study for purposes of generalizable characteristics. The criteria for being selected were good communication skills and rich information to share, based on constructing Roundhouse diagrams and their effectiveness on meaningful learning and understanding of science concepts. The classroom teacher selected the participants because she had knowledge and documentation about their abilities to achieve in this particular learning environment (See Appendix M).

The classroom teacher had agreed to collaborate efforts with this research study and was willing to comply in every way. She had a master’s degree in Educational Leadership and was presently working on a specialist degree in reading education. She had 10 years’ teaching experience and was an excellent science teacher.

**Materials, Instruction, and Assessment**

The Roundhouse diagram was used to break down and grasp abstract scientific concepts such as: food chains, food webs, the water cycle, the carbon dioxide-oxygen cycle (carbon cycle), the nitrogen cycle, light, the electromagnetic spectrum, reflection, refraction, visual perception of color, and sound. In this 6th-grade classroom, the carbon cycle was referred to as the carbon dioxide-oxygen cycle for the purposes of clarity in the middle elementary grades.
The instruction for the Roundhouse diagram began with initial motivational activities which related the Roundhouse diagram to the learners by having them break down concepts using their favorite activities. After a sufficient amount of practice, the students were asked to relate science concepts in their textbooks to the Roundhouse diagram. The Roundhouse diagram worksheet (see Appendix E) was given to each student, with the teacher/researcher guiding them with an identical overhead transparency. Initially the students used pencils and planned out the diagram on the worksheet. After this phase was accomplished, the students were given blank Roundhouse diagrams to complete, along with stating their goals and objectives for that particular diagram. The students were given Sanford Expresso™ (India ink) pens to use for the diagram only. After completing the diagrams, the students used a Roundhouse diagram checklist (see Appendix G) in order to make sure all items were completed. Upon completion of the diagram, the students were given an evaluation sheet to fill out (see Appendix L). The diagrams were collected with all of the other documentation. The teacher/researcher evaluated the diagrams, using the mastery of technique checklist (see Appendix N). The students were asked to write a paragraph about their diagram in an essay form in order to better transfer the knowledge. The assessment the teacher gave in class covered the items used in the Roundhouse diagrams. The assessment task, at times, required that the students construct Roundhouse diagrams.

Students' diagrams were displayed on the classroom bulletin board. The six case study participants sampled for the study were scheduled for individual interviews for each teaching unit. The questions were open-ended and covered material based on the
construction of their own diagrams. The interview tapes were coded and transcribed. The questions varied according to each child’s construction and productivity.

After construction of the diagrams, the teacher assessed the students. These test scores were collected, along with the other materials, to be later analyzed, and averaged. This process continued until the information gathered reached a critical mass, and the researcher ended the study. In all, the study lasted for 10 weeks, approximately one-third of the entire school year.

Procedure

This researcher collected and analyzed qualitative and quantitative data to determine the effectiveness of the Roundhouse diagram in a 6th-grade science classroom. Data included field notes, observations, student responses to Roundhouse diagram worksheets, students’ perceptions from evaluation sheets, students’ mastery of technique sheets, tapes and transcripts of student interviews and student constructed Roundhouse diagrams.

Several statistical methods were used, as well, in this multiple case study. Documentation of science grades, both pre- and post-Roundhouse diagramming were compared using a paired t-test of $H_0: D \leq 0$ vs. $H_a: D > 0$ where $D =$ pre - post. The null hypothesis states that no difference between them exists. The alternative hypothesis states the difference of the two scores is going to be positive which indicates the post-score is higher than the pre-score (pre- and post-scores are defined in the Results and Discussion chapter).
Mean test scores during the 10-week period were examined for an overall grade increase trend for the case study group as well as the whole class. A comparison of average diagram scores for the case study group as well as the whole class were examined as well. Results were analyzed for both comparisons using a one-way Analysis of Variance (ANOVA) repeated measures design.

Pearson's $r$ correlation coefficients were calculated to examine the relationship between the mastery of technique scores and post-Roundhouse diagram test scores, as well as the relationship between icon scores and meaningful concept scores. Descriptive statistics were also calculated for test scores and diagram scores.

Scoring

Statistical data were collected over a 10-week period. This researcher entered the classroom in the middle of the 4th six-weeks' grading period. Three tests had been administered pre-Roundhouse diagram training. Two tests were given post-Roundhouse diagramming method before the 4th six-weeks grades were averaged (see Appendix O). The entire 5th six-weeks grading period was post-Roundhouse diagram and included an additional five test scores (see Appendix P). An additional five Roundhouse diagram lab grades based on the mastery of technique checklist were included in order to determine the effectiveness of diagram construction for the whole class (see Appendix Q).

The mastery of technique checklists were used to evaluate the students' ability to construct Roundhouse diagrams. The mastery of technique lab grades were given to five diagrams in the 5th six-weeks grading period (Roundhouse diagram Nos. 6, 7, 8, 9, and 10). The mastery of technique checklist was divided into 10 learning tasks. Each errorless learning task is worth two points, so a perfect Roundhouse diagram score is 20.
points. One point was earned if the student attempted to accomplish the task. Each diagram received a mastery of technique score for the case study group, although only five of them counted as lab grades. Lab Scores using the mastery of technique sheets were graded on the case study group for all 11 diagrams in order to monitor their progress (see Appendix R). The five mastery of technique lab grades for the overall class counted 20 points each for a total of 100 points or an additional test score at the end of the 5th six-weeks grading period. The mastery of technique scores were used to compare to the students' test scores in order to answer subquestion No. 1.

Each diagram received an icon score. A completed Roundhouse diagram has seven sections. In each section, a concept is required to link with an icon for recall purposes. If a student did not link an icon to the concept, that section received zero points. If the student attempted to link an icon, but the icon was not related, that section received only one point. If the student directly related the icon to the concept, that section received two points. There are seven sections on a Roundhouse diagram, so a perfect score equaled fourteen points.

Icon scores for all 11 diagrams were added, converted to percentages, and compared to meaningful concept scores, which were also converted to percentages and derived from the six test scores (see subquestion No. 3, Results and Discussion chapter).

Meaningful learning concept scores were based on test concepts and were only charted for the case study group. The total number of concepts were numbered and listed down the left column. Each case study group member's test score was analyzed according to the number of concepts learned (+) or missed (-). The number of incorrect concepts was divided into the total number of questions on the test and then converted to
This score was used to compare to the percentage of icon scores in order to answer subquestion No. 3.

This researcher took 35mm photographs during the research study to check for on-task/off-task attention or levels of concentration related to the construction of the Roundhouse diagrams. No pictures were taken the first two weeks of the study. Twenty-four pictures were taken during the following two weeks of the study; 24 pictures were taken during the next two-week time period; and 24 pictures were taken the last two weeks of the study. If a student was on-task, he/she received one point. If the student was off-task, he/she received zero points. The pictures were taken only during diagram construction times. The pictures were taken every 10 minutes during that class period of Roundhouse diagram construction. All scoring was a collaborative effort between the teacher and the researcher (See Table 29, p. 320).

**Data Collection Techniques**

According to Patton (1990), qualitative methods of data collection are composed of three main types: (a) in-depth, open ended interviews; (b) direct observation; and (c) written documents. Evidence for case studies come from several sources: documents, archival records, interviews, direct observation, participant observation, and physical artifacts. In combination with utilizing these data sources, certain principles must be applied such as (a) convergence of multiple evidence, (b) providing a thorough chain of evidence, and (c) providing a structured case study database (Yin, 1994). The main role of the researcher during data gathering procedures is clearly to maintain effective interpretation. One of the most important qualifications of the researcher is experience. This experience enables him/her to observe beyond what is ordinary as well as being able
to detect what leads to vital understanding. This ability requires sensitivity and crucial examination of people and case study events (Stake, 1995).

**Initial Procedures**

The first step in the data gathering process is to gain access into the educational setting in which the research study will take place. Regular access was arranged after an initial visit to the science supervisor of the accommodating parish school board. Contact was established with the school principal and a plan of action was negotiated. An overview plan of the research proposal was discussed and arrangements were made for maintaining confidentiality of data, sources, and reports.

An application was obtained from the Dean’s office at Louisiana State University for Consideration for Exemption From Institutional Review Board (IRB) oversight for studies conducted in educational settings (see Appendix S). A letter was attached to the IRB from the teacher and researcher explaining procedures for the research study in order to obtain parental permission (see Appendix T). An abstract for prospectus was attached along with a blank Roundhouse diagram so that the parents would be advised of the research questions, the construction of the Roundhouse diagram, and the intent of the research study. Another Interviewee Release form from T. Harry Williams Center for Oral History at Louisiana State University was attached for the six participants who will be formally interviewed (see Appendix U). Parental permission will need to be obtained since the students are minors.

**Anticipation**

The researcher visited the site and met with the cooperating teacher to discuss a plan of action and intent. The researcher informed the teacher of the focus of the study as
well as the research questions. The researcher obtained permission to pass out
appropriate forms to the students as well as explain the procedures and activities to the
students. The researcher trained the teacher in observation techniques and how to take
field notes on site.

The researcher reviewed what is expected in the way of case study research before
entering the setting. An outline was made for the teacher and the researcher, considering
the focus of the study, the research questions, and additional issues. Case study literature
was overviewed and Yin's (1994) data gathering suggestions were outlined and selected
to represent rules for the study. Anticipated problems and events were discussed with the
teacher and the role of observer/researcher was reviewed.

Preliminary observations of setting were made prior to entry. Tape recorders,
tapes, batteries, Sanford Expresso™ pens, Roundhouse diagrams, duplicated materials
such as worksheets, checklists, evaluation sheets, mastery of technique sheets, permission
letters, IRB forms, clipart books (seven) with indexes, video camera, laptop computer for
field notes, on site computers with graphic organizer programs and connections to
television, transparencies, and all teacher-needed materials were developed prior to the
first day of the study.

The teacher selected and identified the informants based on stratified purposeful
sampling; two above average, two below average, and two average students. She was
asked to select information-rich students with good communication skills.

Consideration was given to record keeping, files, tapes, coding system, and
storage. Methods used for triangulation purposes have been ensured. The teacher, the
researcher, and the students' perceptions were all considered. Multiple methods of

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collecting qualitative and quantitative data were employed. Multiple interviewers and outside observers were arranged to assist in procedures. Issues have been reconsidered based on the structure of the case study, data gathering techniques, and analysis.

**Sources of Evidence**

According to Yin (1994), there are six types of case study validation (see Figure 2, p. 146):

1. **Documentation**—Documents are helpful in corroborating evidence from other sources. They verify correct spellings. Inferences can be drawn from reading documents and new questions can be generated. Documents can serve as background information and can be used to pursue more fruitful observations and interviews (Patton, 1990; Yin, 1994).

2. **Archival records**—In the educational setting this may refer to grades, standardized tests, and other types of documentation that could prove useful in obtaining case study evidence.

3. **Interviews**—Interviews are essential for case study information. Case study interviews are open-ended, asking participants for insights, opinions, and facts. Key informants can ensure rich information in a case study. The researcher may want to back up what the key informant is saying by asking other opinions as well. Focused interviews are short, but usually follow a guide. The interviewer is careful about asking leading questions. The survey interview is more structured, focusing on a participant's Roundhouse diagram and what it means and represents in the participant's point of view (Yin, 1994).
When tape recording an interview, the researcher must obtain permission. The researcher transcribes the tapes. If the recorder creates a distraction, or if it becomes a substitute for listening, notes should be used instead (Yin, 1994). See pages 128 through 136 of this document for in-depth interview strategies.

4. **Direct Observation**—The researcher made direct observations and documented the dimensions of social behavior: space, actor, activity, object, act, event, time, goal, and feelings (Spradley, 1979, p. 79). Grand and mini-tour descriptions were used which contained direct quotations from participants as well as thick description of the learning environment. To increase the reliability of the observations, more than one observer was used. Multiple observers were used when construction of the Roundhouse diagrams was taking place, video and still cameras were used to back up evidence.

   Field notes were taken by the researcher using note pads and a laptop computer. The researcher trained the teacher and an outside observer to take field notes as well as informally converse with students during Roundhouse diagram construction. Field notes were descriptive, capturing basic information such as the physical setting, social interactions, activities, and verbal and nonverbal accounts. Descriptions were specific, not general. "No skill is more critical than learning to be descriptive, concrete, and detailed" (Patton, 1990, p. 241).

   Field notes contained the feelings of the researcher, experience, insights, interpretations, and beginning analysis. Interpretations were marked and labeled as interpretations (Patton, 1990; Yin, 1994).

5. **Participant Observation**—This was an active role, not a passive role. In this case study, the researcher introduced the Roundhouse diagram and, initially, taught the
students how to construct them. The teacher observed me but then resumed her role of teacher in this process. Most of the time the researcher and the teacher worked together assisting students, making suggestions, answering questions, and taking field notes. The researcher interviewed students formally. The outside observer interviewed the students informally. Participant observation provided an opportunity to view the study from the inside, which was invaluable when portraying an accurate view of the case study.

6. **Physical Artifacts**—This is physical evidence obtained on site. The Roundhouse diagrams were obtained as evidence. The Roundhouse diagram worksheets and student evaluation sheets were also collected and analyzed.

Harry Wolcott (1990) suggests that researchers do qualitative research "start to finish" but think "finish to start." This means the researcher should think about the entire study right from the beginning. The researcher should make tentative decisions and redefine issues as the study progresses. The researcher should make temporary predictions in terms of constructs, themes, and patterns. Thick description, analysis, and interpretation should take place from the very beginning of the study (Gall et al., 1996).

**General Analytic Strategy**

Data analysis is composed of classifying, analyzing, systematizing, and recombining the evidence of a case study in order to address the initial propositions within the study (Yin, 1994). The object of case study analysis is to make sense of an immense amount of collected data, to reduce the volume of information by identifying significant patterns, and to produce a structural framework which is clear and consistent while communicating the essence of what the data reveal to the external reader. Since qualitative inquiry depends on the capabilities of the researcher, qualitative analysis
depends on the capabilities of the analyst. Regardless of what suggestions and guidelines are followed, "analysts have an obligation to monitor and report their own analytical procedures and processes as fully and truthfully as possible" (Patton, 1990, p. 372)

Yin (1994) suggests two general strategies to produce analytic conclusions and to rule out alternative interpretations. The first strategy is relying on theoretical propositions that initially led to the case study. These original objectives led to the development of the research questions, the review of literature, and the decision to use a case study design. The propositions of focus in the case study help to organize causal relationships to answer "how" and "why" questions. The second analytic strategy is to promote a descriptive structure for organizing the case study. If the purpose of the case study is descriptive, this method is acceptable. This approach may help to identify causal links to be analyzed such as quantitative links. The analysis depends on the clearness of the purpose (Patton, 1990; Yin, 1994).

**Dominant Modes of Analysis**

According to Yin (1994), there are four significant techniques to use as part of a general strategy. These "dominant modes of analysis" help to increase internal validity and external validity. The modes of analysis described are pattern-matching, explanation building, time-series analysis, and program logic models. The theoretical base for this present research study can be found in the Literature Review chapter.

Pattern-matching compares empirical evidence with previous predictions. If the case study is explanatory, patterns can be discovered in both the dependent and independent variables. In descriptive case studies, patterns can be detected in predicted patterns prior to data collection. The dependent variable in my case study is the effects of
the Roundhouse diagramming method on the learning of middle school science students. According to the quasi-experimental design, there may be a variety of outcomes, and a certain pattern of organizational concepts may be produced. If the patterns match those patterns in the initial predictions based on theories which support the research, a solid conclusion can be drawn about the effects of this method. If the results fail to match the initial prediction, the initial proposition may be questioned. If changes are predicted and they occur (such as "production may increase," or "students may create a new technique," or "conflicts could occur") the findings could lead to an even stronger conclusion (Gall et al., 1996; Yin, 1994).

Independent variables are also considered in pattern-matching. The Roundhouse diagram represents the potential cause for the increase in meaningful learning and understanding of scientific concepts which in turn could result in higher grade-point averages. The focus is now on why those effects occurred. "The concern of the case study analysis is with the overall pattern of results and the degree to which a pattern matches the predicted one" (Yin, 1994, p. 108). The fundamental comparison need not involve quantitative data and can be solely based on qualitative data which have been collected.

Explanation building utilizes causal links involving the independent variable. Causal links should reflect the theoretical propositions of the study. This method involves making an initial theoretical statement, comparing this statement to the findings of each case study (in a multiple-case study), revising the initial statement, comparing results to revisions, and repeating this process as much as needed (Yin, 1994).
Time-series analysis is concerned with the course of events and sequence. This is
difficult because changes are hard to pinpoint as to when they begin and end. Tracing a
time frame surrounding changes is a major strength of a case study. This timeline can be
compared to other trends based on theories of other research studies. The time frames in
which these changes occurred can be compared (Yin, 1994).

Chronological events can be analyzed in terms of causal events which can cover a
variety of variables. In the case study of the effects of Roundhouse diagrams on
meaningful learning, some events occurred before others. Some events will follow
others. Comparisons among cases can be made to back up the general sequence of events
and when they occurred (Yin, 1994).

Program logic models combine pattern-matching and time-series analysis. These
focus on the key factor for cause and effect. What is the key factor that causes
meaningful learning to occur which results in greater understanding of science concepts?
There is a chain of events which happens over time leading to this answer. In a multiple
case study, this chain of events can be traced in comparisons of each individual cases.
These repeated cause-effect sequences eventually link together and determine whether a
pattern match has been accomplished (Yin, 1994).

Patton (1990) suggests strategies for analyzing interviews. A case study analysis
should be made with each participant interviewed. Doing a cross-case analysis involves
combining all participant answers to similar questions and analyzing different points of
view on major issues within the study. Using an interview guide approach rather than
standardized questions will be more difficult because the answers will not show up in the
same places. Nevertheless, relevant data will surface and can be compared. The
researcher transcribed each case separately using an interview guide and open-ended questions and then composed a cross-case analysis of relevant issues.

**Interview Approaches**

Patton refers to three basic approaches when obtaining qualitative data using open-ended interviews. These three choices are “(a) the informal conversational interview, (b) the general interview guide approach, and (c) the standardized open-ended interview” (Patton, 1990, p. 280).

The first of these approaches, the informal conversational interview, occurs on the spot, in a natural way, so that the respondents never even know they are being interviewed. This method is spontaneous and usually occurs when the interviewer is a participant observer in the research process (Patton, 1996; Gall et al., 1996; Bogdan and Biklin, 1998).

The second approach Patton refers to involves discussing issues with the respondent before the interview occurs. This approach serves as a checklist, making sure the topic is covered well. There exists no set of predetermined questions in this type of interview. The questions can be decided by the interviewer as the conversation evolves. There are definite topics that questions will probe in this type of interview. The conversation is much more focused than with the informal conversation method, yet it is open to multiple perspectives. The interview guide provides a framework for the questions to be based upon, but does not utilize specific questions (Bogdan and Biklin, 1998; Gall et al., 1996, Patton, 1990).

The third approach, the standardized open-ended interview has time constraints. It is also desirable to obtain similar information from each respondent so each person is
asked essentially the same questions. These questions are written out in advance. This type of interview is much more systematic than the other types and is much easier to analyze. Asking different questions to different respondents can affect the credibility of the results because more information may be collected from one person than another using different methods, and it would be difficult to determine qualitative differences in the perspectives received from different people.

**The Qualitative Interview**

A good interview flows easily while talk is natural. An interview which results in the respondent's point of view, full of rich, descriptive data is the desired kind of quality. Communication not only involves verbal language but facial expressions as well. Most people need to be encouraged to elaborate when speaking. The qualitative interviewer should avoid questions which are answerable with a "yes" or "no." Many people need time to warm up, so it is important to keep the interview going and to remain patient (Patton, 1990).

"The goal of understanding how the person you are interviewing thinks is at the center of the interview" (Bogdan & Biklen, 1998). The emphasis should not be on answering every question you designed to ask, but instead on the quality of what is being said. When you ask people to share themselves with you, it is very important not to judge what they are saying. The interviewer must be respectful and not upset the respondent, making the respondent reluctant to reveal any new information.

"Two principal uses of case study are to obtain descriptions and interpretations of others" (Stake, 1995, p. 64). The interview is the best tool for the qualitative researcher who is in search of multiple perspectives. Getting a good interview is often a difficult
A qualitative case study does not use the standardized survey method using the same questions for each respondent. In the case study experience, the respondent is expected to have a unique experience with his/her own story to tell. Instead, the qualitative researcher should have a list of relevant subject questions asking descriptive-type questions in order to determine an explanation. Rehearsal is a good idea (Patton, 1990; Stake, 1998).

Most case study interviews are open-ended, where the interviewer asks for facts as well as opinions and further insights. The respondent becomes an informant the more he/she reveals. The informant can also disclose information with future leads to more information. At times, it is important to rely on other sources to corroborate what has been said (Yin, 1994).

Another type of interview is the focused interview which remains open-ended but only for a short period of time. This type of interview is usually used to corroborate what has already been stated. It is important to probe for a fresh point of view or even a totally different perspective in formulating a fair outlook of the situation (Yin, 1994).

A survey can be used in a case study if one were doing a study of a neighborhood and surveyed the residents which involved their opinions (Yin, 1994). Nevertheless, whatever kind of interview is used, this method is of essential importance to the case study. Case studies are about human beings and the stories should be told by those who were involved. Interviews should always be considered in light of bias and poor recall. It is always important to hear all sides of the story (Yin, 1994; Stake, 1995).
Kinds of Interview Questions

The main part of the interview process involves the development of the questions to be asked. Questions developed prior to investigation or during the interview process depend on what kind of interview one is doing. On-the-spot questions are used in structured conversational interviews. These types of questions depend on the interviewer’s ability to think and have experience in this process. Structured interviews don’t require as much experience because the questions are asked in a specific sequence. Research indicates that more information is likely to be produced when the interviewer and respondent are matched according to race, sex, age, and gender.

"The interview question is a stimulus that is aimed at creating or generating a response from the person being interviewed. The way a question is worded is one of the most important elements determining how the interviewer will respond" (Patton, 1990, p. 295). Questions should truly be asked in an open-ended manner in qualitative research. This permits the informant to answer the question in a multitude of ways (Gall et al., Patton, 1996).

The object of an in-depth interview is to get the informant to talk freely. Questions should not be leading in any way or be the opinion of the interviewer. Presuppositions are another useful method in the interview process. If one assumes the other person has something to say, then, more than likely, something will be said. Also, no more than one idea should exist in anyone particular questions. It becomes confusing, thus two questions cannot be answered efficiently. Multiple questions often create tension. Questions should be focused and clear. The interviewer should be careful about
asking why questions because the informant may not know the answer and may become uncomfortable in the interview (Patton, 1990).

**The Interview Method**

The interview method is a powerful strategy for permeating into the learner's cognitive structure to determine what misconceptions the learner possesses. During the interview process, it was determined that students at the 2nd-grade level were able to meaningfully learn about abstract concepts by using concrete visual props, audio-taped guidance, and explanations which enhanced meaningful learning (Nussbaum & Sharoni-Dagan, 1983). Piaget’s theory stresses maturity in stages of development in order for readiness to occur. Ausubel’s theory which stresses prior knowledge and experience to determine readiness.

Our principal objective in an interview is to ascertain what the learner knows about a given body of knowledge (Novak & Gowin, 1984, p. 122.) Nussbaum & Novak (1976) determined one of the difficult problems in studying conceptual frameworks of children in science is that it is not possible to isolate a single concept and just deal with that one independently. This is because science is part of an integral web of knowledge where everything is ultimately connected. This is one reason why the Roundhouse diagram is such a good graphic organizer. The conceptual turntable associates each section to the next section, where the parts of the whole system are contained in one entity. Science is full of systems and each system depends on other systems (AAAS, 1990, 1993). Learning concepts in science is usually not a one-time happening, it is accomplished in a series of steps over time with relationships and associations. When
children miss out on a relationship, they often fail to get its meaning. Teachers are often not aware that students do not grasp concepts all at once, especially abstract concepts.

To sustain a student's interest in an interview, props and activities can be used to increase understanding. The first step is to review the students' Roundhouse diagram and generate questions based on how the child sequenced the events. The paraphrasing or chunking of information may not be sufficient. The drawings linked to the concepts may not be known to the researcher. A child may draw a perfectly valid picture, but if the interviewer researcher has no idea what it is, only the child understands. At times, this knowledge needs to be communicated.

**Record Keeping**

Keeping good records of interviews is very important. The researcher should write down all key ideas and captured moments. A good interviewer can write down an account of a situation and later confirm it with the informant to make sure it is accurate. The close of the interview, is a good time to go over comments and make sure the interpretation is correct (Stake, 1998).

A tape recorder is a necessity for the qualitative researcher. The accuracy of the conversation is increased and allows the interviewer to be more attentive to the respondent. When one is busy writing, it oftentimes is difficult to have good eye contact. The tape recorder does not take the place of note taking. Notes taken in the interview process can lead to more questions and richer information. Note taking also facilitates later analysis (Patton, 1990). If you choose to use a tape recorder, make sure you ask for permission first. You must accept their request even if they say "No." Notes should be taken on facial expressions and nonverbal gestures to add to the recorded message.
(Bogdan & Biklen, 1998). "The tape recorder reduces the tendency of interviewers to make an unconscious selection of data favoring their biases" (Gall et al., 1996, p. 320).

The main disadvantage to using a tape recorder is that the presence of the recorder tends to change the behavior and responses of the respondent to a degree, especially if sensitive matters are being discussed. It is important for the interviewer to gain the trust and confidence of the respondent.

**Ethics of the Interview**

"Interviews are interventions. They affect people. A good interview lays open thoughts, feelings, knowledge, and experience not only to the interviewer but also to the interviewee" (Patton, 1990, p. 353). For this reason, the interviewer must have an ethical framework to work from. Patton (1990) suggests several issues to consider, such as:

1. Promises and reciprocity. If the interviewer makes a promise, it must be kept.

2. Risk assessment. The interviewer must consider that certain information could put a person at risk and this must be respected.

3. Confidentiality. The interviewer must consider how information will be analyzed and reported, and honor the wishes of the respondent.

4. Informed consent. The interviewer must get informed consent from the interviewee (or if the interviewee is a minor, assent from the minor, and consent from a parent or guardian), for protection purposes of all people involved.

5. Data access and ownership. Be sure to inform the interviewer the purposes for the research and who will have access to the information.

6. Interviewee mental health. The interviewer must consider the state of mind of the interviewee before asking that person highly sensitive information.
7. Advice. The interviewer should have another person to consult on matters of ethics during a study.

Qualitative research studies are highly personal. Naturalistic inquiry takes the researcher into other people’s lives. In-depth interviewing opens up what is inside of people’s minds and hearts. The process is highly sensitive and requires total honesty and respect (Patton, 1990).

There is no such thing as a perfect interview. Not all interviews go well. People are emotional and behavior is never predictable. It is important for the atmosphere to be relaxed and the environment to be calm.

Student Interviews

Asking questions is a very valuable instructional tool which can be integrated into any lesson before, during, or after new material has been presented. Questioning students as part of classroom instruction directs the learner’s attention and provides organized structure, which enhances the encoding process. Questioning prior to listening enhances recall by directing attention to relevant material. Questioning after instruction aids recall by promoting rehearsal of learned material. Careful construction, wait time, form, and sequence should be considered to ensure adequate student response. There is a tremendous amount of educational value in being able to ask questions, but the greatest consideration should be in listening to what is being said (Bogdan & Biklen, 1998; Hohn, 1995; Stake, 1995).

Purpose for Interviewing

The purpose for interviewing is to determine another person’s perspective regarding a particular concept. According to the Vee diagram method, interview tasks are
events which take place between the student and the interviewer and require questions as well as records obtained as a result of the questioning task (Novak & Gowin, 1984). The format of the interview can range from highly flexible. Where questions may vary depending on the answers, to highly rigid, where questions are constructed ahead of time. Piaget’s questions were highly standardized because his goal was to make knowledge claims based on specific patterns regarding performance at a particular level or stage. Dependent on the task for asking the questions, the objective is to reveal knowledge relevant to a particular subject and questions should be asked in such a way as to reveal as much as possible (Novak & Gowin, 1984).

The Interview Process

Open-ended interviewing should remain free of the interviewer’s preconceived ideas, and needs only to pertain to the interviewee’s perspective. The interview process is necessary to determine what exists in another person’s mind which is not observable (Bogdan & Biklen, 1998; Patton, 1990; Spradley, 1979; Stake, 1995). Specific behaviors such as feelings, thoughts, and intentions are personal in nature and not observable, yet are of the utmost importance in the interviewing process. “In all situations, the interview is used to gather descriptive data in the subject’s own words so that the researcher can develop insights on how subjects interpret some piece of the world” (Bogdan & Biklen, 1998, p. 94).

Both quantitative and qualitative research use interviewing to collect information meaningfully. In quantitative research studies, the interview is carefully prepared in advance so that all respondents have the same experience. The interview questions are alike to each individual to ensure that the data collected can be easily compared.


**Generalizability**

Researchers who are concerned with generalizability are able to draw from other studies to determine a representation of their findings. Generalizability refers to the ability of a particular study’s findings holding up beyond the subjects and setting within that study (Bogdan, & Biklen, 1998; Gall et al., 1996). Qualitative research is interested in finding particular patterns or universal statements that often repeat themselves and are in fact generalizable within other cases or participants. Qualitative researchers are concerned with generalizability in regard to social processes and descriptions which may in fact be present in other settings.

A general concern for doing case study research is what will be provided in terms of generalizations due to small sample size (Patton 1990; Stake 1995). It would be difficult to generalize about one single case study, but if many case studies were researched regarding the same phenomenon, there would be characteristics which could be generalizable (Stake, 1995; Yin, 1994). Common problems, actions and responses could arise over and over again. These types of generalizations are referred to as petite generalizations, and will generally occur throughout the case study. Case studies are not chosen when generalizability is the goal. Other types of studies do a better job of this.

"The real business of case study is particularization, not generalization" (Stake, 1995, p.8). Emphasis is primarily on understanding and uniqueness. "Damage occurs when the commitment to generalize or create theory runs so strong that the researchers attention is drawn away from features important for understanding the case itself" (Stake, 1998, p.91). "The common view of generalizability limits the researcher to reconceptualize the role of social science in education and human services" (Janesick, 1998, p.51).


**Triangulation**

Qualitative research uses multiple methods of triangulation in an attempt to secure an in-depth understanding. Triangulation is a heuristic tool for the researcher in an attempt to strengthen a study design. A combination of qualitative and quantitative approaches are used to substantiate data collected in a research study. Patton (1990) and Yin (1994) suggest four kinds of triangulation that contribute to validation of qualitative analysis: (a) methods triangulation—using multiple methods to study the same problem or issue; (b) triangulation of sources—looking for consistency using a variety of sources; (c) analyst triangulation—using several different researchers to review findings; and (d) theory/perspective triangulation—using multiple perspectives and theories to interpret data collected.

Triangulation of methods usually refers to comparing qualitative data with quantitative data. It is believed that grade-point averages will improve as construction of the Roundhouse diagram improves. Triangulation of qualitative data sources is cross-analyzing consistency of data such as comparing interview data with observational data, comparing what is said in an interview with what is said in class, checking for repetitiveness, comparing different points of view from participants, teachers, and researchers. Triangulation through multiple analysts involves using multiple observers and interviewers, which helps to reduce potential bias. Team effort is most important in field work. Triangulating analysts can be used for comparing findings analyzing qualitative data. Another way of analyzing is to have the participants review their findings. Theory triangulation utilizes different theoretical perspectives. The purpose of
this method is to discover different assumptions and fundamental knowledge claims (Patton, 1990).

Case study integrates a wide variety of evidence. Using multiple sources of evidence helps the researcher to analyze the evidence effectively, and this allows the researcher to approach a broad range of actions, attitudes, and behaviors. Any finding is more accurate if it is based on several points of view, because it leads to a fuller understanding (Bogdan & Biklen, 1998; Yin, 1994). Triangulation helps to discard bias which may result from using one data collection method, source, analyst, or theory (Gall et al., 1996; Patton, 1990; Yin, 1994).

**Validity and Reliability**

Patton (1990) notes that validity and reliability of qualitative data depend, to a great extent, on the skill of the researcher. “Validity in quantitative research depends on careful instrument construction to be sure that the chosen instrument measures what it is supposed to measure. In contrast, in qualitative research the researcher is the instrument” (Patton, 1990, p.14). Skillful observations involve much more than being present. The researcher needs to be aware of all aspects of the study including behaviors, actions, verbal and nonverbal messages. Skillful interviewing involves much more than asking questions. One needs to know priorities of which question to ask first in order to draw the most information. Content analysis involves so much more than just reading. It involves seeking out patterns and domains which repeat themselves. These skills require a tremendous amount of practice and training (Patton, 1990).

The way humans perceive reality is highly unique. Several people can observe the same phenomenon yet perceive it many different ways. The major question among
researchers is how one can trust observational data. Ordinary, untrained human observation is very inadequate and definitely casts a doubt on validity. Scientific inquiry using observational methods requires disciplined training and rigorous perception” (Patton, 1990, p.200). Only a skillful trained researcher can account for data based on observation, and still, triangulation methods are necessary in order to be accurate.

Rigorous training involves the ability to record accurate, descriptive field notes as well as use rigorous methods to validate observations. Just as training is required for the qualitative researcher, it is also required for the quantitative researcher. People don’t naturally know how to use statistical methods. “Preparation has mental, physical, intellectual, and psychological dimensions. Part of preparing the mind is learning how to concentrate during observation” (Patton, 1990, p. 201). An expert observer cannot do his/her best job engaging in observation, with a moments’ notice—mental preparation is required in order to get the best results. Although expertise may be involved, the use of multiple methods of data collection enhances the validity of any study.

Yin (1994) describes four tests used to establish the quality of empirical social research, or case study research. They are construct validity, internal validity, external validity, and reliability. Construct validity refers to establishing accurate operational measures for the concepts being studied. Yin (1994) has suggested three ways to remedy construct validity: (a) use multiple sources of evidence (b) establish chain of evidence, and (c) have key informants review the research. Internal validly refers to establishing a causal relationship whereby certain circumstances lead to other circumstances. This causal relationship can be strengthened by pattern-matching, explanations, and doing a time-series analysis. External validity deals with whether the findings of a study are
generalizable outside of the case study. Generalizations do not happen automatically. Follow-up studies are needed to replicate findings, or one can choose to do a comparative multiple case study. Reliability refers to repeating the data collection procedures and getting the same results. The case study procedure should be done so that another person could repeat the procedures and arrive at the same results (Yin, 1994).

Reliability in case study research requires developing a case study database, using a case study protocol, and maintaining a chain of evidence. Creating a database involves collecting evidence and creating a report and keeping these records separate. This way one could read both collections and determine if the results would lead to the same conclusions. “Every case study project should strive to develop a formal presentable database, so that, in principle, other investigators can review the evidence directly and not be limited to the written reports” (Yin, 1994, p.95).

The database, made up of four components: case study notes, case study documents, tabular materials, and narratives. Case study notes come in a variety of structures such as transcripts from interviews, interview tapes, observations and document analysis. These should all be classified into major categories so that later they can be accessed. Tabular materials include survey and quantitative data collected on site. Case study documents relevant to the case study can be collected at any time and should be organized and stored as well. Certain narratives can also be part of the database made up of questions and answers collected formally and informally on site (Yin, 1994).

In a multiple case design, it is essential to have a case study protocol to include an overview of the purpose, objectives, research questions, underlying theories, and setting of the research. The most important part of the protocol is framing good questions which
address issues to which answers are being sought. Such questions are essential for collecting relevant data. The protocol also includes field procedures which integrate real-life events, which may at times intrude on the participants, such as setting up additional interview sessions and asking questions. The major function of the case study protocol is to increase the reliability of the research (Yin, 1994).

Maintaining a chain of evidence in a case study increases reliability. This means the reader will be able to follow the study from the initial research questions to the case study conclusions. The external observer should be able to present the evidence and prove its conclusions. With this objective in mind the construct validity of the case will be determined, thereby increasing the overall quality of the research. The report must indicate sufficient citations from evidence in specific documents, observations and interviews. The database should indicate time and place, as well as circumstances which surround the evidence. All circumstances should be consistent with questions and procedures contained in the case study protocol, and all conclusions should link the initial research questions to the case study protocol. This type of cross-referencing system provides a clear chain of evidence (Yin, 1994).

In this multiple case study the researcher created both a case study protocol, a case study database, and a chain of evidence. In addition, assuming that subject area averages in science are adequate indicators of subject area performance or knowledge, the researcher used students' grade-point averages, prior to the exposure to the Roundhouse diagram, as well as post-exposure averages, in order to determine, the effectiveness of this method used in science.
**Credibility**

The nature of qualitative inquiry is interpretative. To establish credibility in case study research, three distinct elements are suggested by Patton (1990):

1. Accurate techniques and methods for gathering information-rich data, which is carefully examined with attention to issues of validity, reliability, and triangulation.

2. Trustworthiness of the researcher, who depends on experience in the field, exposure to interviewing techniques, track records, known qualities and self presentation.

3. "Philosophical belief in the phenomenological paradigm, that is, a fundamental appreciation of naturalistic inquiry, qualitative methods, inductive analysis, and holistic thinking" (Patton, 1990, p.461).

Yin (1994) describes three principles which are crucial for establishing credibility within case study research: (a) the use of multiple sources of evidence such as direct observation, participant-observation, and interviewing (triangulation of data sources, evaluators, theories, and methods should be used in collection of data.); (b) creating a case study database; and (c) maintaining a chain of evidence.

According to Patton (1990), a credible qualitative study addresses the following issues:

1. What techniques and methods were used to ensure the integrity, validity, and accuracy of the findings?

2. What does the researcher bring to the study in terms of qualifications, experience and perspective?

3. What paradigm orientation and assumptions undergird the study? (p.461)

**Ethics**

"The value of the best research is not likely to outweigh injury to a person exposed" (Stake, 1998, p. 103). Qualitative research exposes the participant’s world and
should be respected. Personal views and circumstances are portrayed and these issues should be discussed in advance. Two issues dominate most ethical guidelines in research with human subjects:

1. Subjects need to understand the nature of the study and be aware of the implications involved. Participants enter research studies voluntarily and give signed permission for interviews which could be taped.

2. “Subjects are not exposed to risks that are greater than the gains they might derive” (Bogdan & Biklen, 1998, p. 43).

Institutional Review Boards check proposed research studies to ensure the safety of the participants in the educational setting. The subjects in qualitative research can continually make decisions about participating in the study. A participant can withdraw from the study at any given time.

Bogdan & Biklen (1998) offer the following ethical principles:

1. Subjects voluntarily enter research studies. Anonymity should be promised verbally and written.

2. Subjects should be informed of all research intentions and give written consent. Researchers should be honest and never tape record without written and verbal permission.

3. Publishing purposes must be agreed upon.

4. Data or findings should not be fabricated or distorted, intentionally or otherwise.
Many educational researchers belong to the American Educational Research Association (AERA) which provides a total of 45 ethical standards which should be read by anyone participating in a research study (Gall et al., 1996).
Goals: To show how evidence is collected while conducting a case study.

Figure 2. Data Collection Methods
THE EFFECTS OF ROUNDHOUSE DIAGRAM CONSTRUCTION AND USE ON MEANINGFUL SCIENCE LEARNING IN THE MIDDLE SCHOOL CLASSROOM

VOLUME II

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy

in

The Department of Curriculum and Instruction

by

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RESULTS AND DISCUSSION

The Learning Environment

As I entered the 6th-grade science classroom, the mood was quiet and the students and their teacher were very curious, realizing they were about to embark on a new experience. Everyone looked up as the door opened. A new face entered the room, and a momentary silence came over the surroundings.

Although the students had previously been informed that I was going to engage them in a research study, their eyes were squinted with a sense of wonder as they sat still, full of anticipation, anxious for me to start speaking. The teacher was collecting papers from them that I previously had asked her to distribute to the class. She introduced me to the class with a welcome and a smile.

I proceeded to walk around the room observing the physical surroundings and looking at the students’ inquisitive faces. The room was small with not much available space. It was full of instructional materials such as books and science equipment, as well as boxes holding various materials. Students’ science fair projects were scattered throughout the background and these projects provided an atmosphere of creativity and inquiry. The wall space was covered with many posters and teacher-made instructional tools centering around science and language arts, the specific topics which were taught in this particular classroom. There were only 19 students in this classroom, but upon first impression, the small space made it appear more crowded than it really was.

The students’ desks were made of wood and metal and had pencil grooves as well as racks underneath to hold their books. The students’ booksacks were next to their desks holding materials they were not currently using. The students’ desks were
situated in five rows with four students in each row and each student had a good view of
the teacher. The teacher's desk was located in the back of the room and was covered
with papers to be graded and teacher's manuals. Next to the desk was a file cabinet for
test papers. A large table was situated horizontally across the back of the room with a
beige skirt around it in order to hide all of the boxes full of papers stacked on top of
each other. The shelves were full of textbooks, paper towels, and outside learning
materials. The floor was covered with green linoleum with speckles distributed
throughout it in lighter colors, and the walls and shelves were an institutional gray
found in many classrooms throughout the state. The windows, with bookshelves below,
covered the entire right side of the room and were covered with white curtains which
allowed sunlight to pass through. Another set of windows lined the left side of the
room, covering the top two feet of space above the bulletin boards. The light provided a
bright, cheery atmosphere for the students to work within. The bulletin board space
extended about fifteen feet and was covered with posters related to the science subject
matter. Pictures displayed throughout the room were bright and full of color with
phrases such as: "The Effects of Heat," "Measuring Energy," "The Effects of Matter,
and "The Characteristics of Sound." There were pictures of the color wheel and
different forms of energy. Above the bulletin boards stood two large, colorful
cardboard work station display centers, one with the word "Think," the other with the
word "Explore" in the center of beautiful science pictures of the human body and other
animals and plants. These displays covered the windows and helped keep the glare off
the front board so the students could see well. One portion of the bulletin board was
devoted to the students' work and had sayings such as "Great" and "Super" written as
fun titles over their work. At the other end of the bulletin board was a huge calendar and a map of Louisiana.

The front of the room had a clear space of about 10 by 20 feet for the teacher’s metal table on wheels where she could perform science experiments. There was also a wooden podium with a high wooden stool. There was enough room for the overhead projector which was often used when teaching visuals. The front blackboard was a white metal board with black marker pens instead of chalk. Above the white board were the letters of the alphabet written in cursive to help those students with handwriting problems. There were two large air conditioning units, one in front of the room and the other one next to the teacher’s desk. The latter unit was covered with papers held on with “post-it” magnet clips used for important reminders.

The back wall of the classroom displayed hooks intended for the purpose of hanging coats and booksacks. However, the room was so crowded that the students were unable to use the hooks. On the back wall was a hanging display of the solar system. The ceiling was painted bright white with metal rafters going across the front and back sections providing support for the two large black fans which helped to keep the air well circulated. Next to the table stood a large flip chart used in reading and language arts classes. A clock hung on the back wall of the classroom next to the teacher’s desk which helped her to meet various schedules throughout the day.

The wall space was covered with interesting, stimulating, and informative posters. The first poster I noticed when I entered the room was a picture of “The Elements” which is introduced to 6th-graders as part of their science curriculum. Next to the element chart, was a huge multicolored plastic map of the United States which
hung over part of the front window space, adding a cheerful array of bright colors to the surroundings. Other wall posters included a picture of the redwood forest with a view from the base of the trees looking up into the treetops and the sky above. There were also colorful poster boards displayed with helpful information related to linking verbs and context clues for reading.

**Role of the Researcher**

My role in this study with this 6th-grade science class was primarily that of researcher. My role as a participant observer included teaching the class only the first two days. I wanted to be sure the students and the teacher were informed about the point of view of the researcher, why the research on Roundhouse diagrams was important, some background information on the learning theories, and, most of all, the procedures for construction of the Roundhouse diagram.

The teacher and I had planned meetings and conversations about these procedures prior to the beginning of the research study. The teacher had informed the students of my role in the classroom and that six students had been chosen as a case study group for the study (see Appendix M). Before we began, the teacher informed the students in the case study group that extra work might be required from them. These six students were situated in two rows in front of where I sat in the room.

The duties I performed as a participant observer included moving about the room, offering helpful suggestions to various class members, taking 35mm photographs of on-task/off-task behavior during construction of diagrams, videotaping, questioning students using informal interviewing techniques, answering questions for the teacher at
times, distributing handouts and worksheets, and performing formal interviews with the case study group.

I interviewed the six students formally every two weeks in the beginning and every week the last three weeks of the study. I had all six students meet me at school at 6:30 a.m. in a vacant room for interview sessions. Before the interviews, I informed each student what we would be talking about so that they could be thinking about how to answer the questions. Each interview took approximately 15 to 20 minutes. The students had never been interviewed before, and some were shy of the tape recorder. We usually discussed completed Roundhouse diagrams and test papers. I found the interview method to be a valuable tool and discovered many misconceptions the students had about their science lessons.

The teacher sat down in the back of the classroom in an empty desk, as I introduced myself as a research teacher from Louisiana State University. Some of the students recognized me from teaching, however I explained to them that I was not teaching school this year so I could complete work on my Doctor of Philosophy degree. The teacher had distributed the Institutional Review Board (IRB) forms to the class. I told the students these forms needed to be signed by their parents in order for them to participate in this research study (see Appendix S).

I asked the teacher to write down quotations of comments made by students, her opinions of how the lesson was taught, her comments about the discussion, and any relevant thoughts which could be helpful that occurred to her during my presentation. I noticed that she was writing notes as I was teaching. I had given her a prepared list with characteristics to look for as she observed the class. In the beginning, I trained her to
observe the students, looking for facial expressions, attitudes, verbal and nonverbal messages, as well as noting when obvious changes occurred in the learning process.

I asked the students if anyone knew what a Roundhouse diagram was. I could tell they were curious, and that they recognized the word “diagram,” but they had never heard the term “Roundhouse” before. I asked the class if any of their teachers had ever used a diagram with them to help them learn. A couple of these students remembered doing concept maps in my fourth-grade class. Another child recalled doing a Venn diagram in another class. I told them these diagrams were called graphic organizers and they were used to help students understand difficult science concepts. I used the overhead projector and showed them a blank Roundhouse diagram (see Appendix F). I asked the students if they knew where the term “Roundhouse” came from. The students had no idea. I told them to look up railroads in the encyclopedia or to use the Internet if they had use of a computer at home. Since we had no resource materials available to the class at the time, I simply told them that railroads used signals and various means to control traffic in order to prevent accidents. I explained that a turntable in the roundhouse connects the incoming rail line to lines going up to 25 stalls, but the Roundhouse diagram used in class only has seven stalls. The traffic control center for the train systems became analogous to the middle part of the Roundhouse diagram. The lines that extended out of this central hub were the train tracks, which represented different concepts. I noticed some of the students looked confused.

I asked the students, “Does anyone know what a concept is?” One child said, “studying.” I said, “A concept is an idea and in science, one idea is often related to other ideas, so it is important to show how they relate to each other.” I had the attention
of the class. One child asked, "What are the different sections for?" I explained to the class that I had to study many theories as the groundwork for this study. I asked, "Does anyone know what a theory is?" One child answered, "To estimate." Another student said, "How you think." I said they were on the right track. A theory is a belief or a hypothesis. The students could relate to what I was doing because they had just finished their science fair projects and had to make a hypothesis and draw conclusions. The class was fully participating in this discussion. I told them that a psychologist named George Miller (1956), had performed a study with human subjects on the memory span and discovered that most people could retain seven items in their memory, give two or take away two items. I told them that is why their phone number had seven numbers. They seemed absolutely fascinated with this discussion.

I also explained at this time what "chunking" meant. I explained to the students that if information is reduced and connected within each section that people could increase the amount of information they could remember. I asked them if they knew how to paraphrase sentences. These students nodded their heads "Yes" and recognized this word from their reading class. I explained that chunking meant reducing the amount of information in a sentence efficiently so that it could be remembered easily. I explained that chunking would be part of putting the information into the diagram. Some of their facial expressions seemed apprehensive after mentioning this part. I asked one child why he looked so worried. He said, "It sounds difficult." I told them that this is like anything else, and it gets easier with practice.

I explained to them that the Roundhouse diagram, with its seven sections, would show me what their brain was thinking, so if any thoughts were not correct, the teacher
would be able to see it on paper. I tried to keep the discussion simple and told them not to worry. The method was very enjoyable and involved visual pictures and was easier than reading, taking notes, and memorizing definitions. I told them they still needed to study, but this method would be much more effective. Many faces lit up and showed interest when I stressed the fact that it was easier and more enjoyable than just memorizing.

When I mentioned the fact that pictures were involved, the students smiled and looked at each other. It was the first sign of relief — that just maybe their expectations of this study could possibly be fun. I explained to the students that the next step involved drawing pictures or icons which directly associated each concept to a picture. I showed them samples of pictures in my clipart books and passed the books around. The students immediately began to talk and get excited. I asked them if they liked to draw and all of their heads nodded “Yes.” I told them they could trace pictures if they needed to and they seemed comfortable with that idea.

**Sample Activity**

I provided each student with a Roundhouse diagram worksheet (see Appendix E). I went to the board and wrote down the word “photosynthesis.” I said, “Now I want you to tell me everything you already know about this word.” Suddenly hands went up and I started to point to individual students, since I knew only a few of their names. One student said, “plants.” I wrote the word on the board. Another student said, “sunshine.” I wrote that word on the board as well. Another students said, “carbon dioxide.” I said, “Good,” and wrote that on the board. One student said, “Water” and
one said, “Sugar.” Before anyone realized it, we had seven good concepts, so we began to fill in the worksheet.

We talked about the main ideas. The classroom teacher also taught reading, so they were used to hearing about pulling out the main ideas. The students began to formulate good sentences, and I wrote them on the board. I wanted them to use the “and” and “of” words in the title. Their faces looked puzzled and it was difficult for them to use these words. One child said, “Photosynthesis of plants.” I was delighted. I said to use other concepts with the “and” word and they came up with many ideas. I suggested to choose the most general concepts which covered all the ideas in the seven sections. I left them on their own a bit.

I directed the students to write out seven complete sentences about their concepts. They looked at what was already on the board and were able to do this fairly easily. This took a few minutes. Then I instructed them to reduce the number of words in each sentence and to start “chunking” their information so they could easily remember it. The students were perplexed and had some trouble with this part. I had previously created a worksheet for the students to look at as an example (see Appendix K). I showed it to them on the overhead projector. The example of this worksheet was also on photosynthesis so they could understand exactly how to chunk the sentences effectively. We spent time paraphrasing each sentence and making sure it made sense.

The next step involved drawing icons which related to each concept. I told them they could make up these pictures, they could use their science textbooks, they could bring in their own pictures, or they could use the clipart books. I suggested to them that they not waste too much time looking through these books, but to use the index on the
front of each book to find out what subject matter the pictures contained. For the purposes of this sample activity, the students just drew their own pictures.

I encouraged the students to be creative and asked them if they knew what creative meant. One child said, “It’s when you do it using your own brain.” I thought that was a wonderful answer. I explained to them that when they were creative, they would own the work because it would be theirs and no one else’s. I told them this ownership of ideas would improve their ability to remember the concept to which the picture connected. Along with creativity, neatness was expected. We read through the rules on the Roundhouse diagram worksheet which reminded them to use their time wisely, to use their best handwriting, and to ask for help if they needed it.

I took out the two boxes of Sanford Expresso™ fine-point black ink pens I purchased for the students to use, along with several white-out pens for erasing mistakes. The excitement level increased. I instructed the students to use only pencils until the teacher or I approved their worksheet and diagram. After approval, they would be allowed to use the pens to go over their writing and pictures so it would have a professional look.

I purchased a hunter green wirebound legal pad for each student to use as a daily journal. I told them the journal served a means of communication between the teacher, myself, and the students. I told them that their opinions were highly valued and I wanted them to write them down. They liked this idea and put their hands out to receive this very important-looking notebook. A few of them felt the top cover and were delighted to have this notebook to use in class. I stapled journal guidelines inside each cover.
The students could look at these suggestions on what to look for while they were working. The guidelines helped them focus their observations.

I proceeded to show the students the different worksheets needed in this diagramming process. I showed them an example of a “wedge” sheet (see Appendix I). I explained to them that at times they would have problems explaining different sections. I went back to our previous discussion on misconceptions and how at times they may put down an incorrect concept. When this occurs a “wedge” sheet is needed to focus on just that section to clear up any incorrect thoughts.

Next I showed the students a Roundhouse diagram checklist (see Appendix G). I told them that after they were fully trained on how to do a Roundhouse diagram, the teacher would be giving them lab grades on their diagrams. I explained that this checklist would be a way to make sure they included all the necessary information. The teacher and researcher used the mastery of technique sheets to grade the students’ diagrams for these lab grades (see Appendix N).

The last sheet I put up on the overhead projector was the student evaluation checklist (see Appendix L). I told the students these answers were very important and that they needed to answer the questions honestly and to take their time filling this part out. We went over the entire sheet to make sure all parts were understood.

Reflections from the Researcher

The students were extremely well behaved and interested in what I had to say. Their faces were full of wonder and their participation was inquisitive. The students appeared to be anxious and overflowing with anticipation. They seemed very fond of and comfortable with their teacher. The students were attentive and the environment
was obviously risk-free. The students had no fear of criticism because they often spoke their minds and raised their hands with questions as well as answers. The students hung on every word I said and listened intently and, at times, were very apprehensive because they were not sure what to expect from me. The students seemed hesitant and unsure of the new circumstances.

The teacher seemed a bit reluctant to give up control of her class to another person. She intensely listened to my presentation and at times stepped in to make sure her students understood what was being said. The teacher’s focus was more on her students than on her observations. She was very interested in the Roundhouse diagramming method, but I could tell she was a bit uncertain about my role in her classroom.

Overall, I felt the mood was pleasant. The students participated in the questions and answers much better than I had anticipated they would. There were a few students who seemed a bit reluctant to change and may have been worried that they would not be successful with a new method of learning. I tried to assure everyone that they would benefit from this new organization of learning.

**Reflections from the Teacher**

The teacher’s field notes stated that the students were attentive and participated well in the example of the Roundhouse diagram method on photosynthesis. She stated the students asked many questions and seemed very interested in the Roundhouse diagram. She mentioned that one of her students asked questions about the seven sections and found it very interesting about the research done on the memory span and retaining seven items effectively (George Miller, 1956).
Case Study Evidence of Student Performance

The following series of Roundhouse diagrams are grouped and analyzed according to thematic units taught by the classroom teacher (see Appendix V). Each unit's data set is composed of multiple Roundhouse diagrams, an assessment based on those diagrams, a student evaluation checklist, a written paragraph in essay form explaining each diagram, and a formal interview session by me with each student in the sample case study group chosen for this study. Reflections from the researcher, the teacher, the outside observer, and the students accompany each diagram.

The sample of students chosen for this study were selected by the classroom teacher. Selection was based on the students' overall grade-point averages and science grades, as well as the information-richness of the participants. Other characteristics were considered, such as gender, race, and communication skills. A table has been constructed which reveals a variety of these qualities (see Appendix M). A conscious effort was given to the selection of these participants who represented a wide range of achievement levels.

Roundhouse Diagram Practice

Initial Activity

The Hobby

I entered the classroom to continue the preliminary instruction process and to direct the students in construction of their first Roundhouse diagrams. I began a class discussion on favorite pastimes or hobbies that were enjoyable to do in one's spare time. I wanted to engage the students in a motivational activity which directly involved the learner. I began the process by showing the students some examples of other students'
work so they would feel comfortable in knowing that other 6th-grade students had done this, therefore they could do it, too. I showed them Brenda's Roundhouse diagram on the world of drawing (see Appendix H). I showed them Carl's Roundhouse diagram on hunting. I showed them my own Roundhouse diagram on riding horses. I went around the room asking students, "What do you enjoy doing when you have free time?" The students were very shy and some of them reacted by shrugging their shoulders. A few of the more aggressive students spoke out and said, "skating" or "baking cookies."

Some students were reluctant to participate. Others were still engaged in thought, trying to figure out what to say.

The Construction Process

The Whole Class

I put my diagram about horses on the overhead projector. The teacher passed out the Roundhouse diagram worksheets. I began by reviewing specific directions with them. I pointed to my first section and I told them, "You always begin at the twelve o'clock position and go around the diagram clockwise. Before I start my diagram, I always plan out what I'm going to write very carefully." At this point I put the Roundhouse diagram worksheet on the overhead projector and said, 'Let's do this together.' The first question asked for the main ideas to be explored. This is where you can simply jot down all of your thoughts and you need not put the ideas in complete sentences, just brainstorm your topic. I quickly wrote, "in the barn...feeding the horse...cleaning him...riding the horse...makes me feel free when I ride...and blue ribbon."

I told the students the next step was to think of a title which would cover all these ideas and would be placed in the middle of the diagram. The title should be very
general so as to include all the parts they planned to write about. The words “and” and “of” were there to include specific items or to break up one idea into parts. I gave them an example from my hobby such as, “The Joy of Riding Horses.” I added “feeding and jumping” and “grooming and walking.” Some of the students kept staring at the Sanford Expresso™ pens, but I told them they had to do this part in pencil and to wait. I proceeded to write out the title of my Roundhouse diagram in a few different ways so I would have a choice later about which one to use.

The next section had to do with goals and objectives. I reminded them about what was said in class the day before related to goals. I told them this part was easy and simply stated what the diagram represented to the observer or the reader. I wrote down that my goal was to show the reader that I enjoyed my favorite hobby, which was riding my horse.

The next section was to take my entire concept and break it down into seven parts. I told them to go back to number one and decide where they wanted to begin with their ideas. I stated that there needs to be a definite beginning and ending and the diagram should show a sequence of events. I asked them if they knew about the term “sequence of events.” The students nodded “Yes” and one child stated, “We use this in reading during a story.” I could tell the child understood. I said, “For example, when you bake a cake, would you start the first section with... I put the cake in the oven?” The students said “No,” and shook their heads from side to side. The class understood what was meant by a definite beginning point. I wrote, “The first thing I do is go to the barn and get my horse out of the barn.” Next, I stated that he loves to eat apples, so I feed him. I brush him and then I put his saddle on before I ride him. Sometimes I
simply take him for a walk. Then I asked the students to think about how they felt when they were engaged in their activity. I wrote, "When I ride a horse it makes me feel as free as a bird in flight." Then I recalled that I won a blue ribbon in a jumping contest and that meant a lot to me, so I wrote about that as an ending statement. The students sat quietly and never took their eyes off what I was doing. They were all listening carefully to the directions.

The following section involved taking my sentences and "chunking" them by reducing the amount of words, at the same time making associations which related one section to the next, as in a story. I proceeded to write short, efficient sentences which would easily fit into each section, still leaving room for the picture.

The final step involved making a direct association between my concept and a picture that reminded me of the idea. I drew my pictures of a barn, an apple, a brush, a saddle, a rope, a bird and a blue ribbon. In the middle I drew a picture of my horse. The students were amazed at the process, but some of them felt insecure about the new lesson. I kept telling them to keep it simple and the teacher and I would help them get started.

I directed the students to begin working through their plans for their diagrams by filling in the worksheets entirely. Some students wanted to go straight to the diagram, but I explained to them the importance of planning. I told them that when one constructs a building, for instance, there must be a plan and a solid foundation or the structure will not be strong enough to remain standing. I explained that I wanted their diagrams to be strong so they would be able to recall the information easily. I stated that this was really a practice exercise of what we would be doing in their science
classes. Scientific information would be constructed into the Roundhouse diagrams so they would be able to recall the information easily when they took a test. Some of the students seemed a bit confused and others were delighted at the new way of taking notes.

The teacher sat in the back of the class and listened carefully. She noticed that some students were having trouble starting so she got up and began to walk around the class helping them to begin. Some students were still thinking about their favorite activity while others were nearly finished with their worksheets. I had anticipated being able to finish this activity in one forty-five minute period, but I clearly noticed that it was going to take more time. "This is a slow class," the teacher said, "so, it will probably take longer." I was concerned that the teacher was becoming impatient. I explained to her the positive results I had had with the pilot study and hoped she would remain patient. She asked me when I thought she would be able to start teaching science again. I told her she could plan her lesson out around the Roundhouse diagram and she could begin by the middle of tomorrow’s science period. I could tell she was anxious to get back to science-related material. I was concerned that the students might take too long to finish their diagrams, and I didn’t want to rush the process.

The teacher and I started helping those students who were just sitting there. We asked them questions to help stimulate their thinking. I asked one child, "What is your favorite activity?" She responded, "Baking." I said, "What do you do first?" She said, "You get the ingredients." I said, "Good, put that down." We proceeded step-by-step until she was finished. Some of the students still seemed unsure of themselves. They wanted to do this right. We had to build up their confidence levels and then they were
able to be independent. As others finished their worksheet, they were allowed to begin
their Roundhouse diagrams. We put the Roundhouse diagram sheets on a table in front
of the room and the students were allowed to go get one as soon as the teacher had
checked their work to be sure they were ready.

The Roundhouse diagrams were completed in pencil because we ran out of time
and were not able to go over the work with the pens. The students were disappointed.
They were looking forward to being able to use the important-looking black ink pens.
Those who did not finish were told to finish their diagrams for homework and to bring
them to school the next day. The teacher mentioned that she was behind in science for
the year because the subject of reading was taking up so much time. She also
mentioned that standardized testing was to be administered in March and she had
several areas in science still to cover. I told her that the Roundhouse diagram could be
used with any subject area, and not to be distressed.

**The Construction Process**

**The Case Study Group**

**Close-up Focus on Marian**

Marian was a very small, light-skinned, African-American female student. She
was meticulous and intensely watched and listened to everything said and done in class.
She was slow because she was a perfectionist and wanted to be sure that what she did
was correct. Her favorite hobby was playing drums. She was able to use the "and" and
"of" words in her title and she put a lot of thought into her work. Very few students
were able to integrate their title in the beginning. She used a sequence of events with
playing the drums in the diagram. She filled out her Roundhouse diagram worksheet in
full, but she forgot to put her goals on the Roundhouse diagram itself. She was able to
“chunk” her sentences well. Her pictures were very detailed and well drawn. She is a
high level student.

Close-up Focus on Elizabeth

Elizabeth was a large, dark-skinned African-American female student. She was
unsure of herself and very insecure. When she spoke she put her hand in front of her
mouth, making it difficult to understand what she was saying. She spoke very rapidly
and in a low voice. Her favorite hobby was baking cakes. She did not use the “and” or
the “of” word in her title. The title was unclear because the words were not used with
correct grammar. She used a sequence of events through part of the diagram, but
changed subject matter halfway through. Her pictures were well drawn. Her goals were
well stated. She did not turn in a worksheet so I could not tell if her plans were clear.
Elizabeth was a low level student.

Close-up Focus on Betty

Betty was an average-sized, medium brown-skinned, African-American female
student. She did not have a favorite hobby, but she stated different things that she liked
doing which included going to the store, spending money, and eating cakes of various
sorts. She used her “of” word correctly in the title, but did not use the “and” words.
Her words were written in a circular pattern instead of up and down as instructed, and
could not be easily read. Her plans on her Roundhouse diagram worksheet were not
written using correct grammar. She repeated many of her ideas over and over again.
She rushed through her work with little thought. Her pictures were very detailed and
drawn well, but she put the same icon in each segment. She was a low level
student. Her grades had recently fallen lower than they were at the beginning of the year, although she came from another school.

**Close-up focus on Willy**

Willy was a very small, active, inquisitive, Caucasian male. His favorite hobby was collecting comic books. He knew everything about his subject and considered his hobby to be an investment. He used the “and” and “of” words in the title very well. His handwriting was very scratchy but he put a lot of thought into his pictures as well as his wording. His diagram was very thoughtful and he liked what he was doing. His goals were stated clearly and he was very proud of his work. He wrote his sentences out well and “chunked” his sentences efficiently. His worksheet was complete and well done, which added strength to his Roundhouse diagram. He was an average student who was capable of doing better in school than he was actually performing. He used a sequence of events in describing his hobby.

**Close-up Focus on Carla**

Carla was an average-sized, quiet Caucasian female. She was an information-rich, average student who was capable of better work in science. Her favorite hobby was caring for her dog. She used one “and” word but did not use the other “and” word. She was extremely neat and her pictures were detailed, yet very clear. She used a sequence of events around her activities with her pet. Her worksheet was completed in detail which definitely strengthened her Roundhouse diagram. She was very thoughtful and took this work seriously.
**Close-up Focus on Collin**

Collin was an average-sized, serious-minded Caucasian male. His vocabulary was very strong, and his pictures were unique, creative, and meaningful. He used his “and” and “of” words. His hobby was flying airplanes and he was knowledgeable about this subject. He chunked his sentences well. His worksheet was complete which strengthened his diagram. He used a sequence of events well in his diagram. Collin was a high-level, confident student.

**Reflections from the Researcher**

The students who put the initial work into the Roundhouse diagram worksheets did the best Roundhouse diagrams. Most of the students did very well on their first activity with their hobby. I found out that these students were never asked to think very much on their own. Most of them are teacher dependent and do not have metacognitive skills. These students do most of their work because they are required to, not because they are being responsible. It took time for the students to get started because the ideas were left up to them and the teacher was not there to tell them what to put down. It was difficult for them to think on their own. Most of the students, really enjoyed drawing the pictures and took their time. I found that most of them were proud of the work they did. By using informal conversation with these students, I found that it was very difficult for them to go from general to specific and to break an entire concept down into seven parts. They had never been asked to do this before. It was difficult for them to consciously think about and use a sequence of events with the various hobbies. Some of the students had a difficult time “chunking” their sentences and reducing them in such a way that they still made sense. About five students wrote their words and
pictures in circles after they were instructed to write up and down so it could be easily read. The students all said they had enjoyed making their diagrams although they really did not like all the planning work involved on the worksheet. Most of the students were not very confident and were unsure of themselves without word-by-word instruction. I think the educational system has stifled creativity in many students by not letting them express themselves.

**Reflections From the Teacher**

The teacher journaled that the students seemed slow and reluctant because they were having a hard time thinking for themselves and they were unsure what to write. Informally, we talked in class about how these students were used to being “spoon-fed” in school. She commented that most of the students did very well once she began walking around helping them.

I questioned the teacher about assessment procedures she planned to use with the Roundhouse diagrams. She showed me an example of her usual tests, which were made up of one-word fill-in-the-blank, true or false questions, and multiple choice questions. I told her that in my research on the memory, many books stated that students need to be asked questions which allow them more than one way to answer. I told her that a child could guess at true or false questions and those results might not actually be representative of what that child knows unless he or she could state why it was false. She nodded her head and smiled and said that she would work on having them answer some essay questions. I sat down with her and showed her some sample diagrams that covered the definitions she wanted to cover. The teacher agreed that true and false
questions were not a good indication of what a child knows. She was very open and receptive to what I had to say.

**Summary of Initial Findings**

The beginning concepts used in the initial diagram were not science concepts although I did discover that if the students put effort into answering each step of the Roundhouse diagram worksheet, the outcome on the actual Roundhouse diagram was clear and effective. The effort put into the worksheet by those students who were truly involved was an obvious product in their diagrams. Those students who put effort into the worksheet produced diagrams that reflected thoughtfulness and meaning, and which ultimately became a unique and creative act for those students who were truly involved.

The greatest problem for the students was their having to think on their own. These students are not usually asked to think, just to perform and follow directions. The students usually sat in straight rows and remained quiet in this setting, and activities such as these get more creative when students are allowed to converse with each other. It was difficult for them not to be involved in conversation while doing this activity. Many students had problems breaking down one concept into several parts and then relating the parts in a sequence of events. The students found it difficult to integrate the title with the "and" and "of" words. Many of the students left the words out and just ignored the fact that they were there. I believe they will get better with this as they become more comfortable with the thinking process. It was difficult for some of the students to think in general terms in order to produce a title to cover all the concepts included in their diagram. Some of these students did not like writing and simply did not answer all of the questions in their worksheet. Some of them have problems with
Figure 3. Student Constructing Roundhouse Diagram

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spelling and grammar and it was difficult for them to write in full sentences. From my observations I discovered that those students who were weak in language arts had more problems with writing skills than others. The students had a difficult time "chunking" their sentences and reducing them efficiently so that they still made sense.

The students seemed thoughtful about their choice of icons in their diagrams. Test scores and icon scores indicated that if the students put a concerted effort into their pictures, the diagrams were much more effective for learning than those diagrams where the choice of icon was not considered. The association between the picture and the concept must be strong in order for the dual-coding process to occur (Paivio, 1986). Consequently, if no picture is drawn, the concept is more likely to be forgotten. If the picture is meaningless, then the association to the concept will not be made. The picture must make sense to the learner when related to the concept (Levin et al., 1979). This relationship requires thoughtful planning on the learner’s part.

**Roundhouse Diagram No. 1**

**Food Chains**

*Description of Science Content*

The teacher focused this lesson on how energy flows through a community. She first addressed the process of photosynthesis and discussed with the students how plants make food. The concept covered carbon dioxide, water, and sunlight as the major components in this process. Secondly, the teacher discussed three kinds of consumers: carnivores, herbivores, and omnivores and that consumers got their energy from producers. The third idea incorporated the role of decomposers within the food chain. Decomposers change these waste products back into substances that producers can use.
The teacher referred specifically to the mushroom as a decomposer. The class discussed the levels of energy within the feeding order of the food chain and realized the least amount of energy was available to the organisms at the end of the food chain. The discussion ended with the fact that food chains are never-ending and continually start over again.

**Roundhouse Diagram No. 1 Construction**

**The Whole Class**

**Food Chains**

This lesson involved the first Roundhouse diagram based on science concepts directly related to the students’ textbook. The students were attentive and listened well to the lesson. The students participated by raising their hands often and answering the questions asked by the teacher. There were absolutely no behavior problems, and the students seemed very anxious about the Roundhouse diagramming process. The novelty of using the Roundhouse diagram in the science class attracted the students’ attention. This attraction aids in stimulating learning as well as in enhancing the encoding of important information (Hohn, 1995; White, 1988). Each time the students read a main idea that the teacher wanted them to put in the diagram, she stopped and wrote that idea on the board. The class worked at constructing the following concepts: (a) that producers and consumers perform different functions in a food chain, (b) that energy and nutrients pass through food chains, (c) that food chains link to form food webs, and (d) that the amount of energy available to a population depends on the population’s feeding order in the food chain. The teacher then handed each child a Roundhouse diagram worksheet. The teacher monitored each student heavily. The
class was slow to respond, almost as if waiting for the teacher to tell them word-for-
word what to write. The teacher used many visuals and showed them pictures of food
chains to stimulate their thinking. They seemed hesitant because this was their first
science lesson using the Roundhouse diagramming method and they wanted to do it
correctly. A few students began working immediately. Collin wrote down the main
ideas he was exploring. He wrote, “Food chains begin with producers,” “Energy flows
through a community,” “Decomposers eat consumers and producers,” and “Food chains
never end.” The teacher came by his desk and read what he had written out loud and
said, “Good!” She read this to the class as an example of what to put, but she stressed
to the students how important it was for them to write this down in their own words and
not to copy from each other. The students proceeded to write down their answers and
seemed more confident now that they had heard Collin’s response. The teacher directed
them to write their titles in different ways using the “and” and “of” words if possible.
The teacher read examples aloud from various students’ papers and she said, “Flow of
Energy, very good!” “Chain of Energy, super!” and “Producers and Consumers, great!”
She did this to help others who were still hesitant in starting to write. The students were
getting a bit faster and gaining a little more confidence as they worked along through
the worksheet.

The teacher was very comfortable teaching the Roundhouse diagram and
appeared to be very much in control of her class. She needed no coaching from me at
all. She was, however, very uncomfortable with the length of time it was taking the
students just to complete the worksheet. When it came time for the students to list their
seven main ideas, they just started copying from their notes. They were more confident
at this point since the teacher had already had them list the main ideas in their notebooks. The teacher brought their attention to the fact that they must remember the sequence of events. The students got their books and many of them re-read the material carefully to make sure the sequential order was correct. I noticed one child with his finger on the page reading very carefully, line per line, checking for the order. This is a metacognitive learning strategy referred to as “checking back” or “re-reading.” As a student read, they go back over the material on their own to check for accuracy (Bonds et al., 1992). The teacher noticed this as well and pointed to him for me to observe. That was a good sign that she thought positive results were occurring. I later assured the teacher I was aware that time was important, and that I felt the students would get faster with practice. I told her that during my pilot study students were able to work more quickly with practice, and to remain patient with the process. Teaching science for understanding is a time-consuming process, but quality is more meaningful than quantity (Mintzes & Wandersee, 1998).

The teacher asked the students to take their seven main ideas and to “chunk” them effectively, so that the sentences or phrases would be easy to remember and still make sense. Most of the students found it challenging to reduce the sentences to smaller chunks and put them into their own words. A few hands went up for help and others calmly sat and waited for help. As they examined each idea carefully and restructured the information once again, questions came into their minds and hands went up. The teacher called on Jonathan. He wanted to know how a mushroom ate dead things. When he asked that question, it stirred up other imaginations and many students were wondering the same thing. Willy’s hand went up wanting to know how
the mushrooms got there in the first place. The teacher told Jonathan that mushrooms absorbed dead materials that were broken down in the soil. She told Willy that mushrooms needed spores in order to reproduce. These answers were accepted although I do not think the students were satisfied. They still looked very confused.

The teacher noticed that they were asking questions that they normally would not have asked if they were just reading the material and answering the questions at the end of each lesson. Another metacognitive learning strategy is asking questions when students are involved with learning tasks (Costa, 1991).

The teacher decided to let the students turn their desks and sit in small groups to help each other chunk since it was taking so long to help each student. I agreed that the students should work together, especially in the beginning. The teacher reminded the students to write their goals. Some students seemed unable to do so. The teacher said this simply meant stating what you want your reader to know about what you were going to construct in your diagram. The students were making this more difficult than it was. In this case, the goal would be to explore food chains and food webs or to see how energy traveled through a community. The teacher noticed that many students were finished with the worksheets and were ready for the diagrams. This first day was spent entirely on the worksheets, and the diagramming itself was planned for the next day.

The teacher placed the Sanford Expresso™ pens, the white-out pens, and the blank Roundhouse diagrams on the front table and allowed the students to get their materials whenever they were ready. The teacher stressed to each student not to draw their diagrams in a circular fashion, but to align their letters going up and down so they could be read easily. She showed them an example of the correct way to write this to
make sure they understood. The students were told they would not be allowed to use the Sanford Expresso™ pens until the teacher had checked their diagram first done in pencil. As they finished their work, their hands were raised so they could be checked. They were very anxious to use the black pens. I noticed that several of the diagrams were alike. I believe this occurred because they were in groups during the actual construction process. The teacher and I decided to let them brainstorm in groups, but go back to individualized seating arrangements after completing their worksheets. This would ensure more uniqueness in their drawings as well as their sentence structure.

**Roundhouse Diagram No. 1 Construction**

**The Case Study Group**

**Close-up focus on Marian**

Marian’s goals were clearly stated. She wrote, “The way the food chain (energy) flows in a community.” She understood that the chain of food within the community represented the flow of energy. She even used parentheses around “energy” in order to clarify this point for the reader. For learning to be meaningful, the learner must have relevant prior knowledge, and it was obvious that Marian had a good foundation for learning about food chains (Mintzes & Wandersee, 1998). The central title was well stated. She used the “of” word and put “Chains of Energy.” She used the “and” words by stating “Decomposers and Consumers” as well as “Producers and Sun.”

Marian drew a picture of an animal in transit, walking across the section. She said the animal was a deer because deer eat producers. Each section had an arrow going to the next section to show the flow of energy in the sequence. Her next section stated “Omnivores, herbivores, and carnivores are consumers.” She had no icon in this section

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except for an arrow going to the next section. It was difficult for me to determine if she understood the differences between herbivores, omnivores, and carnivores because she had no picture. She drew a mushroom in the next section to represent decomposers and stated, “Decomposers eat dead materials.” The next section stated, “Bacteria and fungus are decomposers” and she drew squiggly lines to represent what she thought bacteria looked like. This statement came from her textbook and had not been listed on the board which showed me that Marian was using her own brain and had read the material in the textbook thoroughly. She was choosing to relate the new knowledge to the existing prior knowledge in a nonverbatim manner (Ausubel, 1968). The content in the diagram was good and indicated she was thinking on her own.

Marian’s Roundhouse diagram worksheet was completed with many thoughts on each question which offered multiple solutions from which to choose her answers. It was obvious that she had been thorough and had thought of several ways to use the information she investigated and extracted from the textbook. Her sentences were full, complete, and correctly written. It was obvious that Marian had a strong language arts background. Marian’s final paragraph was well written and evidenced her thorough understanding of what her diagram represented. Marian was thoughtful, meticulous, and hardworking in completing her diagram.

Close-up Focus on Elizabeth

Elizabeth’s goals were not clearly stated. She wrote, “To show how energy and consumer works. and what they do. and how they work.” Elizabeth has some obvious general misconceptions about the overall concept of how energy flows in a community. Her language arts background is very weak which hinders her attempt to express
herself. Her central title used only the “of” word, “Chains of Energy.” She did not attempt to use the “and” words. She drew a nice picture of a circular chain which showed that the energy never ended but instead kept going.

The first section of her diagram was concise and correct. She included, “plants trap energy” and drew a picture of the sun, writing the word “sun” inside of it so the reader would be aware of what was represented. Her next statement read “consumers get energy from produce.” Elizabeth’s words were misspelled and incomplete. She uses arrows to indicate that energy is being passed. The next section stated “omnivores hervores, & carnivore are consumer.” There were many spelling mistakes, and there was no icon in this section at all to show that Elizabeth understood what these words in her lesson meant. The next section stated “decomposes eat dead material.” She drew pictures of mushrooms to show that she understood that mushrooms were decomposers. The next section had just two words written in it “mushroom” and “decomposer” with no icon. The last section was stated correctly, “Chains don’t end.” Elizabeth used many arrows placed in a circle to show that there was no ending.

Elizabeth’s Roundhouse diagram worksheet was complete but had many spelling and grammatical mistakes. Many sentences were incomplete and did not make sense. Elizabeth’s thoughts were inconsistent. I did not believe she had relevant prior knowledge about food chains. A student with little prior knowledge often resorts to rote learning, which prevents meaningful learning from taking place (Smith, 1990; Wandersee, 1985). I believed she was capable of better work and this method would help her if she followed directions and read her material.
Elizabeth's final paragraph had many grammatical and punctuation mistakes but her statements showed she had some general understanding of the subject matter. Elizabeth and I talked about her diagram. She understood that plants trap energy for photosynthesis to take place. She understood that consumers got energy from producers and that herbivores, carnivores, and omnivores are all consumers. I did not believe that Elizabeth knew the difference between herbivores, omnivores, and carnivores. She did not know the meaning of these words.

**Close-up Focus on Betty**

Betty's goals were clearly stated but needed to be put into her own words. I noticed that the group members were copying from Marian's paper. The entire group had the exact same goals stated.

Betty's diagram was almost exactly like Marian's except that her language skills were not as good. Her first segment stated "plant trap energy"—the word "plant" should have been plural. Again in the next section she put "Consumer get energy from producers,"—the word "consumer" should have been plural. The next section was correct but copied word for word from Marian's paper. She was not confident about her pictures. She would draw a picture, white it out, but still leave it somewhat visible. I was unable to tell if she wanted it there or not. The next section contained a misspelled word such as "omnivor" leaving off the final "e." She stated that omnivores and herbivores were consumers but she totally left out carnivores. Her pictures in that section did not reveal that she understood what those terms meant. She had arrows drawn but they were meaningless and had no relevance to the concept. The next section revealed pictures which were also unrelated to the concept. Students come into the
classroom with a prior knowledge base which is often faulty. When the learner is
exposed to new information, unless there are multiple connections for the new
information to link to, the more likely it will not be remembered (Connor, 1990; Smith,
1990; Wandersee, 1985). Again she misspelled the word “decompose” and did not
complete the term as “decomposer.”

Betty’s worksheet is completed well. Her sentences were well-developed
because they were copied from the blackboard. Betty had a difficult time being able to
use the scientific vocabulary effectively. It was difficult for her to write the sentences
over in her own words because she was unfamiliar with how these terms should be used.
The title was simply stated as “Chain of Energy” and she did not try to use the “and”
words.

Betty’s final paragraph, written as an essay question to describe her diagram,
was also full of grammatical and spelling mistakes. She had made no attempt to look up
the definitions and missed these concepts on her test.

**Close-up Focus on Collin**

Collin did not clearly state his goals. He wrote, “express the food chan.”
Actually his goal was to explore and construct a diagram about food chains. Collin is
an intelligent boy who is very serious about his school work. He thinks and acts at a
more mature level than most of the other students. Collin also has an attention deficit
disorder but does take medication to help him stay on task. The first segment stated
“Plants trap energy.” I could not tell what his picture indicated. When I asked him
about it, he said it was a picture of a rat tap with a plant in it. Collin is very creative and
because this thought is entirely his, he did not forget the concept or the picture
associated with it. Imagery is a process which stimulates encoding (Hohn, 1995). The next segment stated, “Producers are first in the chain.” Again he misspelled the word “chain.” His picture is a straight-link chain with an arrow pointing to the first link with the number “1” over the link. The next section stated, “energy passed”—he uses arrows going from consumer to consumer. In the next section, Collin misspelled the words “omnivore,” “herbivore,” and “carnivore”—but it is obvious he understands their meaning because of the associated pictures. He associated a tree with the herbivores. He associated a T-bone steak with carnivores. He associated a T-bone steak and a vegetable with omnivores. Collin remembered this diagram on his test (see Appendix W). Research suggests that images enhance the memory. Whenever an abstract concept is made concrete, it is easier to recall and retrieve (Hohn, 1995). This is one reason why the Roundhouse diagram is so effective.

The title read, “The Flow of Energy.” He did not use the “and” words. He drew pictures of several arrows placed in a circular path.

Collin’s worksheet was complete. His spelling was correct in the worksheet because he copied the main ideas out of his textbook. He continued to misspell the word “chain.” His handwriting needed improvement. These characteristics are prevalent in students with attention deficits. The novelty of the Roundhouse diagramming method helped him to focus his attention and improve his grades, although his spelling still needed care (Langer, 1997). I could tell that he wrote quickly through the worksheet and that it was not difficult for him to construct this Roundhouse diagram.
Collin’s paragraph was very well written. His use of grammar and spelling was correct. His sentences were ordered well and in proper sequence. The paragraph made sense and revealed his understanding of this material. His work was creative because it belonged to him, and was very unique.

Close-up Focus on Carla

Carla wrote her goals out clearly in her worksheet but she forgot to put her goals on the diagram sheet. Her work was extremely neat and her handwriting was clear and legible. The title was kept simple and stated, “Chains of Energy.” She had several chains drawn around the center. She did not try to use the “and” words.

Carla was able to chunk her sentences well. Her statements were concise, direct, and to the point. Her first section stated, “Plants trap energy.” She associated the sun with that concept. Her next section stated, “consumers get energy from producers” and she had a picture of a producer and a bird or a consumer with an arrow drawn to the bird to show the flow of energy. She wrote the same words the rest of the group copied from Marian. She stated, “consumers pass energy on,” and used an arrow but did not draw an icon here. The next section stated, “omnivores, carnivores, and herbivores are consumers.” She drew an arrow but no picture. It was unclear whether she truly understood the difference between herbivores, omnivores, and carnivores. The next section was Carla’s idea and not taken from the other group members. She wrote “fungus, bacteria and mushrooms are decomposers.” She associated the pictures of the mushroom and a hand lens used to see bacteria. This indicated that Carla was being responsible in some of her decisions on this diagram. Her work was very aesthetically pleasing.
Close-up Focus on Willy

The goals and objectives were clearly stated but the words and pictures were exactly the same as those of the other students in his group. He did not uniquely create any of these ideas himself so he probably did not remember them as well as another child who meaningfully developed the concepts and connected the concepts to creative pictures. Conceptual models, such as Roundhouse diagrams, are most beneficial when students construct the diagrams themselves (Novak & Gowin, 1984). The first segment stated, "Plants trap energy." Willy used the sun to represent this concept. The next section stated, " Consumers get energy from producers." He associated a picture of a plant for the producer. The next three sections stated concepts but he had not drawn any icons to associate with these concepts. There was no way to indicate whether he understood the definitions used in these sections. His concepts were clearly written. His grammar and spelling were correct. The title simply stated, "Chains of Energy." He did not try to use the "and" words. His work was neat but lacked the substance of having pictures in each section. He was not following the teacher's directions to draw an icon for each concept.

Willy had an understanding of the subject matter but was capable of being more creative and unique with his ideas. The Roundhouse diagram worksheet was complete and actually listed the concepts better than was done in the actual diagram. Willy was capable of chunking his sentences effectively. His paragraph was very well written and indicated understanding of the material. Willy stated that it was difficult for him to draw the pictures. He stated that it was difficult to do the worksheet as well. I explained to him that the worksheet was a blueprint plan for his diagram.
**Roundhouse Diagram No. 2**

**Food Webs**

**Description of Science Content**

Another Roundhouse diagram was constructed as a way to elaborate on the previous Roundhouse diagram on food chains. The objectives in teaching this diagram were to show how food chains in a community are linked to form food webs, and to show that the amount of energy available to a population depends on the population’s feeding order in a food chain.

**Roundhouse Diagram No. 2 Construction**

**The Whole Class**

**Food Webs**

The teacher incorporated the lesson with the energy pyramid into a hands-on lesson for the entire class. The first group of students were the crickets and ate producers since they were herbivores. The next group of students represented lizards who grabbed the food from the crickets. The number of survivors decreased each time as the energy pyramid evolved. The teacher asked the students, “What would happen if poison were sprayed on the popcorn?” Jonathan answered, “The whole food chain would be affected.” The teacher drew an analogy to pesticides and how they affected food chains. The teacher asked, “What would happen in an ocean food chain if the algae increased? Brad said, “The smaller fish would increase.” The teacher said, “As a result the whole fish population would increase. When there is more food, the number of organisms increase.” The students seemed to understand the concept involving the energy pyramid.
The teacher decided to let the students brainstorm to arrive at the main ideas. The students got out their textbooks and re-read the material. One child had her finger in her book carefully looking for ideas. This is a metacognitive strategy exemplifying awareness and control over one's own learning (Wittrock, 1994). There was a lot of conversing and a lot of writing. As I looked around the room, I noticed that all children were participating. Once the teacher felt the subject matter had been covered, she stopped the class from conversing and they got back into rows.

I passed out the Roundhouse diagram worksheets to each student. The teacher directed the students to start their work and this time to work individually. The teacher put the Roundhouse diagrams on the front table and told the students they needed to have their worksheets checked before they could start the diagram. The students were much more relaxed doing this follow-up diagram so soon after the first one. They seemed calmer and more familiar with the process. I observed that the students were more focused when they worked individually.

**Roundhouse Diagram No. 2 Construction**

**The Case Study Group**

**Close-up Focus on Marian**

Marian’s diagram included the goals stated very clearly. The title used the “of” and both “and” words. She wrote “Webs of Food Chains” and off to each side stated, “Energy and Populations” and “People and Communities.” Her concepts were stated clearly and there were no misspelled words or grammatical errors. There was an icon connected to each concept. The design of the entire diagram was aesthetically pleasing.
The worksheet was completed which gave her many options to choose from for her diagram. Her chunking was efficient.

The first section simply stated, "Many food webs link." She drew pictures of several small spider webs to connect to the concept. Next she stated, "energy pyramids show energy" and she drew a picture of the pyramid with the energy decreasing at higher levels. Next she said, "People pollute communities" and drew a picture of a man littering and pouring trash out. The following sections were well structured and concise. The last section stated, "People can keep America clean." She drew a man putting garbage in a can. The diagram was very well done.

Marian's worksheet was very thorough and well written. Her plan was complete.

Marian's evaluation sheet said the most important thing she learned from doing the Roundhouse diagrams was "how to take out the important details." When asked what problems she had, she stated, "Hard to draw the pictures and to make the titles." I noticed improvement in her second diagram.

Close-up Focus on Elizabeth

Elizabeth stated her goals clearly. Her title covered all of the concepts in her diagram. She effectively used the "of" and "and" words in the title. The key concepts were covered in her lesson. Two of the concepts were not stated accurately because of spelling and grammatical mistakes. Her pictures were drawn very well. She had an icon linked to each concept. Her handwriting was very neat, and the diagram was very aesthetically pleasing.
The first section stated, “Food webs are formed by food chains.” Her grammar was not correct. She drew a picture of the energy pyramid with an arrow pointed to a chain. The second section said, “Energy pyramid shows energy.” Her picture was of the energy pyramid and showed less energy the higher the levels go on the pyramid. The next section said, “Population is a problem” and showed a picture of the road with a tire on it. I was not sure what this meant. The last section said, “Keeping environment clean helps prevent pollution.” Her grammar and spelling were wrong, but her message was good. Her picture was of a house and trees.

Elizabeth’s worksheet was very well done. She had language mistakes but her work effort had improved. Elizabeth’s grades improved, which motivated her to follow directions. Transforming the written material into a visual form was helping her to promote a mental image to be recalled (Paivio, 1986). Her sentences were chunked effectively and much better structured than on the previous diagram. I believe the writing practice will eventually help Elizabeth.

Elizabeth’s evaluation sheet stated that the most important thing she learned by doing this Roundhouse diagram was to organize her information. She wrote, “It was just hard to draw out the picture and it will help me pay attention.” When asked what her greatest problems were she put, “Yes, on drawing and finding a title.”

**Close-up Focus on Betty**

Betty stated her goals clearly on this diagram. She covered the concepts well with the title. She used both the “ands” and the “of” words correctly. She drew pictures of a Ferris wheel and buildings and people in the center to show energy and people in communities. Her diagram covered the necessary key concepts. The concepts,
however, were not accurately stated because of spelling and grammatical mistakes. She used a pencil and two different colored pens to construct her diagram. The diagram was not neatly done and lacked effort and details. She did not seem as though she was trying.

The first section stated, “Many food webs links.” With a pencil she drew some squiggly lines not really related to a web—just scratchy lines not really meaning anything. Next she stated, “energy pyramid show energy.” Her picture was not related at all. It is a picture of a person saying the word “energy.” Since her picture did not relate to the concept, that concept will not be easily recalled. Next she wrote, “people pollute communite.” Her picture was a face saying, “am pollute.” Next to this she put a bottle and a circle. I did not understand what she was saying. I did not think Betty put any effort into relating her concepts to her pictures. Betty sat next to Marian in class and would often copy her work, which accomplished little for Betty in terms of recall and retention.

Betty’s Roundhouse diagram worksheet was complete. She did a better job on the worksheet than she did on the diagram. She had spelling and grammatical mistakes in the worksheet. It looked like she constructed the diagram because she was required to rather than because she wanted to.

Betty’s evaluation sheet stated, “I learn how to think better, become more creative. I also learn how to chunking.” When she was asked what problems she had constructing the diagram she said, “No, not really.”
Close-up Focus on Collin

Collin stated his goals clearly. He said, “to explain the way the environment is effected.” His spelling was not good, but his ideas were good. His title covered the concepts well and he used the “of” and “and” words correctly. He put no icons in the title, nor did he put an icon with each concept. He did state his concepts accurately. He did not seem to put as much effort into constructing this diagram as he had on the first one.

The first section stated, “food webs are formed by food chains.” He drew a picture of a chain and arrows in a circular path. The next section said, “The energy pyramid shows energy.” He misspelled pyramid. He drew the picture of the energy pyramid to connect to the concept. The next section said, “people pollute with chemicals.” He had the word “toxic” in a circle with lines going through it. Next he stated, “people use trees for materials.” He drew a tree with an arrow going to a pencil. The last section stated, “keeping the environment clean helps the environment.” He included no icon at all.

Collin’s worksheet looked very complete. He had more pictures drawn on the worksheet than on the diagram. His retention of his mental representations was reflected in his grade improvement. Paivio’s Dual-Coding Theory supports the importance of imagery-based material (Paivio, 1986). He may not have been finished when the class ended. His paragraph had some full, well-written sentences although there were still spelling mistakes.
Collin's evaluation sheet stated, "It helped me understand the difference of carnivore, omnivore and herbivore." When asked if there were any problems he put, "I had a problem on one of the pictures."

**Close-up Focus on Carla**

Carla's diagram stated her goals very clearly. She used the "and" and "of" words correctly and all of the concepts were covered in the title. She included all necessary key concepts and they were accurately stated. She had no spelling or grammatical mistakes and obviously had a strong language arts background. There was an icon drawn in each segment which well represented each concept.

The first section stated, "food webs link chains." She drew a small spider web, an arrow with the word "link" written over it, and a chain with the word "chain" under it. The next section said, "energy pyramid shows energy passed on." She drew the pyramid with each level decreasing in energy as the pyramid got higher. The next section stated, "people pollute communities." Her picture was of a beach with bottles and cans and a tree with litter under it. The last section said, "People can protect the environment." She drew the bags full of plastic, metal and paper. Her pictures were well associated to her concepts. This was the main reason Carla's grades improved so much. She was able to mentally visualize her concepts as she put the time into associating them well (Hohn, 1995). She was creative and her handwriting was very neat.

Carla's Roundhouse diagram worksheet was very well planned out down to the last picture. She effectively chunked her sentences and correctly punctuated each main idea.
Carla’s student evaluation sheet stated the most important things she learned from the diagrams was that “energy flows through food chains and that food chains don’t end.” Carla stated that her major problem was “drawing icons.” Her diagrams were very thoughtful. This method did prove to be very positive for her.

**Close-up Focus on Willy**

Willy’s goals were clearly stated in his diagram. He used the “and” and “of” words effectively in his title. His title covered all of the concepts in his diagram. His concepts were accurately stated. His words were spelled correctly and his grammar was good. He connected an icon to each one of his concepts. His concepts were well associated to the pictures. Willy’s good organization and well-related concepts contributed to his great improvement (Hohn, 1995). His diagram was aesthetically pleasing.

The first section stated, “Many food webs link.” The section was a full spread spider web. The next section stated, “energy pyramids link the energy.” He had an energy pyramid drawn with four levels of energy decreasing at the higher levels. The next section stated, “people pollute communities.” His picture was of a large building with smoke coming out of the top. The next section said, “trees are cut down for material.” He drew a picture of a tree standing, and one cut down next to it.

Willy’s Roundhouse diagram worksheet was very well completed. His sentences were chunked efficiently. Willy’s paragraph was written well. I only questioned one of his sentences which stated, “The population is growing because people want to help clean the earth.” Willy’s overall work had definitely improved.
Willy's student evaluation sheet stated, "It'll help me make better grades in science." When asked if there were any problems, Willy said, "It was hard to draw the pictures and it was hard to do the worksheet" (see Appendix X).

**Reflections from the Researcher**

I felt that the students did a great job on the first two science-related diagrams. They enjoyed the novelty of doing something different (Langer, 1997). The Roundhouse diagramming method requires a great deal of writing and most of these students had problems with language arts. The additional practice of structuring sentences and writing paragraphs was good practice for them and that the students would eventually be able to transfer this diagramming method to other subject areas.

The students were definitely studying more in class because they were required to go over the material many times. This process was wonderful for those students who did not study at home. This learning task was really much more difficult for them than what they had traditionally been used to. Because many of these students liked the drawing part, they did not realize all the additional reading and writing they were having to do.

This class needed a lot of guidance and a lot of monitoring. Many of the students did not have a good foundation of prior knowledge about the subject matter, so new associations were difficult to make (Mintzes & Wandersee, 1998). They were instructed to put their ideas on paper and much of what they thought was correct was actually not correct. Students often come to science classes with alternative conceptions (Connor, 1990; Wandersee, 1985). Conceptual models which diagram concepts help learners to fill in missing links (Novak & Gowin, 1984). The students were not capable
of reading the textbook and ascertaining the main ideas by themselves. This was primarily a class effort in order to be sure that all students were beginning with the correct information. It was necessary for the students to write sentences in their own words because the teacher checked each child’s work before they were allowed to construct a diagram.

The restructuring process stimulated the students’ imaginations and they started asking questions about material they did not understand (Costa, 1991). Reconstruction of existing ideas may lead to replacement or additional information which eventually leads to conceptual change (Gunstone, 1994). The concept behind the decomposers is one that left many students questioning their understanding of the subject matter. Some students were re-reading material from the textbook in order to check for the proper sequence of events. This additional investigating on the student’s part represented a metacognitive learning strategy (Bonds et al., 1992). Some of the students began to take responsibility for their own learning and really enjoyed the diagramming process.

Metacognitive learning also facilitates conceptual change (Wittrock, 1994).

The students who were being more creative and putting thoughtful effort into this process were the students this method benefited the most. The students who put effort into their Roundhouse diagram worksheets produced better diagrams than those who expended only minimal effort. The students who associated meaning with their pictures remembered their concepts more effectively (Paivio, 1986). In all cases, when work goes into a project, the end result is a positive one.

The students who did not know the definitions were unable to link their pictures. The misconceptions were obvious when the diagram did not make any sense. In
traditional learning situations, the learner’s thinking is not exposed, thus misconceptions are overlooked and never noticed (Novak & Gowin, 1984). In contrast, this Roundhouse diagramming process requires learners to expose what they are thinking by entering information into the worksheet and the diagram itself. If the learner is unable to integrate thoughts and establish relationships in the diagram, the concept is generally not well understood.

The teacher taught the Roundhouse diagram as though she had been doing this for years. She taught the science lesson very well and did a nice job of integrating the hands-on activities into the lesson. She asked the students many questions and motivated them to find the main ideas. Teachers need to model metacognitive strategies in order to teach students responsibility in learning (AAAS, 1989). She seemed more relaxed about the time issue. I believe she was seeing some interesting results, as I was.

Reflections from the Teacher

These comments were taken from the teacher’s journal. She wrote,

The class is attentive. The students are participating in asking and answering questions about the Roundhouse diagram. The students seem to be interested in the diagram. Some students seem reluctant to participate because they are having to think for themselves what they want to write. Most of the students did very well once I began helping them. The students have been working in groups in order to help each other chunk the main ideas. Some groups are doing a good job of chunking and are working quickly. Other students are confused about working in groups. They feel like they must all write the same thing. We explained to them that they should not be doing identical work. Students are finding that they need to rewrite some of their chunks because they have changed the original meaning of the sentence. I am concerned about how much time the diagrams are taking now because the students are very slow at it. Students seem to be getting more interested in using the Roundhouse diagram. They are writing in their journals about the diagram. This is serving as a review for the test. I really like the idea of the amount of writing the students do in this process. The students are getting more confident. They have written paragraphs
about food chains and food webs. Their writing skills are improving. Grades are improving.

**Reflections from the Students**

At the end of every thematic unit, the students were asked to fill out evaluation checklists (see Table 1).

Table 1. Student Evaluation Checklist: Whole Class Results

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Yes</th>
<th>No</th>
<th>Sometimes</th>
<th>Most of the Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enjoyment</td>
<td>17</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Organization</td>
<td>12</td>
<td>-</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Ability to chunk</td>
<td>10</td>
<td>1</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Uses time wisely</td>
<td>15</td>
<td>-</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Works well independently</td>
<td>9</td>
<td>1</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Works well with others</td>
<td>13</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Uses own words</td>
<td>9</td>
<td>2</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Ability to link pictures</td>
<td>14</td>
<td>-</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Creativeness</td>
<td>11</td>
<td>1</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Improves understanding</td>
<td>11</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

There were two important open-ended questions asked at the end of each student evaluation sheet:

1. The most important things I have learned constructing the Roundhouse diagram were:
I got better grades, I learned my lessons on food chains (5), I learned the difference between herbivores, carnivores, and omnivores, I learned to think better, I learned chunking (2), I learned to organize my information, I learned to pay attention, I learned how to take out important details, I remember my pictures, I learned paraphrasing (2) and summarizing, I learned about consumers, producers, and decomposers, I learned how to put things in order (2), I learned how to study better, I learned how to draw concepts, I learned to start the diagram at the twelve o’clock position.

2. Did you encounter any problems while constructing your Roundhouse diagrams?

Drawing pictures (9), doing the worksheet, finding a title (3), using “and” and “of” in the title, chunking, writing the goals, paraphrasing, I didn’t have any problems (6).

Table 1 indicated that the students enjoyed constructing the Roundhouse diagrams. The positive numbers also revealed that the diagram helped them to use their time wisely. All of the numbers indicated positive responses from the students.

**Formal Interviews with Case Study Group**

**Close-up Interview with Betty**

Betty said she was having a good school year but admitted that science class was difficult. She said she did not like having to study all of the vocabulary and questions in her science class. When I questioned Betty about consumers, she understood that they got energy from producers. She was unable to give me examples of herbivores, carnivores, and omnivores. These were also concepts she missed on her test. She was not motivated enough to find out these definition meanings before her assessment. I asked her to look at the pictures in the book and to create a food chain. She said, “First,
plants trap energy from sunlight. The consumer has to get energy from producers.

Then I put consumers pass energy and another consumer pass it on to another consumer.”

I asked Betty to tell me the animals involved in the food chain. Betty answered most of my questions correctly and part by part she was able to think about it and answer, but when she took the test, she was not able to answer the question, “Explain everything you know about a food chain.”

She stated, “First a food chain starts with a producer and ends with a producer.”

I was confused as to why she put that answer. Betty’s lack of prior knowledge about what animals were herbivores, omnivores, and carnivores was the reason she failed to comprehend the total picture. When students lack relevant prior knowledge, new associations cannot be linked to the cognitive structure (Wandersee, 1985). During the interview I told her that she would have an essay question where she would have to describe the food chain. She chose not to find out the needed information for the test. I believe the Roundhouse diagramming method helped her gain an overall insight into the general facts about food chains, but she was unable to get specific. In Betty’s Roundhouse diagram she wrote the words omnivore and herbivore but she never mentioned carnivores. She had only a drawing of a plant in that section which could have related to either concept.

When I asked Betty if she liked doing the Roundhouse diagram she said, “Yes.” She also indicated “yes” on her student evaluation sheet. I asked Betty why she liked the diagram and she said, “Because it can help you when you don’t understand something, and you can just look and it kind of helps you know it better.” When I
asked her what the most difficult part of doing the diagram was she said, “Putting it in words. The pictures would be easy, but just the words and the sentence and chunking it, and putting it on the paper, on the Roundhouse diagram.” She also said she encountered problems writing the title. “Sometimes because like if you have a title and the title and it probably don’t go with “and” or it probably go with “of” and like if you want to use both one of the “ands” you’ve probably got to think of another title for it and you probably don’t have anymore.” She also added that “I learned that drawing pictures would help you better understand. Because you can just look at the pictures and kind of understand what’s going on up in the Roundhouse diagram.” Betty indicated she had no problems on her student evaluation sheet.

Close-up Interview with Willy

I began by asking Willy how he was doing in science and he indicated, “Not too good.” Willy said it was difficult for him to learn “but the diagram kind of helps.” I asked him if he liked doing the Roundhouse diagram. He said, “It’s pretty fun.” On Willy’s student evaluation sheet he said he had a hard time remembering even when he studied, and that he probably did not spend enough time studying. He said he asked questions in class and he was curious about science because there was a lot he did not understand. He said, “The activities are fun to learn about, like the different scientific things.” He said he preferred to work in groups rather than individually “because like we get to share our answers and it helps us learn more.”

I asked Willy to explain his first diagram to me. I asked him what order the animals were in on his diagram. He said, “First the carnivores.” Then he changed his mind. He said, “No. First the herbivores, then the omnivores, then the carnivores.”
think Willy knew this information but he was confused with his answers. He said, "Then the decomposers eat the omnivores, carnivores, and herbivores, and they eat them after they die." I asked him if a decomposer could eat a carnivore and he said, "Oh, well, it can eat an omnivore." I could tell Willy was not sure about this part. His answers kept changing. I asked him if a decomposer was an animal and he said, "No, it's a mushroom or a fungus. "It grows on top of them like, then it digests them." Willy said, "Whenever the animal dies, a mushroom grows on it." I said, "I thought mushrooms grew by spores." Willy said, "Like if the omnivore or carnivore or herbivore has a spore then they can get on them and eat them." Willy sounded confused and I suggested to him that he look over his material again in the textbook.

We started talking about the Roundhouse diagram again. He said the diagram made him think. Actually, it was the reconstruction of the material that was stirring up his imagination. Active involvement of student construction of concepts helps to generate conceptual change (Wittrock, 1994). I asked him his biggest problem with the diagram. He said it was "hard to... like after you break it down, it's hard to figure out... like how you paraphrase it and stuff." Willy said, "If you draw good pictures, you’ll be able to remember." Incorporating linking promotes good learning (Fensham et al., 1994). He said his drawings and his handwriting needed improvement. On Willy's student evaluation sheet he indicated it was hard for him to do the drawings.

**Close-up Interview with Marian**

I asked Marian to explain her diagram on food chains to me one section at a time. Marian's diagram did not associate pictures with the words "herbivore," "omnivore," and "carnivore." I asked her for some examples. She said a dog was an
omnivore. I explained to her that they had canine teeth because they were carnivores. She did not know that omnivores ate both plants and animals. She said, “So do people.” She knew that herbivores ate only plants and she had drawn a deer on her diagram sheet as the consumer. She knew carnivores ate only meat and related the idea to a lion. She understood that a decomposer was bacteria, fungus, or a mushroom and lived off of dead materials. Her prior knowledge of the subject matter was much more thorough than with the other students. This is why she was able to incorporate new associations so easily (Mintzes & Wandersee, 1998). She made a perfect score on her test. I believed she was capable of doing better work on her diagrams with more practice.

Marian indicated that she really liked science because of the experiments and hands-on activities. She said she liked the Roundhouse diagramming method both in the interview and on her evaluation sheet. She said, “The diagram gives you all the information in your lesson in short sentences.” She said, it was not a problem to chunk them, just finding the right sentences. She was referring to the main ideas. The interview indicated to me that Marian had a very good understanding of the lesson, although her diagram really did not show her true understanding. I told her next time to be sure and draw pictures for all of her concepts so that I could tell what she knew and what she needed help on.

Close-up Interview with Collin

Collin told me he had a difficult time studying and that he went to a tutor. He said he usually memorized his definitions and the tutor called them out to him before a test. He said he liked the Roundhouse diagram because it provided a summary of the lesson to be learned. Conceptual models strengthen relationships between concepts and
help to create good organization (Hohn, 1995). He said it was difficult for him to come up with drawings and to chunk his sentences. Collin's diagram was very creative and each picture strongly related to each concept. He easily remembered his diagram and felt the process worked well for him. He said he mentally pictured his diagram when he answered the test questions. Novak & Gowin refer to this characteristic as metalearning (1984). He said he liked the drawing part the most. I asked him what the most difficult parts were for him. "Coming up with the drawings and summarizing." He said sometimes it was hard to think of what pictures to draw. He said, for instance, "Plants trap energy—I put a rat trap... It's explaining how the sun is being trapped." Collin's evaluation sheet indicated that he enjoyed doing the Roundhouse diagram. He said his drawings helped him understand the difference between the carnivore, the herbivore, and the omnivore. It was obvious, looking at his diagram, he had no misconceptions about this.

**Close-up Interview with Elizabeth**

Elizabeth told me she was distracted at home and was unable to study. Elizabeth enjoyed doing her diagram and said it helped her to organize her thoughts. She told me that plants trap energy from the sun. She understood that consumers got their energy from producers which got their energy from the sun. She did not know the definitions of herbivores, omnivores, or carnivores. She did not try to find out these answers before her test. She missed these questions on the test and was still able to do better than on previous tests. Elizabeth admitted she did not study at home so the information she retained was strictly based on what she had learned during class time. I believe the Roundhouse diagram helped her to retain the general information she needed to make an
average grade on her test. I asked Elizabeth how the diagram was helping her to do better in class. She said, “Because it helps me to apply my information in shorter words where I can understand them and pictures to see.” She said, “Because instead of learning the words, when you see the pictures, you’ll know the answer.” She said when she closed her eyes she could still see the pictures (Paivio, 1986). Increased exposure to mental representations help people to encode information and thus more easily recall what they have pictured in their mind (Searleman & Herrmann, 1994). I believe if Elizabeth had learned what herbivore, carnivore, and omnivore meant before the test, and had drawn out pictures of what they meant, she would have made an excellent grade on the test. I encouraged her to go the extra step in the future. As Elizabeth assumes more responsibility for her own learning, I believe the Roundhouse diagramming method will be of great benefit to her (Wittrock, 1994).

Results of how meaningfully science concepts were learned as shown by the first test which covered Roundhouse diagram Nos. 1 and 2 are shown in the appendix (see Appendix Y). Each child in the case study group was examined in order to determine what concepts were learned and which concepts were not learned. The test grades from the case study group in the 4th six-weeks indicated improvement based on past test grades. (see Appendix O). The mastery of technique sheets were used for the teacher and me to determine whether the students were constructing their diagrams well. Mastery of technique results, or lab grades, for each of the students in the case study group appears in the appendix (see Appendix R).
Reflections from the Researcher

From my perspective, the major problem the students had was directing their thinking. Most of these students have never had to work through a process like this before. They had initial problems using the "and" and "of" words in the title. They had problems extracting the main ideas although this was practically done for them. They had problems because they did not recall the meanings of terms and consequently their prior knowledge was at a low level. It was difficult for them to reduce the amount of material by chunking the main ideas. Sequencing the events was difficult for them as well as thinking of appropriate pictures to relate to the concepts. They wanted to be better at drawing than they were. I observed some students erasing a great deal because they were dissatisfied with their pictures. Surmounting these difficulties will take time, training, and practice.

The students became more proficient in connecting concepts to appropriate pictures over time. Their ability to recall these associations also improved. One student, Collin, seemed more adept at connecting the concepts to the pictures than were the other students. This ability to form associations from icon to concept has helped him improve his science grades (Paivio, 1986). He directly created his images according to the concept. For example, the rat trap connected to the plant symbolized the trapping of the sun's energy by plants. The T-bone steak connected to his knowledge of the carnivore. The cross symbolized death when he related his idea of decomposers eating dead material (see Appendix W). I did not find the other students able to connect their ideas as well. Concepts which involve imagery are encoded better because the concept is encountered not only verbally but in written form (Hohn, 1995;
Paivio, 1986). This is an area which will need training in order for improvement to occur. Other students who listed terms on their diagrams but neglected to draw associating pictures did not know what the terms meant and thus were unable to draw related icons. There needs to be relevant prior knowledge in order to connect the pictures to the concept (Wandersee, 1985).

**Roundhouse Diagram No. 3**

**The Water Cycle**

**Description of Science Content**

In this lesson the students learned how water cycles through the environment. The teacher prepared a synopsis of the water cycle and gave it to the students which stated:

Water is cycled through the biosphere. Water condenses and falls to the ground as precipitation. Some of the water soaks into the soil. A portion of this water is used by plants and animals. Much of the rest of the water runs off into rivers, lakes, ponds, and other bodies of fresh water. Groundwater and the water in rivers and streams may eventually flow into the ocean. The water from the earth's surface and oceans then cycles back into the atmosphere as water vapor through the process of evaporation. Water vapor is also given off by plants, animals, and other organisms. The water evaporates and goes into the clouds and condenses and comes down as precipitation. The cycle continues over and over again.

The teacher gave the students a science fact checklist with a drawing of the water cycle. She gave them an additional diagram which describes and shows, step by step, the water cycle with ways water enters and leaves the atmosphere.
The teacher reviewed earlier lessons in order to find out what the students already knew about the water cycle. She showed them a diagram of the water cycle on the overhead projector. The class and the teacher discussed this concept thoroughly. The students were all attentive and listened while they were looking at the projected images. The teacher then distributed a written sheet on the water cycle, an activity sheet on facts, and the diagram of the water cycle.

The teacher handed the students their Roundhouse diagram worksheets. She allowed them to sit in groups for the purpose of making sure they were able to extract the main ideas. She told them they would be receiving a grade on their diagrams, and gave them a Roundhouse diagram checklist so they could be sure they had included all the necessary elements. The students were somewhat slow getting started and the room was really quiet. There was probably some tension because the students knew this work would be graded. The students had to decide on what they thought was the most important information. The teacher had also stressed that the diagram must have a particular order or sequence, and the students needed to decide where to begin. Some were confused and some were even overwhelmed by this task.

The students were able to list seven main ideas. They had more than enough information to guide them in achieving their goal. They returned to their individual seating and all of them were writing. Some of their facial expressions indicated that they were involved in deep thought. As they completed their worksheets they
raised their hands so the teacher could check their work. When she permitted, they could begin their diagram construction.

**Roundhouse Diagram No. 3 Construction**

**The Case Study Group**

**Close-up Focus on Marian**

Marian stated her goals clearly—"How a Water Cycle Works." She used the “of” word, putting down “Ways of Water Cycles.” She used both “and” words, stating “falls and condenses” and “enters and leaves.” She integrated her title smoothly. Marian was able to break down her central theme into different parts. Her title clearly covered the concepts stated in the diagram. She stated her concepts accurately and drew an icon for each concept. Her sequencing was accurate, and her diagram was well balanced and aesthetically pleasing. The first section stated, “Sun evaporates water.” She put a picture of a puddle and a tree with arrows going up to the sun to indicate the water was evaporating. Next she wrote, “Water condenses in clouds.” She had an arrow going from evaporation to condensation, and her picture was of the sun and a cloud. Marian’s worksheet was full and complete. Her ability to chunk her sentences was effective, and her diagram indicated that she totally understood the water cycle. Marian’s concentration level was very high. This quality was evident in the 35mm photographs taken during Roundhouse diagram construction to determine if she was on-task or off-task (see Figure 6, p. 322). The metacognitive learning skills were becoming automatic with Marian. The more competent science learners facilitate better transfer to other subject areas (Wittrock, 1994). She worked through her diagram and barely looked up until she had finished. At times she stopped and thought while she analyzed her
decisions. She asked many questions during the process of building her connections (Costa, 1991).

**Close-up Focus on Elizabeth**

Elizabeth's goals were not clearly stated. She wrote, "Trying to learn how a cycle work and form." Her title does not cover the concepts in her diagram. She wrote, "Materials Cycle of Ecosystem," "Water cycle and carbon dioxide," and "oxygen and nitrogen." She did include the key concepts in her diagram; however, she did not accurately state these concepts. She did draw an icon for each of her concepts although they were not correctly related. The sequence was inaccurate, though the diagram was well balanced and aesthetically pleasing. Elizabeth's first section stated, "Evaporation is oceans or burning fuels." Her picture was of a car burning fuel with arrows going down. It was evident Elizabeth had some misconceptions. The picture she was given to look at showed the ocean with arrows going up to the sun to show that water was being evaporated. She was obviously confused with her facts, for one section stated, "Evaporation is the sun of condensation clouds." Her picture was of the sun with arrows going to the clouds. I asked her and she did not know what the words "evaporation" or "condensation" meant. It was obvious that Elizabeth did not understand the definitions used in this lesson. She was using words from her handouts, but out of context in the diagram. The Roundhouse diagram revealed conceptual difficulties the learner was experiencing (Wandersee, 1987).

I noticed on Elizabeth's worksheet she stated as her first idea that "Water evaporates from oceans and burning fuels," which was somewhat a correct statement. But when she went through the chunking phase, she lost the meaning and by the time it
reached the worksheet, she had written something totally different. Elizabeth could improve with this process with more practice in paraphrasing and not omitting important facts.

**Close-up Focus on Betty**

Betty’s goals were stated clearly. Her title revealed good thought integration. The title also clearly covered the concepts contained in the diagram, which included the necessary key concepts stated accurately. There was an icon to represent each concept and the sequencing was accurate. The diagram was well balanced and aesthetically pleasing. Betty revealed evidence that she understood the water cycle. Additionally, Betty’s worksheet was full and complete. Her paragraph sequentially listed correctly all the steps in the water cycle. Her picture in her journal indicated that she understood the definitions. She had the potential to do well on all of her work when she applied her efforts (see Appendix Z). I noticed when Betty’s work indicated good links and relationships, her grades improved tremendously (Fensham et al., 1994).

**Close-up Focus on Collin**

Collin did not state his goals clearly. He put, “To study the cycle of the ecosystem” but there are many cycles in the ecosystem and he needed to specifically refer to the water cycle. His title was also very general and did not refer to the water cycle. His diagram did include the necessary key concepts and he did accurately state these concepts. There was an icon representing each concept. The diagram displayed an accurate sequence of events and was well balanced. Collin’s Roundhouse diagram worksheet was full and complete. His work showed evidence that he understood the
water cycle. Collin’s paragraph indicated he knew the stages in sequential order for the water cycle.

**Close-up Focus on Carla**

Carla’s goals were clearly stated. She put, “To learn about the water cycle.” Her title stated, “Cycles of water.” She used the “and” words with “Cycles and Ecosystems” and “Sun and Rain.” Her integration of ideas was evident in the title. Her title covered the concepts in the diagram. The diagram included the necessary key concepts accurately stated with an icon for each concept. The sequence was accurate. Her diagram was well-balanced and pleasing to the eye. Carla’s Roundhouse diagram worksheet was full and complete; furthermore, her work indicated she understood the lesson on the water cycle. Her pictures were her own ideas, not copied; her work was exceptionally neat.

**Close-up Focus on Willy**

Willy’s goals were clearly stated. His title clearly covered the concepts stated in his diagram—“The Ways of the Water Cycle.” He used the “and” words by putting, “enters and leaves” and “condenses and falls.” His integration of thought was obvious here. His diagram included the necessary key concepts, although not all the concepts were accurately stated. He had written, “Water condenses into the ground. I do not think he understood what the word ‘condenses’ meant here where he may have meant ‘absorbs’—water condenses into vapor or clouds not into the ground. He wrote, “Water condenses into the ground.” The last two sections said the same thing. One stated, “Water travels in a cycle,” the other said, “Water travels in an endless cycle.” He used arrows in a circle to represent the cycle. Willy’s worksheet was full and complete.
He had planned out his diagram well. His pictures indicated that he understood some of the content in the lesson. Willy needed to re-read over his definition for condensation to be sure he understood the correct meaning of that word. There was an icon representing each concept, and an accurate sequence of events. The diagram appeared well balanced and aesthetically pleasing.

Reflections of the Researcher

As a reinforcement, the classroom teacher questioned the students on what they already knew about the water cycle. She referred to the states of matter. They discussed evaporation and how water vapor condenses into clouds. They talked about precipitation and the various forms it took. They discussed rain being absorbed into the ground and excess water accumulating in puddles or flowing into rivers, lakes, and oceans. The students all participated attentively in this discussion. The teacher was excellent in her method of asking questions that involved and motivated the students.

The students started out together in groups, and at first were very quiet, not discussing very much. The worksheet required much writing and thinking on the part of the students. With traditional methods of teaching science, they did not have to work as hard. With the Roundhouse diagramming method they were required to think of titles, list main ideas, paraphrase those ideas, and link their concepts, written in their own words, to icons. Many of the students enjoyed drawing, but were unaccustomed to thinking and working on their own. Since some of their grades had improved, their confidence improved as well. Informally in class, I asked questions similar to those in the formal interviews. They seemed to be very honest and most of the time
consistent, but not always. They revealed more when I was able to speak with them individually.

The students were told that the diagram on the water cycle would be for a grade and would count as a test. The students were very careful in completing the work on these diagrams. All of the students seemed to be putting good effort into trying to do their best work. Research indicates that illustrations direct students' attention and aid in the encoding process (Hohn, 1995; Searleman & Herrmann, 1994). When the students had completed their diagrams, the teacher asked them to write their final paragraph and to explain the water cycle in an essay question. I noticed a big change in their drawings this time. The diagrams had become their own creations.

**Reflections from the Teacher**

The following comments were taken from the teacher's journal:

We began the water cycle today. I taught the lesson. I gave the students sheets with the sequence of events in the water cycle. They seemed to understand it fairly well after we went over the worksheets. When I taught this class, I still got nervous that they were daydreaming and not paying attention. I felt that way because they always had very short attention spans.

**Reflections from the Outside Observer**

These comments come from the outside observer's field notes:

The students were attentive and working well on this activity. Marian is very creative and told me she enjoys working in groups. She told me the picture diagram helps her. Willy said he thought the diagram was helpful. Betty said it was hard sometimes, and she had to think more. Betty said, "In a group it's hard because some people don't try."
Reflections from the Students

The Case Study Group

These comments were taken from the students' journals:

**Marian** It is better to work in groups. I learn important ideas. It is fun to work with others. The diagram is helpful for the lessons. The picture explains more about the chunked sentence.

**Elizabeth** Some groups are helping each other. Marian has a happy expression. Melinda is asking questions. Collin helps Tim and Melinda.

**Collin** I had trouble doing the pictures.

**Betty** It's like kind of hard because you have to think even more. Everyone in my group has a sad face. Working in groups is still hard because you still have to think. Others may not like what you are thinking. You have to think for yourself and think for others, too.

**Carla** I think this will help me in science. This is better than taking notes.

**Willy** I think the members of my group enjoy the diagram. I think they are all thinking about how they like the diagram. I think some of them like to work on the worksheet. I like it a little bit. I have fun doing the diagrams, and I like to draw the pictures. I think the people in my group are all smart and all hard-working people who are excited about the Roundhouse diagram.

Roundhouse Diagram No. 4

The Carbon Dioxide-Oxygen Cycle

Description of Science Content

The teacher gave each student an overview of the lesson:

As you inhale, you take in air from the atmosphere to get the oxygen your body needs to carry on respiration. As you exhale, you give off carbon dioxide. Plants and other producers need carbon dioxide to carry on photosynthesis. During this process, they take in carbon dioxide and release oxygen back into the atmosphere. Animals, plants, and other organisms take in oxygen, removing it from the atmosphere. These same organisms return carbon dioxide to the atmosphere as waste products during respiration. The cycle then begins again. Carbon dioxide also enters the atmosphere as a product of decomposition, and when fossil fuels such as oil, natural gas, and coal are burned.
The students began their class in groups discussing the ideas in the handout about the cyclic pathway in which carbon dioxide and oxygen move through the environment. The students needed guidance with this topic. The teacher asked students to read from their textbooks about the carbon dioxide-oxygen cycle. She referred them to the pictures in their book and asked them to observe the pictures carefully. The students read both the handout and their textbook and later wrote their main ideas after discussions with their groups. Some students started having problems remembering the sequence of events. The teacher continued to stress that in cycles there is a definite order.

I noticed many of the students were using the “of” and “and” words. Their pictures were beginning to show more detail. Details indicate a sign of complexity and creativity within the learner’s cognitive structure (Starko, 1995). Their discussions seemed to be more on task, and they were finishing their worksheets faster. The teacher encouraged the students to write full titles. She wanted the students to stop whiting out the words and to start thinking of all the parts involved in the diagram. This task was difficult for them to accomplish. The students had begun to get more efficient in constructing the diagrams.
Roundhouse Diagram No. 4 Construction

The Case Study Group

Close-up Focus on Marian

Marian’s goals were stated accurately. She wanted to learn about the carbon dioxide-oxygen cycle. Her title covered all of her concepts well—“Carbon dioxide-oxygen cycle of plants and animals.” She used the “and” words and stated “carbon dioxide and oxygen” and “photosynthesis and respiration.” She integrated her title well and covered all of the key concepts. The concepts were accurately stated in the diagram. There was an icon which represented each concept. She used the sequence of events correctly. The diagram was well balanced and the design was aesthetically pleasing. She drew a picture of a person with carbon dioxide going out leading to the green leaves around a flower with carbon dioxide going in. From the leaves was an arrow with oxygen going out back to the man. Marian did a beautiful job. She filled up each section without repeating herself. She has the ability to break down concepts into their parts. The Roundhouse diagram, a metacognitive tool, was helping her to restructure knowledge in a meaningful way (Mintzes & Wandersee, 1998). Her icons were directly related to what she had stated. Marian’s concentration level is very strong (see Figure 6, p. 322). She worked well individually and put a lot of thought into her work when she constructs a Roundhouse diagram. Marian’s Roundhouse diagram worksheet continued to be well planned in every aspect. She wrote each main idea out clearly, which enabled her to sequence the events easily and break the concepts down into smaller parts. Her handwriting and pictures have remained clear and well established. Her final paragraph indicated that she understood her diagram.
Close-up Focus on Elizabeth

Elizabeth stated her goals clearly, but not accurately. She stated, "I'm trying to find out how a carbon dioxide-oxygen use in a cycle." She told me she meant to say, "How the carbon dioxide-oxygen cycle is used." Elizabeth had a difficult time expressing what she really meant, yet she was improving with this method. She still had not tried to integrate her title and represent its parts. She simply stated, "The study of carbon dioxide-oxygen cycle." She erased the "and" words completely. Her title covered the concepts stated in the diagram. The concepts were accurately stated with some minor grammatical errors. There was an icon, which was representative of the concept, in each section except one. The diagram included some unique pictures which were Elizabeth's own ideas. She had been working better individually, and her ideas were her own creations. Visual imagery helps to stimulate students' ability to recall and helps to direct the students' attention in the learning environment (Levin et al., 1979). She had established more ownership of the diagram. The sequencing of events was accurately done, and her design was pleasing to the eye. The first section stated, "Carbon dioxide and oxygen move in a cycle." She had no icon but did use an arrow in the lower corner, which pointed to the next section. She stated, "Decomposers release carbon dioxide in the air and plants can take it in." She drew a picture of a mushroom with arrows pointed to the tree next to it. The last section stated, "Animals release CO₂ and the cycle continues again." She drew an animal with arrows pointed out with CO₂. This diagram was a big improvement over the others she had done. Elizabeth was showing more confidence with this method. Although she had writing problems, she indicated that she understood the science content in this lesson. Her worksheet was
planned out well. She seemed to really take her time and try this time. Her ability to chunk her sentences was improving.

**Close-up Focus on Betty**

Betty did not state her goals or put a title on her diagram. I looked at her worksheet and saw that it was not completely filled out either. She did write a title on the worksheet, “Carbon dioxide-oxygen cycle of plants and animals.” She did write goals on the worksheet, “To learn about the carbon dioxide-oxygen cycle.” She had plenty of time to do this in class. If she had needed more time, the teacher would have allowed her to come in and work on her diagram. Betty had still not taken responsibility for completing the task. The classroom teacher revealed that Betty’s home life contributed to her inconsistency in class. This could have been one reason she did well one day and seemed apathetic the next.

The diagram contained the necessary key concepts needed to describe the carbon dioxide-oxygen cycle. She followed a sequence of events correctly. The icons she did put in were good and had more detail than usual. I think Betty had much more potential than she had shown with this process. In one section she stated, “Then the plant goes into photosynthesis.” Her picture was of an arrow with the word photosynthesis written on it, which was pointed to a flower. Another arrow was pointed downward at some dots. The dots might have represented sugar, but the reader really would not know if she understood the process of photosynthesis or not. In one section she stated, “Human and animals are going during respiration.” Betty had not indicated that she understood the process of respiration with that comment. The pictures and the words written in this diagram were not unified and were very confusing.
Close-up Focus on Collin

Collin stated his goals clearly. He said, "I am trying to learn how the CO₂ and O₂ cycle is being used." Collin’s title stated, “The Study of CO₂ and O.” He also put “plants and animals” but he ignored the other “and” word and does not use it. Collin was not integrating his title in this diagram. He was not being consistent with his symbols for oxygen. He went from putting “O” to putting “O₂.” Collin’s title did cover the key concepts in his diagram. His concepts were stated accurately, but he still had problems spelling words correctly. He had an excellent average in spelling, indicating that he could do better with spelling science vocabulary words. There was an icon which was representative of each concept. The sequence of events was correct. The space in the diagram was well used and the design of the diagram was aesthetically pleasing. In one section he stated, “Decomposition also releases CO₂.” His picture was of smoke. His last section stated, “The cycle never ends.” He drew arrows in a cyclical pattern. Overall, Collin’s diagram was well done and showed evidence he had worked hard on it. Collin’s Roundhouse diagram worksheet was full, complete, and accurate.

Close-up on Carla

Carla stated her goals clearly. The title stated, “The carbon dioxide-oxygen cycle of plants and animals.” She did not try to use the “and” words. There were many possibilities she could have chosen. Carla was capable of integrating her thoughts more in constructing her title. She needed to work on that area. Her title did cover all of the key concepts covered in the diagram. She had stated her concepts accurately. She drew an icon to represent each concept, and she used the sequence of events correctly. The diagram used space well and was pleasing to the eye. Her handwriting was
exceptionally neat and her pictures well drawn. Carla did a beautiful job on this diagram. Her pictures were so well done they spoke to the reader. Paivio discovered that concrete information is remembered more easily than abstract information (1986). This is probably why Carla’s grades had come up so much in science. The Roundhouse diagram helps to make concepts more concrete. She used all the important vocabulary words from this lesson and showed evidence that she understood the content. Carla’s worksheet was well planned and helped her to create such wonderful diagrams. Her final paragraph was written well and explained the carbon dioxide-oxygen cycle thoroughly. This method definitely appealed to Carla, and she obviously enjoyed putting in the extra work. Her products were admirable. This method helped Carla to bring her grades up (see Appendix AA).

**Close-up Focus on Willy**

Willy’s goals were clearly stated. His title used the “and” and “of” words correctly. He stated, “Carbon dioxide cycle of plants and animals.” He included “carbon dioxide and oxygen” as the two gases discussed, and “photosynthesis and respiration” as the two processes discussed. This is the best use of the title I have seen from any of the students. His title completely covered all of the key concepts discussed in his diagram. His key concepts were accurately stated. The diagram was well written and the design aesthetically pleasing. Willy’s worksheet revealed planning and evidence that he understood the carbon dioxide-oxygen cycle. Willy’s paragraph was well written and indicated he understood the content of this lesson.
Reflections from the Researcher

As the students worked on their diagrams they were much more aware of what
to do next. They needed to pay more attention to sequence of events. Some students
were out of order with the sequence of the cycle. The teacher walked around the room
and helped them by asking them questions. In some cases, she got another student to
help someone. With sufficient training, these students were eventually able to do this
with less guidance. They were becoming less dependent on the teacher. They were
having to think for the first time on their own and it was difficult for most of them.

The teacher had told me she was worried about completing everything she
needed to do before the Louisiana Educational Assessment Program (LEAP) testing.
She had told me that she could tell the diagramming method was going to help them in
terms of reading. The teacher also mentioned that she was actively dealing with
students’ misconceptions. This comment was enlightening in terms of the realization
that although this diagramming method is indeed time consuming, especially in the
beginning stages, yet it offers a unique opportunity to educators to discover
misconceptions and correct them. Traditionally, a teacher never has the chance to
discover what the child is thinking (Novak & Gowin, 1984). Many teachers do not take
the time to find out what the child knows and what he or she does not know. Teachers
need to be more selective about what they teach and realize that teaching for meaningful
learning of less material can be more beneficial, although it is at times more time
consuming (AAAS, 1989; Mintzes & Wandersee, 1998).

The teacher was skilled at asking questions to keep the students on track. She
asked, "Why do plants take in carbon dioxide?" A child answered, "for
photosynthesis.” She did this so the students could arrive at the main ideas themselves. The class was usually very attentive. Hands were always raised. Answers seemed to flow with ease. Grades indicated this process helped the slower students. When a slow student answered incorrectly, the teacher never criticized or embarrassed them. The teacher asked me, “If a student just does this and pushes it aside, do you still think it helped that student?” I said, “Absolutely.” I told the teacher that many times teachers teach, but because of time constraints, they may pass over what may be important, and consequently the students never fully grasp the concepts. I told her that constructing this Roundhouse diagram made the teacher responsible for making sure these students understood what they put on their diagrams.

**Reflections from the Teacher**

These comments were taken from the teacher’s journal:

The students are discussing the carbon dioxide-oxygen cycle. They have their book and a typed paragraph to help them construct their Roundhouse diagrams. The students are reluctant to discuss. They are not very good with verbal skills when it comes to learning. Much prompting at this point is needed to get them going. They are beginning to brainstorm more in order to come up with ideas. They know they have to do the diagram and each student is accountable for their work. Sometimes it helps them to ask others for assistance.

**Reflections from the Outside Observer**

These comments are taken from the outside observer’s field notes:

I really like the Roundhouse diagram method. I know from experience that seeing what you are reading is the greatest way of remembering and learning something that may be complicated. A visual picture stays in your memory and is easy to recall. This concept is important to all children but especially those who have attention disorders. They will sit in class and listen as hard as possible, but when a question arises, they have forgotten what they have heard. When students have problems learning, they feel inadequate. The Roundhouse diagram will help slow learners. The students will feel equal to the
other classmates and boost their self-esteem. The students who are already doing well can become even more creative.”

The teacher is going over the diagram. The children seem to understand what is being said. Collin seems to be daydreaming a bit. I asked Marian if she remembered her diagram well enough to write a paragraph without it. She said she did. Willy used his diagram to write his paragraph. Betty wrote down that plants took in oxygen. I talked to her about that. Now she understands that humans and animals take in oxygen. I would never have known she thought that if I hadn’t seen it on her diagram. This process is very good to catch what students don’t understand.

**Reflections from the Students**

**The Case Study Group**

These comments are taken from the students’ journals:

**Marian** This is fun. This is better than taking notes. This is cool. This is easy. I don’t want to go to another subject. This will help me in science.

**Elizabeth** We are explaining the answers and what to write. Melinda said she is enjoying the Roundhouse diagram and she is learning from it. The teachers are walking around helping us. Collin said he likes this better than taking notes. This diagram is helping me a lot because it’s my own words and I understand it better.

**Collin** I have asked for help chunking. I am enjoying the process. I am learning from it. It helps me to understand the process. It forms a good picture in my mind.

**Betty** I think the diagram is cool. Carla said it feels like we are in college.

**Carla** This is cool. I like doing this. Everyone looks like they are understanding.

**Willy** I think everybody in my group likes doing the Roundhouse diagram.

**Roundhouse Diagram No. 5**

**The Nitrogen Cycle**

**Description of Science Content**

The nitrogen cycle is the circular pathway in which nitrogen moves through the environment. Bacteria and lightning break down nitrogen gas into compounds. Plants change the nitrogen compounds into protein. These proteins pass through organisms in the food web. Organisms at the end of the food chains die and the bacteria decompose
them and convert the protein back into ammonia. This ammonia is used by producers, but most of it goes back into the atmosphere as gas. Rain washes these gases back to the ground. The cycle begins over again.

**Roundhouse Diagram No. 5 Construction**

**The Whole Class**

**The Nitrogen Cycle**

The teacher used the overhead projector and instructed the class to watch and listen. She drew pictures and explained each concept in the nitrogen cycle. The students listened as the teacher taught using visual displays. After she finished the lesson, she instructed the students to take out their textbooks. The students took turns reading the lesson aloud. The textbook also provided a good illustration of the nitrogen cycle which the teacher went over with them step by step.

I noticed students accurately stating their goals. The students seemed to have learned how simple that part is by now. Many of the students who were not using the "and" and "of" words are now using the words with no problem. The students were much more efficient and they were using their time wisely. They sat in groups for only short periods of time—most of the work was now being done individually. The students were more confident because their grades were improving. They were not as dependent on the teacher for all of their information.
Roundhouse Diagram No. 5 Construction

The Case Study Group

Close-up Focus on Marian

Marian stated her goals clearly. She stated, "How nitrogen flows and works through a cycle. She used the "and" and "of" words in her title. She stated, "The flow of nitrogen." She added "proteins and amonia" and "plants and decomposers." Her title clearly covered the concepts stated in the diagram. The concepts were accurately stated. She drew an icon in each segment to represent the concept. There was a definite sequence of events. The diagram was well balanced in regard to use of space, and the design was aesthetically pleasing. Marian said she liked constructing the diagrams. She was always pleasant and smiled as she worked. She was confident and it showed in her work. She was always there to help others if they needed it. She raised her hand and asked questions when she didn’t understand a part. She had a good relationship with her classmates. The first section stated a fact out of her textbook. She stated, "80% of the atmosphere is nitrogen. She looked on the element chart on the wall and wrote "N80%." Her thinking was direct and her icons specifically related to each concept clearly. Marian’s worksheet was well planned. Marian always used the references around her to help fill in details on her diagram in order to make them her own creation. Marian’s final paragraph indicated that she fully comprehended the content of this lesson.

Close-up Focus on Elizabeth

Elizabeth’s goals were clearly stated, but were a bit awkward in wording. She stated, "How nitrogen flow and works throughout a cycle." The title is very well stated
and she used the “of” and “and” words. She stated, “The flow of nitrogen in an environment.” She added, “proteins and ammonia” and “plants and decomposers.” She drew pictures of mushrooms and flowers around the title. Elizabeth was showing more confidence and her work was becoming more detailed. Her writing was improving and so was her grammar. The title clearly covered the concepts stated in the diagram. The concepts were accurately stated. She drew an icon in each segment to represent each concept, and her concepts were sequenced properly. One section stated, “the decomposers of the bacteria die and the protein goes back to ammonia.” I did not think Elizabeth understood that bacteria were decomposers. She drew a picture of a flower bent over as if it were dying. She had some misconceptions here. She stated, “The decomposers of the bacteria.” The diagram was requiring her to work through the vocabulary she had never had to address before in traditional methods.

**Close-up Focus on Betty**

Betty had her goals stated clearly. She wrote, “To explore the nitrogen cycle.” She used the “and” and “of” words correctly. She wrote her main title as “The Nitrogen Cycle of the World.” She added “decomposers and plants” and “ammonia and plants.” Inside the center circle with the title she drew plants, mushrooms, and several rows indicating a cycle of events. Betty’s work had gotten very detailed and artistic, as previously she had left icons out totally. The title included the key concepts covered in this lesson. The concepts were accurately stated. There was an icon represented in each segment for each concept. The sequencing was accurate. Betty seemed to be putting much more energy into her work. She was like a changed student. She was confident and always on task constructing her diagram. Betty was relating her icons directly to
her concepts. She seemed to be trying very hard to complete her diagrams as well as she could. Her attitude had changed in this class since beginning work on the Roundhouse diagrams. Betty’s worksheet was full and complete. She had planned her diagram well. Her final paragraph indicated that she understood the content in this lesson (see Appendix BB).

**Close-up Focus on Collin**

Collin stated his goals clearly. He said, “To learn the flow of nitrogen in a cycle.” His title effectively stated, “The Flow of Nitrogen in an Environment.” He added “proteins and ammonia,” and “plants and decomposers.” Collin is now using the “and” and “of” words without a problem. His title clearly covered all the concepts stated in the diagram. The diagram accurately stated the key concepts to be learned in this lesson. There was an icon represented in each segment for each concept. The sequence of events was accurate. The diagram was well balanced and the design was aesthetically pleasing. Collin had constructed the Roundhouse diagram well the first time he did one. He improved regarding the amount of detail in his work. His thoughts were well related and he seemed more focused. He stated next, “Protean is made by plants with nitrogen compounds.” He misspelled “protein” throughout the diagram. Collin’s Roundhouse diagram worksheet was well planned, although some parts of it looked as though he had rushed. He still needed to concentrate more on his spelling and handwriting, yet his ideas were good.

**Close-up Focus on Carla**

Carla stated her goals clearly. Her title stated, “The Nitrogen Cycle of the World.” She added “ammonia and protein” and “decomposers and plants.” The title
clearly covered the concepts stated in the diagram. The diagram included the necessary key concepts covered in the material. The concepts were accurately stated. There was an icon in each segment to represent each concept. The sequence of events was accurate. The design was well balanced in regard to spacing. The drawings were clear.

Carla's handwriting was extremely neat. She had well-stated relationships within the diagram. Her work indicated that she enjoys constructing the Roundhouse diagrams. This method has proven to be extremely effective for Carla, and her science grades have greatly improved. Carla's test papers indicated that she mentally pictured her diagram while answering her questions. Novak & Gowin refer to this characteristic as metalearning (1984). The first section stated, "80% is nitrogen." She drew a cloud of nitrogen. Next she stated, "Bacteria and lightning break down gas into compounds." She drew lightning and bacteria. Next she stated, "Plants change compounds into proteins." She drew a picture of what she thought proteins looked like. Her icons were directly related to her concepts. Carla's worksheet was full and well planned, and her paragraph indicated that she understood the material in this lesson.

Close-up Focus on Willy

Willy's goals were stated clearly. The title was accurately stated. He put, "The Nitrogen Cycle of the World." He added "protein and ammonia" and "decomposers and plants." Willy seemed to be able to use the "and" and "of" words accurately now with no problems. His title clearly covered the concepts stated in the diagram. The diagram included the necessary key concepts covered in the material. Willy stated his comments accurately. Each section had an icon which was representative of the concept in each section. He sequenced the events accurately. The diagram was well balanced and
aesthetically pleasing. Relationships between ideas were clear. Willy’s pictures were
detailed and full of thought. He had greatly improved in his method of constructing the
diagrams. His pictures were unique and of his own making. Empirical evidence
concludes that students recall more with visual representation of content (Levin et al.,
1979). Many of Willy’s pictures were abstract, and only he truly understood what they
meant. He labeled the parts for the reader so that they could be understood. Many of
his ideas were complex, evidencing that he really thought about what he drew. Willy’s
worksheet was full and complete. It was hard for him to chunk his sentences. Many
sentences were longer than they should have been, yet his final paragraph indicated that
he had learned the content of the lesson.

Reflections from the Researcher

The teacher initiated the discussion on the nitrogen cycle by reminding the
students of the role of decomposers. She said, “Bacteria and lightning break down
nitrogen gas into compounds. A chemical change takes place.” The facial expressions
on some of the students’ showed concern and confusion. She went on to say, “Plants
take the nitrogen compounds and change them into proteins. The consumers get the
proteins from the plants when they eat them. People eventually get this protein because
we eat the consumers. When the organism dies the protein converts back to ammonia.
Some ammonia is used by the plants but most of the ammonia goes back into gas. Then
rain washes these gases back to the ground.”

Willy was disturbed by these comments. He admitted he did not understand the
part about the decomposers. He asked a series of questions such as, “How do the
mushrooms get there? How do spores get there? Why don’t mushrooms grow
everywhere? They are not in my yard at home.” The teacher decided this would be a good time to do a wedge to explain the role of decomposers—especially the mushroom—in the environment. The teacher answered by telling him that mushrooms need heat and moisture to grow and a spore to reproduce. Willy still seemed confused, and other students looked perplexed and confused as well. We need many more researchers in the field of mycology because most people do not comprehend mushroom development.

The teacher allowed the students to sit in groups to resume their discussion and to fill in their Roundhouse diagram worksheets. The pace had picked up and the students were writing much more quickly than they had in their earlier diagram work. There was much more conversation about the lesson going on in the room. The students were thinking faster. They were getting better with practice. There was more discussion from and more confidence in the students. They had really good ideas although they were still having trouble with sequence of events. The students worked well in their groups, using the clipart books as well as their science books to get ideas about what pictures to draw. They were definitely and successfully putting thought into their plans for their diagrams.

Reflections from the Teacher

These comments were taken from the teacher’s journal:

I do like the Roundhouse diagram. I feel that it incorporates many important skills to be practiced. We are using the Roundhouse diagram to learn science, but in reality the students are also practicing reading skills such as sequencing, paraphrasing, topic, and main idea. They are also writing a lot with the diagram and are having to revise and proofread what they are writing. Some of the slower students are still having trouble choosing their main ideas, but I feel with time they will become better at it.

I will definitely use the Roundhouse diagram every year as a graphic organizer to help students learn how to study and learn material on their own.
have used it myself to study for my own class. I also have shown my daughter how to use it for her science class. It really has helped improve her science grades.

The only drawback with the Roundhouse diagram is that it slows down the progress of my science class in the lower group. I do, however, realize that quality is better than quantity. I use it with my top group students also. They, however, have caught on very quickly, and it does not slow them down at all.

The slower students were never able to write paragraphs very well. Using the diagrams enables them to write a clear description of the entire lesson. The paragraphs serve as a summary of the lesson and practice for answering essay questions. The diagram helps them to perform this writing task.

Reflections from the Outside Observer

These comments were taken from the outside observer's field notes:

Willy likes the Roundhouse diagram very much. He thinks it is fun and it helps him learn. He said the pictures help him to remember. He would rather draw pictures than to take notes. Carla said the pictures were easier for her to remember than notes. She associates icons with her concepts. Marian likes chunking. She writes very neatly. Betty thinks the diagram is easier than note taking. She said the icons help her to understand and remember. She likes to draw. Collin enjoys drawing icons, but he said sometimes it's hard to think of pictures. He said chunking was difficult. He prefers this method to notetaking. He completes his assignments faster than other students. Elizabeth likes the Roundhouse diagram better than notetaking. She recalls the material better with this method. All of the students reported an increase in their grades. The teacher moved around the room assisting and encouraging students to continue. The students are engrossed in their work. There are absolutely no discipline problems. The students seem to be very interested in what they are doing. The students seem to enjoy writing in their journals. They seem to be able to write their paragraphs with ease using the diagrams.

Reflections from the Students

The Case Study Group

These comments were taken from the students' journals:

Willy: I like the Roundhouse diagram. I think it is the coolest thing that will be fun and will help me learn the material.

Carla: Everyone looks like they are understanding. Willy said, "This diagram is all right." Collin looks like he is having trouble chunking. Betty thinks the Roundhouse diagram is great. Marian thinks the Roundhouse diagram is helpful. It looks like everyone is having a great time with the black pens.
Denisha is looking for good icons. Everyone is using their time wisely. It looks like everyone's diagram is neat. The teacher said this is great and should help us for the test. She said the pictures are important. Melinda has a smile on her face.

**Betty:** Everyone is talking to each other. Everyone is talking about what they want to put on their diagram. Some people look lost.

**Collin:** It's fun picking at each other.

**Elizabeth:** It is easier to work in groups. Denisha has nice pictures. Melinda likes doing the diagram. Collin said it's cool doing this. I love doing the Roundhouse diagram because of the pictures and using my own brain.

**Marian:** It's easier to work in groups. Explaining is easier.

**Wedge Construction**

**Decomposers**

**Description of Science Content**

What is a fungus? A mushroom is a type of fungus. Fungi are simple organisms made of cells that have cell walls and absorb food from their surroundings. Fungi are made of hyphae, formed of many cells with pores between them. The cap and stalk of a mushroom are made of tightly-packed hyphae. Underground, beneath the cap and stalk, the hyphae wind together to form a mesh called mycelium which acts as a root system for a mushroom.

Fungi do not produce food by the process of photosynthesis. They are consumers, but they do not eat the same way animals do. They digest their food source by secreting chemicals onto it from their hyphae. The food source is broken down into nutrients by these chemicals and the nutrients are absorbed by the hyphae.

On the underside of the mushroom cap there are microscopic reproductive structures. These structures are spore cases and hold thousands of microscopic spores. Spores are cells from which new organisms are produced without being fertilized by another cell. When spore cases break open, thousands of spores are released into the air.
When a spore lands on an object and there is adequate warmth and moisture, it reproduces and grows into a new fungus. To reproduce, fungi need moisture, and they grow better in darkness.

**Wedge Construction**

**The Whole Class**

**Decomposers**

The students were first introduced to decomposers when they did their first two Roundhouse diagrams. At that time, many students were confused about the role of the decomposer. They understood that decomposers consumed dead material, but many students did not understand how this was done. Many questions were asked about mushrooms and how they grew and ate dead materials. When the students did their Roundhouse diagram No. 4 on the carbon dioxide-oxygen cycle, they were told again that carbon dioxide entered the atmosphere as a product of decomposition. The students brought up questions again about how mushrooms appeared when they grew in some places and not others. In Roundhouse diagram No. 5 on the nitrogen cycle students were told that bacteria were decomposers and that bacteria broke down nitrogen gas into compounds. The teacher told them that organisms at the end of food chains died and bacteria decomposed the material, converting proteins back to ammonia. The students were still confused about the role of decomposition and they asked questions such as: How do fungi eat dead animals? How do decomposers reproduce? Why do mushrooms live on tree stumps in the forest?

The classroom teacher was amazed that these students were so inquisitive because normally in their science lessons they did not ask so many questions.
Inquisitiveness is a characteristic of metacognition (Bonds et al., 1992). The students had not been restructuring the material in their lessons or making relationships. The teacher decided to do a wedge just on the decomposers in order to clear up any questions or misconceptions.

The teacher distributed the wedge sheets to the students and instructed them to listen to instructions carefully because they would be doing something new. The teacher had specifically planned for this lesson. She had made up packets for the students with three pages of written material along with pictures which explained to them about decomposers. She distributed the packets which were titled, “What is a fungus?” The students took turns reading the material in class. She often referred to the visual pictures on each page which were very graphic and represented the concepts being relayed very well. After going over this material, the students seemed satisfied because they got their answers. The concept is a difficult one and some of the students may not have totally understood, but they were able to construct some good ideas based on the information.

She allowed the students to sit in groups and discuss this material to arrive at some main ideas. She explained that this was unlike the Roundhouse diagram and the students could fill up the wedge with their main points. She encouraged them to draw pictures to back up what was being said. The teacher went back over the material with the students and had them underline the parts she wanted them to know.

The class created the wedge together with the teacher guiding them. The main ideas were basically the same. The students drew their own pictures and organized the wedge as they wanted to create it. This activity seemed to clarify a number of questions.
in the students' minds. Since the students did not yet have a worksheet designed for the wedge, they were told to write out their ideas in their journals before they could put them on the wedge sheet. The teacher told them as they finished the journaling to raise their hands so that she could check their concepts before they put them into the wedge sheet.

**Wedge Construction—Decomposers**

**The Case Study Group**

**Close-up Focus on Marian**

Marian's wedge was very clearly organized. Organizational processes enhance encoding. Organization is often necessary for remembering (Searleman & Herrmann, 1994). Each concept was represented with a picture taken from the handout. Marian also numbered this diagram and I felt this was significant in terms of organization and sequence. It amazed me how easily Marian was able to take this complex vocabulary and put it into such short, concise, easily understood sentences (see Appendix CC).

**Close-up Focus on Elizabeth**

Elizabeth's wedge was also very organized including numbering. This represented growth for Elizabeth over her previous diagrams. She really drew them carefully and tried to copy them accurately from the pamphlet that was given to her in class.

**Close-up Focus on Betty**

Betty did not number her concepts. She spread her concepts out over the wedge haphazardly. The diagram compelled her to be organized with the sections, but with the
wedge she just filled up empty space. She wrote very large so the wedge would appear full. Betty’s pictures showed that she had understood some of this material.

**Close-up Focus on Collin**

Collin did not number his concepts and, as a result, his ideas are not very organized. He has spread out his concepts in a haphazard fashion. Collin continued to misspell words. Collin seemed to understand most of the material presented. I questioned some of his drawings such as the spores out to the side of the mushroom. He may have meant they were released from the casings and were spreading in the air.

**Close-up Focus on Carla**

Carla’s concepts were not numbered, but they were incredibly neat, clear, and in separate parts on the wedge. Her drawings were very clear and directly related to the concepts.

**Close-up Focus on Willy**

Willy’s concepts were not numbered or laid out in any particular order. Willy “cut-up” and made jokes in his diagram. He drew a stick figure and wrote by it, “Big Willy!!!!” Willy wrote good concepts and indicated that he understood the material.

**Reflections from the Researcher**

A wedge was done on decomposers. The teacher researched outside reference materials and found answers to Willy’s questions. The information and the pictures were difficult to understand and could possibly have been too advanced for some of these students. She handed out packets to the students. They read the material aloud and carefully reviewed the pictures. The students wrote down the important concepts. The teacher had them underline certain parts as they read so they would know the main
ideas she wanted on the wedge. Willy was chosen to read first, since he had asked most of the questions. He read the section on how mushrooms eat. Willy said, “I have dead leaves in my yard, but there are no mushrooms. Why not?” The teacher said there needed to be spores present in order to reproduce. She showed them under the mushrooms there were cells which contained spores. She also said they needed moisture and warmth. She explained that mushrooms did not go through photosynthesis and they did not need light. The teacher was able to clear up many misconceptions going through the reconstructive process one step at a time. Willy asked, “When a mushroom eats a tree, is the tree numb?” The teacher said, “No. There are dead cells on the outside bark that mushrooms feed off of.” Jonathan’s face showed surprise. He said he did not realize the outer part of a tree was dead. The process was causing the students to ask many questions. This was one of the major changes I was seeing more and more. The students were being motivated to think, thus stimulating their curiosity.

The students got in groups to do their wedges. Collin said, “Shall we go with the definition of fungi first?” Where to start always seemed to be the toughest part. Once they started, they seemed to go much faster. There was much discussion going on among the students. Self-esteem and confidence had gone up. The students were not nearly as fearful of the process as when they first started out.

Reflections from the Teacher

These comments were taken from the teacher’s journal:

The students are still having trouble verbalizing their main ideas. The flow of discussion is much better now. The students are conversing more. The students seem more confident. Their raise in grades is helping them to feel
better about their work. The groups are generally low in language skills ability. This process is helping them to verbalize. This is also helping their social skills. The students work better in groups and individually. They always seem to be on task. They are working more than they used to...less daydreaming. They are becoming more responsible. Their writing of paragraphs has greatly improved. Some of the students are doing a beautiful job on their diagrams but do not ever look at them at home, therefore their grades have not changed too much on their tests. Some students do not study and are disinterested in school. The Roundhouse diagram has helped to stimulate interest even in these students.

**Reflections from the Students**

The student evaluation checklist covering Roundhouse diagram Nos. 3, 4, 5, and the wedge on decomposers indicates that most students are experiencing positive results with the Roundhouse diagramming method (see Table 2).

**Table 2. Student Evaluation Checklist: Whole Class**

<table>
<thead>
<tr>
<th>Roundhouse Diagram Nos. 3, 4, 5, and Wedge</th>
<th>Yes</th>
<th>No</th>
<th>Sometimes</th>
<th>Most of the Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics</td>
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<tr>
<td>Enjoyment</td>
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<td>--</td>
<td>2</td>
<td>1</td>
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<tr>
<td>Organization</td>
<td>12</td>
<td>--</td>
<td>2</td>
<td>1</td>
</tr>
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<td>Ability to Chunk</td>
<td>11</td>
<td>--</td>
<td>2</td>
<td>2</td>
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<tr>
<td>Uses time wisely</td>
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<td>--</td>
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<td>--</td>
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<td>Works well independently</td>
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<td>1</td>
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<td>2</td>
</tr>
<tr>
<td>Works well with others</td>
<td>14</td>
<td>--</td>
<td>1</td>
<td>--</td>
</tr>
<tr>
<td>Uses one's own words</td>
<td>7</td>
<td>1</td>
<td>5</td>
<td>2</td>
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<tr>
<td>Ability to link pictures</td>
<td>9</td>
<td>1</td>
<td>4</td>
<td>1</td>
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<tr>
<td>Creativeness</td>
<td>11</td>
<td>--</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Improves understanding</td>
<td>13</td>
<td>--</td>
<td>2</td>
<td>--</td>
</tr>
</tbody>
</table>
Two questions were asked at the end of each student evaluation sheet:

1. The most important things I learned constructing the Roundhouse diagrams were:
   chunking (3), the water cycle (5), the nitrogen cycle (6), the carbon dioxide-oxygen cycle (6), forms of precipitation, condensation, how to study, how to link pictures to my thoughts (3), to improve my grades (2).

2. Did you encounter any problems while constructing your Roundhouse diagrams? drawing pictures, coming up with main ideas, it has gotten easier (3), the worksheets help, working in groups helps, thinking, chunking, none (8).

A table has been provided for meaningful learning concepts (see Appendix DD) of the case study group which covers Roundhouse diagrams Nos. 3, 4, 5 and the wedge on decomposers. The first test grades for the 5th six-weeks revealed grades for the Roundhouse diagrams Nos. 3, 4, and 5 (see Appendix P).

**Formal Interviews with the Case Study Group**

**Interview with Marian**

Marian told me that the Roundhouse diagramming method was getting easier for her, especially finding the main ideas and chunking the sentence’s into her own words. The process of chunking involves organizing material into meaningful clusters (Searleman & Herrmann, 1994). She said the diagram helped her to organize her ideas and to put things in order like the sequence of events. She also said it was getting easier to do the title using the “and” words. Marian said, “The title tells you what’s going to happen in the diagram.” Marian said chunking sentences is also helping her in reading. She said that doing the diagram was making it easier for her to write. When I asked her why, she said, “Because when you finish taking all your main ideas out, you can make it
shorter and you can do some drawings to represent the rest of the words.” She said the Roundhouse diagram “forces you to think, to find the main ideas. You have to think and find the main ideas, the important parts.” She said most of her classes did not ask her to think on her own. I asked Marian how her choice of pictures helped her learn. She replied, “Because it shows you, like the sun evaporates water, you can show what is water, like you can have an ocean or a tree and the sun shows it evaporates water.” I asked Marian if the diagrams helped her with her tests. She said, “If you study the diagram, it’s like you’re studying the whole lesson, but only in a few words.” She said sometimes it was hard breaking down something into its parts. She said the worksheet helped her to plan out the diagram. I asked Marian if she could remember her diagrams. She said she could close her eyes and remember certain parts of it. There is evidence that metalearning took place on Marian’s test (Novak & Gowin, 1984). She numbered her answers one through seven as she envisioned her Roundhouse diagram (see Appendix EE). Marian was able to look at her diagrams on her different cycles and explain each one to me very easily. The words just flowed freely and clearly from her. She knew her work and she was very confident in what she did.

Interview with Elizabeth

Elizabeth told me that it is difficult for her to put the main ideas together. She said the chunking was becoming easier. She said that meant putting that into her own words. I found out by going over the water cycle with Elizabeth that she did not know how to tell me what evaporation was, although she did have it on her diagram. I gave her several examples such as rain on the sidewalk on a hot summer day and steam evaporating from a pot of boiling water. She finally understood that the water
went from a liquid into a gas and went into the air. Elizabeth understood about the five forms of precipitation with some prompting. I asked Elizabeth what the most difficult part of the diagram was for her. She told me drawing. I think she drew very well. Elizabeth's real problem was being able to express herself because sometimes she did not understand the concepts. She had a difficult time relating a picture to a concept she was unable to understand. Elizabeth also had a difficult time with sequence of events. I asked her what she was learning by doing the Roundhouse diagram. She replied, "To help make the picture that matches and what they are saying and to put my work in an order in which to learn them better." I asked her what she meant by matching a picture. She said, "So like if you have a question on a test, if they don't have a picture, I can remember it in my head to put down, to know that's the answer." She said it was difficult for her to come up with seven sentences and draw pictures from them. Elizabeth explained her diagrams of the cycles to me fairly well. She had language problems but she was definitely learning the science content in these lessons. She said, "The pictures and how it's helping me with my grade, because my grades is improving. I'm not using someone else's brain, it's my brain." A month ago, Elizabeth would never have been able to answer my questions. She knew she was doing better and she was not fearful about expressing herself. She had come a long way in a short time.

**Interview with Betty**

Betty told me that the Roundhouse diagramming method was helping her in science. She said chunking and thinking of the title were the hardest parts. She said, "I'm starting to get the hang of it." Betty perfectly described and explained the water cycle to me step by step. I asked her if pictures helped her to remember. She said,
“Yes, Ma’am, because it’s like a symbol of whatever you’re talking about.” She said chunking was the most difficult part for her. She said, “It’s getting easier, but it’s like you gotta think even more about how you’re going to break it down, or the seven ones you have to break down.” Betty was not very interested in the beginning with this method. Now that her grades had been improving, she was more confident and she was definitely more into doing the process. She was always working hard and on task now that she had taken interest in her work.

**Interview with Collin**

Collin told me the Roundhouse diagram was helping him. He said, “You’re using icons instead of writing. And if you think it’s good, then you’ll learn it.” I asked him why the icons helped him. He said, “It’s coming from my head. I’m thinking and not someone else.” He said the Roundhouse diagram is “your creation.” He said the most difficult part for him was chunking. Collin explained his diagrams on the cycles very well. He said the diagram was helping him. I asked, “How?” He said, “I know it is helping. It’s like breaking down a test into a simple form. Collin was very intelligent. He had done well with the diagram since the beginning. He was capable of better work. He sometimes made careless mistakes in spelling. I thought he linked his pictures to his concepts more easily than most of the students. His grades had improved greatly.

**Interview with Carla**

Carla loves the Roundhouse diagramming method and thinks it is fun. She said the icons really helped her. I asked her how. She said, “They help me to remember better, and it’s easier than writing.” She explained her diagrams of the cycles to me perfectly. She said chunking was the most difficult part for her. She said the diagram...
helped her to make better grades and it was easier than taking notes. She said the diagramming process was getting easier for her. I asked her how this method was helping her. She said, “This is the best benefit—I can see my thoughts.” Carla caught right on to this method. She was an average student in science but strong in language arts. This process had increased her grades greatly. She loved writing so it really appealed to her.

**Interview with Willy**

When I asked Willy about this diagram he said, “I think it will help me get to know my lessons more, and probably draw good pictures, and how to break concepts down, how to figure out a way to help me learn.” He said the Roundhouse diagram helped him to understand the cycles. He explained them to me very well. Willy said drawing pictures helped him. Imagery enhances recall because ideas are encoded verbally and visually (Paivio, 1986). He said that chunking was getting easier for him. When asked how the diagram helped him, he said, “I think it helped me with mysterious studying and, it helped me to make better grades on my test.” He said he liked working in groups and “the diagram helps me to break down stuff.” Willy liked to ask questions. He asked questions often and most of the time he was sincere with his curiosity. This method had definitely stimulated his curiosity. His grades were improving. He seemed to enjoy the Roundhouse diagram.
A wave is a way of carrying energy from one place to another. Transverse waves move matter up and down or side to side as the wave passes through. Transverse waves have oscillating, repetitive motion in which the medium moves at right angles to the wave direction. Light is one example of a special kind of transverse wave—an electromagnetic wave. Light travels at 300,000,000 meters per second through empty space. Wave characteristics in this lesson include the wavelength, the crest, the trough, and the amplitude. The high point of the wave is called the crest. The low point of the wave is called the trough. The wavelength is the length from one crest to the next. The amplitude is the distance from the crest to the trough of the wave. The wave’s amplitude tells you how much energy the wave carries.

The teacher started the lesson by asking the students for prior knowledge about light. She drew a web diagram on the board and several lines stemming out from it. She asked, “What do you already know about light?” Hands were raised quickly. Several answers were revealed such as, light reflects, provides heat, and has colors. The answers continued to flow—light helps one to see and it carries energy. The discussion progressed to the differences between transverse waves and compressional waves. She gave the students a handout with pictures and explanations of these waves. It is important that the teacher help to develop visual thinking abilities (Blystone & Dettling,
1990). The teacher asked for a volunteer and the two of them simulated an example of how waves carry energy using a toy slinky. They proceeded to describe different types of waves and define the wave characteristics such as crest, trough, amplitude, and wavelength. The students now had their main ideas for constructing the Roundhouse diagrams. The students worked individually the entire lesson.

Many of the students were still only using the "of" word in the title. The students were not integrating their thoughts on their own yet. The teacher encouraged them to break down their concepts from general to specific but they had not yet mastered this ability. She would have to force the issue soon if the students did not begin doing so on their own. Their pictures had gotten much more detailed and associations to the concepts were much more direct. Their wording seemed to have become more concise as their ability to chunk had advanced. The relationships within the diagram had gotten more proficient with practice.

**Roundhouse Diagram No. 6 Construction**

**The Case Study Group**

**Close-up Focus on Marian**

Marian’s goals were stated clearly. Her title was well integrated. She wrote, “Description of Transverse Waves.” She added, “wavelength and amplitude” and “crest and trough.” She was able to clearly cover the concepts stated in the diagram by using that complete title. The diagram included all the necessary key concepts covered in the material. The concepts were all stated accurately. There was an icon for each segment representing that concept. The icons were directly related to her statements. Marian’s diagram was simple, to the point, and thorough. Marian’s worksheet was well planned.
Her ability to chunk effectively continued to improve. Her final paragraph indicated she understood the lesson (see Appendix FF).

**Close-up Focus on Elizabeth**

Elizabeth’s goals were clearly stated. She wrote, “The concepts of waves.” The title stated, “Description of Waves (Light).” She added “transverse and compressional,” but she did not use the other “and” word. Elizabeth’s title clearly covered the concepts stated in the diagram. The diagram included the key concepts but the concepts were not accurately stated. She did not place an icon in each section which clearly represented the concepts. Elizabeth continually repeated the same pictures through the diagram. She stated it was difficult for her to understand. Light waves represent an abstract concept that students cannot visualize. It was difficult for Elizabeth to grasp it in its entirety.

Elizabeth’s worksheet is well planned. She still continued to write grammatically incorrect although she has shown improvement. Elizabeth had problems chunking her sentences. At times she left out words which changed the meaning. Her final paragraph indicated she did understand the definitions in this lesson but not all of the concepts related to it.

**Close-up Focus on Betty**

Betty stated her goals clearly. She stated her title awkwardly. She wrote, “Lights of transverse waves.” She added the words, “keys and concepts” which was not related to the subject matter. Betty was trying to integrate her ideas but she was still confused about associating the whole picture to its parts. She tended to get off on other tangents which were not important to the data in the diagram. Her title did not cover the
concepts in the diagram. The concepts were not all accurately stated. The icons in each segment did not represent that concepts. The diagram was unclear in its meaning.

Betty’s worksheet was well planned but she used definitions without knowing their meanings. If a student just writes a word without meaning it does not fit in the context correctly. She also lost meaning when she was chunking her sentences because she left out important words. Betty needed to read her material well before she tries to diagram the parts. Her final paragraph was also inconsistent. I did not think she understood the content in this lesson.

Close-up Focus on Collin

Collin stated his goals clearly. He wrote, “I am trying to learn the light structure of a transverse wave.” His title stated, “Discription of Transverse Waves.” He still has spelling errors. He added “light and structer.” He did not use the other “and” word. His title clearly covered the concepts in the diagram. Collin included the necessary key concepts covered in the material. His concepts were accurately stated. Collin’s icons were well related to his concepts. The diagram was aesthetically pleasing. Collin’s worksheet was well planned. His final paragraph illustrated understanding of this lesson.

Close-up Focus on Carla

Carla’s goals are simply and accurately stated. She wrote, “To explore light.” Her title stated, “Repetitive Motion of Transverse Waves.” She added, “crest and trough” and “amplitude and light.” This title was the best written title in the entire class. She also drew waves in her title area. The title clearly covered all of the concepts stated in the diagram. She explicitly covered all of the concepts and related them well.
to her icons. The entire diagram represented hard work and careful thought. Carla’s worksheet was well planned. Her final paragraph indicated she understood the information within this lesson.

**Close-up Focus on Willy**

Willy’s goals were well stated. He wrote, “To explore transverse waves.” His title stated, “Lights of Transverse Waves.” Willy tried to integrate his thoughts. He was a bit confused in his thinking. The diagram included the necessary key concepts. His concepts were accurately stated. Willy did not draw an icon for each concept. Willy’s sentences were long and he did not seem to be trying to chunk his sentences. Willy’s worksheet was not complete, nor is his diagram. His final paragraph did indicate that he understood the material.

**Roundhouse Diagram No. 7**

**The Electromagnetic Spectrum**

**Description of Science Content**

Light is one example of a special kind of transverse wave—an electromagnetic wave. An electromagnetic wave is energy that travels through space at a speed of 300,000,000 meters per second. Electromagnetic waves are arranged by their wavelengths and frequencies into the electromagnetic spectrum. Gamma rays are at the far left of the spectrum and are the shortest electromagnetic waves. They have the most energy. An x-ray has a wavelength much shorter than visible light. Ultraviolet rays have an invisible wavelength and have more energy than light waves. Many are harmful to organisms. Many of these high-energy waves can also help kill cancer cells and are used for other medicinal purposes. Visible light is the entire color spectrum of
light which we see. Examples of visible light are the light that comes from lamps or rainbows. Infrared waves and radio waves are two kinds of waves to the right of light in the electromagnetic spectrum. Hospitals use infrared rays to treat some skin problems or sore muscles. Infrared lamps are used to keep food warm in restaurants. Microwaves are short radio waves. Many homes use microwaves to cook or heat food. Radio waves are the longest electromagnetic waves. They have the least energy.

**Roundhouse Diagram No. 7 Construction**

**The Whole Class**

The students read the material orally in the textbook. The teacher asked the students to trace the arrangement of the electromagnetic spectrum with their fingers. The students were attentive, listening, and had their fingers in the book. The class discussed these ideas and wrote sentence fragments on the board. She then passed out a sheet with seven types of waves, seven definitions, and seven examples of those definitions. The students were instructed to pair up with their neighbor, to cut up these definitions, shuffle them, and put them back together. The students became very involved and worked well together for a short time. Then the teacher asked them to go back to individual seating arrangements. She instructed them to begin their Roundhouse diagram worksheets using their definitions and text material. The students were told that their diagrams would be graded.

Some of the students were still unable to integrate their titles. Other students were becoming quite proficient at doing the diagram. They seemed to be able to write their goals easily. Their pictures had gotten very detailed. They had improved with their ability to chunk effectively.
Roundhouse Diagram No. 7

The Case Study Group

Close-up Focus on Marian

Marian's goals were stated clearly. Her title stated, "Arrangement of Electromagnetic Waves." She added "light waves and radio waves" and "gamma rays and x-rays." She wrote G-X-U-L-I-R-M across the center to symbolize each kind of wave she learned about. The title clearly covered the concepts stated in the diagram. The diagram included all the necessary key concepts covered in the material. The concepts were stated accurately. There was an icon to represent each segment which represented that concept. The sequence of events was correctly stated. Space was used well in the diagram and it was very aesthetically pleasing. Marian created an excellent diagram. Her worksheet was well planned. Her final paragraph indicated she totally understood this material in the lesson.

Close-up Focus on Elizabeth

Elizabeth's goals were clearly stated. She wrote, "To learn about the electromagnetic spectrum." Her title stated, "Spectrum of Electromagnetic Waves." She added "waves and energy" and "waves and spectrum." Her title clearly covered the concepts stated in the diagram. The diagram included the necessary key concepts covered in the material. Her concepts were covered accurately. There was an icon to represent each concept. The sequence of events was correct. The diagram was well balanced and aesthetically pleasing. Her punctuation needed improvement. Elizabeth's final paragraph and worksheet indicated she understood the science content in this lesson (See Appendix GG).
Close-up Focus on Betty

Betty stated her goals clearly. She wrote, “To learn about the electromagnetic spectrum.” Her title stated, “Spectrum of Electromagnet.” She never finished the statement. The title was incomplete. She added “rays and energy” and “wave and spectrum.” The diagram included the necessary key concepts. The concepts were stated accurately. There was not an icon to represent each concept. The sequence of events was in order. I do not believe Betty put her best work into this diagram.

The first section stated, “Electromagnetic wave travels a 300,000,000 pre. second.” She left out “meter” and “pre” should have been “per.” She drew a transverse wave. Next she wrote, “Gamma rays has the most energy.” She uses improper grammar. Betty’s worksheet was complete but her chunking was not efficient. Her final paragraph also used improper grammar and misspelled words. Betty was capable of better work.

Close-up Focus on Collin

Collin stated his goals clearly. He wrote, “I’m trying to learn how the spectrum of magnetic waves operates.” His title stated, “Spectrum of Electromagnetic Waves.” He added, “waves and energy” and “spectrum and arrangement.” His thoughts were well integrated. His title clearly covered the concepts stated in the diagram. He included the necessary key concepts covered in the material. His concepts were stated accurately. There was an icon in each segment which was representative of that concept. The sequence of events was accurate. The diagram was well designed and aesthetically pleasing. Collin’s Roundhouse diagram was excellent, simple, and well planned. His final paragraph indicated he understood the material in this lesson.

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**Close-up Focus on Carla**

Carla’s goals were clearly stated. She wrote, “To learn about the electromagnetic spectrum.” Her title stated, “Spectrums of Electromagnetic Waves.” She added, “energy and rays” and “spectrums and waves.” Carla had indicated that she was able to integrate her title well and cover all of the concepts stated in the diagram. Her concepts are accurately stated and there was an icon in each segment representative of that concept. The sequence of events was in order. The design was well planned and the diagram was aesthetically pleasing. Her diagrams were simple, direct, and excellent. Her final paragraph indicated she had learned this lesson well.

**Close-up Focus on Willy**

Willy’s goals were stated clearly. He wrote, “To learn about the electromagnetic waves.” His title stated, “The Spectrum of the Electromagnetic Waves.” He added, “wavelengths and frequencies” and “energy and waves.” His integration of thought about the title is well done and he covered all the concepts stated in the diagram. He included the necessary key concepts covered in the material. His concepts were accurately stated. There was an icon in each segment but not always representative of that concept. The sequence of events was accurate. The design was not well balanced because Willy used too many words in some of his segments. He was not reducing his sentences and putting them into his own words. One side of the diagram looked crowded and the other side looked empty. Willy’s work was well planned and his final paragraph indicated that he understood the content of this lesson.
Reflections from the Researcher

I like the way the teacher started the lesson. Research shows that finding out about a student's prior knowledge helps reduce the number of misconceptions. If a teacher can find out what a student already knows before trying to make new associations with information, the student will have a greater chance of straightening out any concepts he or she may not understand. As a result the new connections will be more meaningful and the student will make the new connection with less difficulty (Mintzes & Wandersee, 1998).

The teacher used visual props to help the students understand the very abstract concept of transverse light waves. She was very good about making an abstract concept concrete by simulating different concepts using hands-on materials, such as the toy slinky. A teacher can bring the importance of visual literacy to a productive position in the classroom (Blystone & Dettling, 1990). The teacher always reviewed the lesson from the day before to help establish strong connections to new relationships of the concepts to be learned. She communicated well with the class. She made many positive comments in her feedback to the students. She engaged the students in hands-on activities and allowed them time to explore answers for themselves.

The Roundhouse diagram is a wonderful tool to add substance to a hands-on lesson. This learning method is a way for the students to organize their thoughts. It is excellent for sequencing learning events. The students were very involved in the thought process while working on their diagrams. There were never any behavior problems. The students were too busy to be distracted. They seemed to enjoy the process and they had not lost interest in this new method of learning.
The students' major problems seemed to focus around integrating their titles. They still had trouble going from general to specific with their thoughts. The students were improving with sequence of events. Some students still have problems putting sentences into their own words, but they have shown much improvement. The relationships within the diagrams appear to be more connected and meaningful. The students' mastery of technique seemed to vary according to subject matter. The more difficult and abstract the concept, the harder it was for them to integrate their thoughts and link pictures to the concepts.

**Reflections from the Teacher**

These comments were taken from the teacher's journal:

I find that the students are questioning more in science class. They are asking intelligent questions and really seem to be more inquisitive. Another thing that I see with the Roundhouse diagram is that before a test, the teacher really gets to see which children understand the lesson and which do not. The diagram also allows the teacher to see exactly what it is that the student cannot understand. Therefore these misconceptions can be clarified before the students take a test. That is a great benefit. The old traditional way of teaching did not give me insight into what the child did not understand. I think that this is a wonderful improvement in my science classroom. I am getting more and more optimistic as I see these students become more proficient with this learning task.

I feel that the process we are going through really ensures that the child learns the information. Johanna made a C on her last test and she usually makes F's. Brandon was beaming with pride when he saw a 96/A on his paper. When I told their homeroom teacher that I gave them an essay test, she asked how many failed. When I told her none, she was totally surprised. I am a very happy teacher right now. I told my principal about the test grades. He was impressed. I told him I was definitely going to use the Roundhouse diagram next year.

**Reflections from the Outside Observer**

These comments were taken from the outside observer's field notes:

The students participated well in class. They read orally their lesson on electromagnetic waves. The teacher cited specific definitions and examples of
The students participated in an activity to get them ready to work on their diagrams. My attention was directed mainly on the case study group. These were my observations.

Willy asks questions about the sun’s rays. Then he spoke about his pet iguana and how they used a heat lamp to keep him warm. Students try to relate the subject content to their own life and reality. I removed a pair of scissors from Willy because he was distracting other students. Willy assisted his partner with the main ideas in the lesson.

Carla followed the reading period well. The teacher floated nearby and gave Carla some positive reinforcement. Carla shared with me how much this method has helped her to improve. She is quiet, yet she participated well in her group discussion. She seems to be very relaxed with finding the main ideas. Many other students struggle with this part.

Collin appeared to follow the lesson well while others read. He is working at an above-average speed. He listened carefully to directions and carefully planned his diagram. He had some difficulty in matching his definitions but he succeeded. He corrected his mistakes as answers were checked orally.

Betty was working hard today. The teacher assisted her with the activity. She did well in matching her definitions. Her confidence level has picked up as well as her interest in class. The teacher encouraged her by giving her positive recommendations with her work. She leads her group and seemed to have understood the lesson.

Marian answered many of the teacher’s questions concerning length of rays on the spectrum. She is very organized and careful with her planning for the diagram. She understood the material and had no trouble matching her definitions.

Elizabeth was uncertain how to match her waves to the definitions. The teacher assisted her by placing the waves in sequential order first according to where they were in the spectrum. It is difficult for Elizabeth to get organized but she is trying very hard. She participates much more in class now than she did in the beginning.

**Reflections from the Students**

The student evaluation checklist on Roundhouse diagram Nos. 6 and 7 indicates a high number of students still enjoy the Roundhouse diagramming method. They are also enjoying working independently, which is encouraging to see (see Table 3).
Table 3. Student Evaluation Checklist: The Whole Class

<table>
<thead>
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<th>Characteristics</th>
<th>Yes</th>
<th>No</th>
<th>Sometimes</th>
<th>Most of the Time</th>
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<td>Enjoyment</td>
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<td></td>
<td>1</td>
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<tr>
<td>Organization</td>
<td>14</td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Ability to Chunk</td>
<td>10</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Uses Time Wisely</td>
<td>13</td>
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</tr>
<tr>
<td>Works well independently</td>
<td>14</td>
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<td>1</td>
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</tr>
<tr>
<td>Works well with others</td>
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</tr>
<tr>
<td>(one student did not answer)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uses own words</td>
<td>7</td>
<td></td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Ability to link pictures</td>
<td>13</td>
<td></td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Creativeness</td>
<td>13</td>
<td></td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Improves understanding</td>
<td>15</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Two questions were asked at the end of each student evaluation checklist:

1. The most important things I have learned constructing the Roundhouse diagrams were: the subject matter (7), to use the definitions in the diagram, grades came up (5), helps me to think (4), helps me to use my own words (3), to organize, to chunk (2).

2. Did you encounter any problems while constructing your Roundhouse diagrams? chunking (2), to find main ideas, to draw pictures (2), no problems (10).

A table of the students' meaningful learning concepts has been provided based on Roundhouse diagrams Nos. 6 and 7 (see Appendix HH).
Reflection of Light

Description of Science Content

Reflection is defined as a bouncing of a wave off of a surface. When light waves are reflected off very smooth surfaces, images form. Smooth surfaces, such as mirrors and calm lakes form better images than rough surfaces. Light waves bounce off a surface at the same angle as they hit that surface. On curved surfaces, because of the curvature, waves are reflected in different directions, causing the reflected image to be bigger, smaller, thinner, or wider than normal.

A concave mirror is a reflecting surface that curves like the inside of a spoon. Examples of devices that contain convex reflectors (mirrors) are searchlights, headlights, flashlights, and telescopes. A convex mirror is a reflecting surface that curves like the outside of a spoon. The light image is reversed from left to right. Examples of convex mirrors are side-view mirrors and department store mirrors.

Roundhouse Diagram No. 8 Construction

The Whole Class

Reflection of Light

The teacher continued to make outlines of the lesson for the students so that they would be able to correctly extract the main ideas. The students must still be able to decide what information was the most important to put on the diagram. The students must also put these ideas into their own words. They still needed to be monitored and guided during class. The teacher explained to each student the importance of constructing these diagrams correctly. These diagrams were now being graded.
The teacher began this lesson by asking questions in order for the students to get motivated. The teacher asked, "How does light behave?" They proceeded to discuss reflection and refraction. The teacher told them they would be doing two separate diagrams—one for reflection and one for refraction. She related the subject matter to the students. She said, "When you woke up this morning, you looked in the mirror and saw a reflection. Let's look at the definition for reflection. It is the bouncing of a wave off of a surface." The students thoroughly discussed the definitions in their textbooks—"refraction," "convex lens," and "concave lens." The teacher passed out activity sheets.

The teacher provided the students with some exploratory exercises. She then instructed the groups to go to the activity stations. There were hands-on activities distributed throughout the room. She reminded the students that these observations would lead to their main ideas to put on their worksheets.

The teacher asked the students to sit individually. Some of them looked disappointed. She told them that she was going to give them primarily essay-type tests from now on and she handed a list of concepts that they needed to be familiar with for the test. She asked them to be sure they included the concepts on this list in their diagrams. The students began their work. The teacher passed out the Roundhouse diagram worksheet.

As I walked around the room I noticed that most of the students were referring to their textbooks for information as well as pictures. There were some very good illustrations that went with this lesson in the book. The students were involved in thought while they were doing their worksheet. The pictures they were drawing were so well done. I noticed that many students were able to fill out the titles well but not
completely. Some were still unable to integrate all of the known concepts. They had no problems stating their goals. I noticed the students were much more unique with their sentence structure as well as their pictures working individually.

**Roundhouse Diagram No. 8 Construction**

**The Case Study Group**

**Close-up Focus on Marian**

Marian stated her goals clearly. Her title was well integrated. Her title covered the concepts stated in this diagram. The diagram included the necessary key concepts covered in the material. The concepts were stated accurately. There was an icon in each segment representative of each concept. The space was used well in the diagram. The design was aesthetically pleasing. Marian related her concepts well to the pictures she drew. Her first section defined reflection accurately. A sequence of events was not needed for this lesson. Her ideas were simple and direct. Her sentences were concise and full of thought. Her worksheet was well planned and full of multiple concepts to choose from for her diagram. Instead of writing a paragraph, the students were given questions to answer for homework. Her evaluation sheet indicated she was finding the main ideas easier and that the construction of her Roundhouse diagram was getting better.

**Close-up Focus on Elizabeth**

Elizabeth’s goals were stated clearly. She wrote, “Trying to learn about the behavior of light.” Her title stated, “Reflection of Light.” She added “concave and convex.” She took out the other “and” word and did not use it. Her title covered the concepts in the diagram. The diagram included the necessary key concepts covered in
this lesson and these concepts were stated accurately. There was an icon in each
segment which was representative of each concept. The diagram was well balanced and
aesthetically pleasing. Elizabeth’s worksheet was full and complete. Her pictures were
very well related to her concepts. Her use of language was getting much better.
Elizabeth was really trying harder to construct these diagrams properly. Her grades had
improved and this motivated her to do better. Her evaluation sheet indicated that she
preferred this method to notetaking. She said she was still having problems finding the
main ideas and linking icons to the concepts. This fact is probably due to the lack of
prior knowledge in science classes (Mintzes & Wandersee, 1998).

Close-up Focus on Betty

Betty stated her goals clearly. She wrote, “To explore the behavior of light.”
Her title stated, “Behavior of Light.” She added “concave and convex” and “reflection
and light.” Her title clearly covered the concepts in the diagram. The diagram included
the necessary key concepts covered in this lesson. The concepts were not all stated
accurately but there was improvement over her previous work. There was an icon in
each segment which was representative of that concept. The diagram was well balanced
and aesthetically pleasing.

Betty’s worksheet was well planned. She was trying much harder to construct
her diagrams well. She had improved a great deal. On her evaluation sheet, Betty wrote
that she was learning to think more and to find answers for herself. She said she was
still having problems chunking and thinking of good pictures. This diagram conveyed
the fact that Betty was much more serious about her work.
Close-up Focus on Collin

Collin’s goals were clearly stated. His integration of concepts was well stated in his title. There was an icon in most segments which was representative of that concept. There was one icon which did not match the concept. The space was used well in the diagram and the design was aesthetically pleasing.

Collin’s worksheet was well planned and complete. Collin’s evaluation sheet said the Roundhouse diagram made him think. He said he still had problems thinking out pictures. Collin’s diagrams are usually very thoughtful and reflect his potential.

Close-up Focus on Carla

Carla’s goals were stated clearly. She wrote, “To explore about reflection.” Her title stated, “Behavior of Light.” She added “concave and convex” but she did not use the other “and” word. Her title covered the concepts stated in the diagram. The concepts were stated accurately. There was an icon in each segment which represented that concept. The space was used well and the diagram was aesthetically pleasing.

Carla’s worksheet was well planned. Her diagrams were clear, direct, and to the point. Her evaluation sheet said that the diagrams helped her learn the subject matter. She indicated she had no problems. Her diagram exemplified that her work was full of thought. The associations between concepts and pictures were direct. Her work was exceptionally neat (see Appendix II).

Close-up Focus on Willy

Willy’s goals were clear but too general. He stated, “To explore the behavior of light.” This diagram was specifically about reflection. He wrote, “Behavior of Light.” He added “concave and convex” and “light waves and reflection.” The integration of
his wording was well stated in the title. It clearly covered the concepts stated in the diagram. The diagram included the necessary key concepts covered in the lesson. Most of his concepts were accurately stated. Willy got confused in a couple of segments. There was an icon in each segment which was representative of that concept. The space was not used well in the diagram. One side of the diagram was full of statements which had not been reduced or chunked.

Willy's worksheet was well done. He failed to chunk all of his sentences. He needed more practice with this. His evaluation sheet stated he was having trouble chunking information. Willy's work was usually better than this. He did indicate that he understood the material in the lesson.

Roundhouse Diagram No. 9

Refraction of Light

Description of Science Content

Refraction is the bending of a light wave as it moves from one material to another. Light travels more slowly in water than it does in air. When light waves hit a surface at an angle they change speed and they bend. Light waves are also refracted when they pass from air into clear plastic or glass. A lens is a curved piece of glass, plastic, or other clear material. Convex and concave lenses are different. Convex lenses are thicker in the middle. Concave lenses are thicker at the edges. Each of your eyes has a convex lens. Magnifying lenses, camera, microscopes, and telescopes have convex lenses.
The Whole Class

Refraction of Light

The teacher began the lesson by showing the students a pencil in a glass of water. She explained to them that the bottom of the pencil looked wider because the speed of light slows down from air to water. The class was quiet and paid attention. Jonathan said, “Stand the pencil straight up instead of slanted and maybe it won’t look bent.” The teacher held the pencil straight up. The bottom of the pencil still appeared wider although not as much as when it was leaning against the glass.

The teacher handed the students another outline from the chapter to help guide them with their main ideas. The students read their textbooks aloud. The teacher allowed them to brainstorm in their groups. They were quiet, concentrating, and appeared to enjoy what they were doing.

Most of the students simply wrote, “Refraction of Light” for their title. Very few students were able to integrate other ideas into the central theme. Very few students were using the clipart books. Most of the class was using the pictures in their textbook because they related directly to the information being diagrammed. The students appeared to be able to chunk their sentences more concisely. Many of the diagrams had more details in the pictures.
Roundhouse Diagram No. 2 Construction

The Case Study Group

Close-up Focus on Marian

Marian's goals were stated simply and clearly. The title covered the concepts within the diagram and was well integrated. The concepts were accurately stated. There was an icon to represent each concept. The diagram was direct, concise, and to the point. The diagram was aesthetically pleasing. Marian's worksheet was well planned. Her sentences were well chunked. Instead of a final paragraph, she had answered some questions on refraction. Marian's diagram and questions indicated that she understood the material in this lesson (see Appendix JJ).

Close-up Focus on Elizabeth

Elizabeth's goals were clearly stated. She wrote, "To study the refraction of light." Elizabeth's title stated, "Refraction of Light." She added "convex and concave." Her title covered the concepts in the diagram. The diagram included the necessary key concepts. The concepts were accurately stated. There was an icon for each concept. The diagram was well designed. The pictures were full of detail. Elizabeth's pictures were really beginning to be her own creation. Elizabeth's worksheet was well planned. She did a wonderful job. She had improved in every area, especially in her writing and grammar. Her questions on refraction indicated she understood the material.

Close-up Focus on Betty

Betty stated her goals clearly. She wrote, "To explore light and light behavior." Her title stated, "Refraction of Light." She added "light and waves" and "bending and moving." Her thoughts were beginning to get more integrated. Her title clearly covered
the concepts in the diagram. The diagram included the necessary key concepts covered in the material. The concepts were accurately stated. There was an icon in each segment to represent that concept. She made good use of the space in the diagram. The diagram was aesthetically pleasing. Betty had improved tremendously. Her pictures were detailed and meaningful. Betty’s worksheet was well planned and very thorough. She had really improved. Her questions on refraction indicated she understood the material.

Close-up Focus on Collin

Collin stated his goals a bit awkwardly but I understood what he was trying to say. He wrote, “I am trying to express the refracting of light, bending and speed, concave and convex.” His punctuation and spelling were erroneous and his wording sounded confusing throughout the diagram. Sometimes it was difficult for Collin to think in simple terms. He tended to overcomplicate the subject matter. His title was well integrated. He wrote, “The Refraction of Light.” He added “speed and bending” and “convex and concave.” His title clearly covered the concepts stated in the diagram. He drew a picture of a meter and a curved lens in his titled area. The diagram included the necessary key concepts covered in this material. The concepts were accurately stated. There was an icon which represented each concept. The diagram was very easy to understand and laid out nicely according to space. The pictures were well done and the design was aesthetically pleasing. Collin chunked his sentences very effectively. Collin’s diagrams have gotten more detailed and more complete. Collin’s worksheet illustrated good planning and thoughtful intent. His questions answered on refraction indicated that he understood the material in this lesson.
**Close-up Focus on Carla**

Carla's goals were stated simply and directly. She wrote, "To explore about refraction." Her title was well integrated. She wrote "Refraction of Light." She added, "lens and angles" and "convex and concave lenses." Her title clearly stated and covered all of the concepts in the diagram. She included the necessary key concepts covered in this lesson. The concepts were accurately stated. There was an icon which represented each concept. The diagram was extremely neat and laid out beautifully. Carla's drawings were correctly related to each statement. Her design was aesthetically pleasing. The Roundhouse diagramming method had stimulated her creativity as well as her artistic talent. She had expressed to me that she truly enjoyed doing this kind of work and it showed. This diagram is excellent. Carla's ability to chunk her sentences was amazing. She was always very concise with her wording. Carla's worksheet was well planned. Her answers to questions indicated that she understood the material in this lesson.

**Close-up Focus on Willy**

Willy's goals were stated clearly. He wrote, "To explore about refraction." His title was well integrated. He wrote, "The refraction of light." He added, "distorted and smooth" and "bending and rough." Willy was showing more detail and he was trying much harder to be thorough in his work on the diagrams. His title clearly covered the concepts stated in his diagram. The concepts were accurately stated. There was an icon in each segment which represented that concept. Willy's diagram still indicated he had problems chunking. His sentences were long although they were well written. His diagram was aesthetically pleasing and his pictures were interesting although they may
not indicate accuracy. I question whether he understood that refracted light waves bounce back in different directions. He showed a normal angle in his picture. He did not chunk some of his sentences and they took up most of the space in the sections. Willy’s worksheet was well planned and thoughtful. He was having problems reducing his sentences. His answers to his questions indicated that he understood the material.

**Reflections from the Researcher**

The students still needed guidance with extracting the main ideas from the chapter. The teacher had continued to narrow these choices down for them without giving them the answers. She usually asked them questions which led to the answers but this prompting was necessary with this class. This skill was so important in all of the students’ subjects, especially reading. The training they were getting on the Roundhouse diagram incorporated so many language skills. The students were writing in class more than they ever had.

The style of their assessment had also changed to a more challenging task. The teacher used to give them one-answer, fill-in-the-blank definitions accompanied by a word bank. A student could study enough to remember that an answer began with a particular letter and choose the correct word by the process of elimination. Now they were being required to explain their answers in complete thoughts. Before they were getting true and false questions. Now they had to answer in such a way that they had to explain why something was true or false.

The students were working at a much faster pace as well as performing better. They were not as dependent on the teacher. They were owning their material more and remembering more in the process. The students’ communication skills and social skills
had gotten better since they were doing more of both. The teacher told me some
students which had never participated before in this class were now participating and
seemed interested. The Roundhouse diagramming method had motivated them to do
more work without their even realizing it. It had also stimulated their thinking and had
made them very inquisitive (Costa, 1991).

The students were not afraid to take risks or to ask questions. The teacher told
me she could not believe all of the questions they were asking. She said many of the
questions were higher-order questions. The students were becoming metacognitive
learners (Bonds et al., 1992). The children asked questions in class such as: “How do
scientists measure the speed of light in water?” “How fast does light travel in water?”
“What instruments do scientists use to measure the speed of light?” The teacher had
been forced to obtain outside reference materials in order to find these answers. She
said this had made her a better teacher and she was also learning a great deal.

During my one-on-one interview sessions, I noticed the students who spent more
time thinking about the rationale behind their pictures were the ones who remembered
the most. The students who did not just draw the first thing that came to mind, but who
really thought about the relationship were the ones who were recalling these
associations (Searleman & Herrmann, 1994). I also noticed the students were easier to
talk to. They were not so tense. They were more relaxed and more fluent with their
answers.

All of the students seemed to be concentrating better. I watched the videotapes
and looked at the pictures I took. All the students seemed to be participating. They
worked for the full 45 minutes that I was in the classroom. The teacher said that
usually they had a very short attention span. So this process was holding their attention (Hohn, 1995).

The teacher was amazed at the fact that this method allowed her to see what the student was thinking. She said traditionally if a child was asked to read and answer questions, the teacher had no means to visualize the misconceptions that students may have had (Novak & Gowin, 1984). She also mentioned that behavior had improved because the students were so busy with all of the written work they have now. She also stated that the students were asking more questions when they did not understand something.

Reflections from the Teacher

These comments were taken from the teacher's field notes:

I like the Roundhouse diagram because it allows the teacher to see what the students understand and what they do not understand. It seems that before the Roundhouse diagram, I really still was not sure how many students had totally mastered the concepts. Now I am being forced to see this because of the process you go through in doing the diagram. Before, if the students answered questions or did a worksheet after the lesson, we checked it as a class. If a child did not understand, I did not know it because they simply corrected the answer in their notebook and I did not find out about the misconception until I graded their tests. Now I have to review everyone's worksheet before they go on so I see who is not understanding and I can clarify it before the test. I really love this aspect of it.

I can see the students working faster on their worksheets and diagrams. I think this is great. Their confidence level is rising higher and higher. Grades are improving. What more could a teacher want? Best of all, students tell me that they enjoy doing the diagrams.

Students are getting faster and better. Many of these students do not like to write but I love it because it is forcing them to write down their thoughts. They are having to write and revise more than one time in this process. It has greatly affected the majority of the students' science grades. I feel if the students begin this process at the beginning of the school year, they will be well trained enough to do this as homework and not only in the classroom.
Reflections from the Outside Observer

These comments were taken from the outside observer's field notes:

The students read pages in their textbook in order to understand the terms "reflection" and "refraction." Examples were given by the teacher. Hands-on activities were provided so that the students will discover meanings for themselves. After the hands-on activities the students began their Roundhouse diagram worksheets.

Willy talked to his group about the speed of light. He tried to contribute but he was not sure about answering his questions. Willy decided to copy from Carla. Willy was daydreaming and watching the other groups. Willy mentioned to his group that stores have convex mirrors so they can watch for theft. Willy indicated to me that it was difficult for him to break down concepts. He did say that he enjoyed doing the Roundhouse diagram because he could remember the pictures. He knew the difference between concave and convex images when I asked him.

Marian offered suggestions to other students in her group. She asked them if mirrors on a car were convex mirrors. No one seemed to know that answer. Marian found the main ideas eventually but she said it took time because that was difficult. She said the hardest part was putting thoughts into her own words. She said, "I like this because it summarizes the whole lesson, so I can remember it better. I helped her to reword part of her diagram. She was very receptive.

Collin was engaged in hands-on activities. He drew a diagram of the light rays passing through the comb. He was slow and hesitant because he did not think he was doing it correctly. He did a fine job. Collin recorded the results of his observations. He was serious about his schoolwork. Collin indicated that the Roundhouse diagram was easier for him than taking notes. He said that chunking was difficult. Collin worked well individually. He had excellent concentration. He reviewed what he had written and made corrections as needed. He said, "Drawing pictures is not my favorite part." His handwriting is difficult to read.

Carla was serious about trying to carry out the assignment given by the teacher. She correctly answered her questions on her worksheet. Carla was very attentive. She said that chunking was the most difficult part of the diagram for her. She preferred the Roundhouse diagram method to traditional methods.

Betty was playing with Elizabeth’s scarf. She began to work when the teacher came by her desk. She was also playing with a flashlight. Betty seemed to be diagramming well. She said chunking was the most difficult because she had to use her own words.

Elizabeth was playing with white-out. She was answering her questions correctly. Elizabeth defined refraction correctly. She said the most difficult part for her was stating the main ideas. The teacher asked her to correct her grammar in one section and she did. She was encouraged to do more proofreading.
Reflections from the Students

The student evaluation checklist on Roundhouse diagram Nos. 8 and 9 indicates positive responses from the students (see Table 4).

Table 4. Student Evaluation Checklist: Whole Class

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Yes</th>
<th>No</th>
<th>Sometimes</th>
<th>Most of the Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enjoyment</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organization</td>
<td>16</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to Chunk</td>
<td>14</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Uses Time Wisely</td>
<td>17</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Works Well Independently</td>
<td>15</td>
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</tr>
<tr>
<td>Works Well With Others</td>
<td>9</td>
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<td>Uses One’s Own Words</td>
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<td>Ability to Link Pictures</td>
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<tr>
<td>Creativeness</td>
<td>16</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Improves Understanding</td>
<td>17</td>
<td></td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Two questions were asked at the end of each student evaluation checklist:

1. The most important things I’ve learned constructing the Roundhouse diagrams were:
   how to think for myself (4), about reflection and refraction, main ideas got easier (2),
   better than taking notes (2), find answers for myself, chunking (2), helps with grades
   (2), how to paraphrase (2), how to organize.
2. Did you encounter any problems while constructing your Roundhouse diagrams? To draw pictures (3), it’s getting easier, find main ideas, how to link pictures to ideas (4), chunking (3), how to put main ideas into essay answers, understanding, no problems (9).

A table has been provided with the meaningful concepts learned by the case study group on Roundhouse diagram Nos. 8 and 9 (see Appendix KK).

Formal Interviews with Case Study Group

Interview with Marian

Marian felt the Roundhouse diagram method was very helpful. She said, “You have everything on the diagram that will be asked on the test. Like if you would think about the pictures, I would just remember some of the words and it would help me.” Marian stated that on a test she usually did best with the definitions. She was not used to essay tests. I asked her “Why do you think you were able to explain your essay questions?” “Because I remember from the diagram the seven parts. And I just went around it.” She revealed metalearning characteristics on her essay answers where she actually mentally envisioned the seven parts of her diagram (Novak & Gowin, 1984). I asked her, “What is the most important thing you do when you do a diagram?” She said, “To try to get all the important details so that you can know what to study. I asked Marian what changes had taken place as far as your concepts since we started doing this? She said, “It’s easier to get out seven important details and to get the title.

Interview with Elizabeth

Elizabeth liked the Roundhouse diagram method. She said, “My thoughts about the Roundhouse diagram are good because it is helping me because I am using my
brain. It makes me think harder.” I asked her how the diagram helped her. She said, “This method is helping me by the information is in shorter version and you can draw the pictures to help you.” I asked Elizabeth what the most difficult part of constructing the diagram was for her. She said, “Sometimes I can’t find the seven main ideas, and then the pictures to find for some of them.” I asked Elizabeth why her choice of pictures was important. She said, “Because if you’re looking in a test and if they have...well, you look at the pictures, but if you don’t have no pictures, and they have the words, well that’s how you can learn it, by looking at the words.”

**Interview with Betty**

Betty said the Roundhouse diagram helped her. I asked her how. She said, “Helping me think more and get involved more in my work. She said she paid attention more and looked around the classroom less. I asked her if the diagram helped her when she took a test. She said, “If I study. If I don’t study, I like get most of them right, but not all of them.” I asked her if her choice of pictures was important to remembering the diagram. She said, “Because like if I draw a picture and it’s like whatever the information is in that box is a symbol for that information that I could use in the box.”

**Interview with Collin**

I asked Collin to share his thoughts with me about the Roundhouse diagramming method. He said, “I feel good because it makes...it forces me to think, and it makes me find the material I need to put on the Roundhouse diagram. He said it was helping him in terms of his grades because he remembers the icons he puts down. I asked him what the most important part of the diagram was. He said, “The main ideas because that is most likely to be on a test.” I asked him, “When you take a test, what process do you go
through to remember your diagram?” He said, “First I think of the icons for the main ideas and once I get that, it’s really a breeze.” Cognitive scientists have discovered that visual imagery is the first step in the encoding process (Searleman & Herrmann, 1994). I asked Collin if he was having any problems. He said, “Really sometimes, but not it’s really that I’m not finding enough information, so I’m starting to use the definitions.” I asked him how his science concepts have changed since he started doing the Roundhouse diagram. He said, “I’m able to think of more pictures and it makes it a lot easier. I’m getting used to it.”

Interview with Carla

I asked Carla how she felt about the Roundhouse diagramming method. She said, “The Roundhouse diagram is fun and easy. It is helpful and it helps me to remember things.” I asked her how. She said, “By the pictures. It is easier to draw the pictures than taking notes.” She said she thought chunking was the most difficult part for her and it has gotten easier over time.

Interview with Willy

Willy said the Roundhouse diagram is fun and it helps him to study. I asked him how. He said, “By remembering the phrases and diagrams. By remembering. . . it’s easy to remember the pictures that I drew. You have to draw good concepts to be able to remember them.” I asked him how constructing the Roundhouse diagrams helped him the most. He said, “It helps me to study and remember what’s going to be on the test.” I asked him how this method helped him on a test. He said, “I can remember the pictures that I drew if I draw good pictures, and then I’ll be able to remember the words
that were with the pictures.” I asked him his greatest problems. He said, “To try and remember the diagram.”

Reflections from the Researcher

All of the students were improving and developing mastery of technique in constructing Roundhouse diagrams. The students’ grades were improving. Their organizational skills were getting better. The students were becoming more metacognitive in their learning skills and conceptual change was taking place. They were asking more higher-order questions. They were becoming less dependent on the teacher. They were much more confident and their self-esteem had greatly improved. Levels of concentration had increased. The students’ ability to link pictures with their concepts had gotten better. Their work was much more integrated and thorough.

The students’ writing ability had transformed. They were making less frequent mistakes with grammar, punctuation, and spelling. Their handwriting had improved. The neatness of the diagrams had increased. It was getting easier for them to complete their worksheets as well as their diagrams. They were more aware and familiar with the process, therefore they were less fearful with taking steps on their own.

The teacher was becoming much more positive. She was making a tremendous effort to recognize the students’ misconceptions and to work with them individually. She was being forced by the process to check their diagrams and to make sure they were on the right track. The teacher was very impressed with the fact that the diagram allowed her to see what the students understood and what they did not understand.

The Roundhouse diagramming method was helping the students in other subject areas. Learning tasks such as choosing the main ideas as well as paraphrasing were
incorporated heavily in this process. The students also had to sequence events, revise, and reconstruct the learning material. This reconstructive process was helping all of the students, even if they did not study outside of class (Wittrock, 1994). Most of all, this process was helping the students to think on their own and to make decisions based on their thinking.

**Roundhouse Diagram No. 10 Plus Wedge**

**How Do You See Color?**

**Description of Science Content**

Your eyes have cells called rods and cones. The rods enable you to see in black and white. The cones enable you to see in color. The cones are sensitive to red, blue, and green light. All other colors are combinations of these three. Isaac Newton discovered many years ago that white light contained a mixture of colors (Roy G. Biv--red, orange, yellow, green, blue, indigo, violet). Sunlight or artificial light such as electric lamp light is called white light. A prism is a specially shaped object that separates white light into its colors. Each color of white light has a different wavelength. Red has the longest wavelength (least energy). Violet has the shortest wavelength (most energy). A rainbow is a visible spectrum. Drops of water in the sky act as mirrors or prisms and the sunlight shines into them revealing the spectrum of colors. Opaque objects do not reflect their own light. They absorb some of the light and reflect the rest.

Why do we see white, black, and colors? We see white because all of the colors of the spectrum reflect to our eyes at the same time. We see black because all of the colors of the spectrum are absorbed and none reflect to our eyes. We see red or green or
any other color because that color reflects to our eyes and the rest of the colors are absorbed.

The teacher noticed some students confused about why we see white, black, and colors. She decided to have the students immediately follow up the Roundhouse diagram with an extra wedge sheet constructed to separate these ideas. The additional writing of the concepts and relating these concepts to pictures would hopefully clear up any misconceptions. The students did an excellent job with this wedge sheet. The concepts they included were indicators that they enjoyed the follow-up work.

Roundhouse Diagram No. 10 Plus Wedge Construction

The Whole Class

The students read the lesson orally. The students were alert and motivated. All were anxious to read and many had hands raised. The teacher had prepared a typed paragraph with the main ideas for the students. The class discussed the lesson and handout. The teacher decided to let them work individually on their diagram sheets. She put a prism on the overhead projector and the students were able to see the visible spectrum on the classroom ceiling. Excitement was in the air.

The students seemed involved with their work, as they sat quietly and wrote. One student asked if he could use colors and the teacher decided it would be very appropriate to use color in this lesson. The students were excited, and worked silently for 45 minutes, seeming to enjoy the activity, especially being able to use color.

I walked around the room and noticed that the students diagrams were beautiful. The students were all involved with drawing the colors of the visible spectrum. Their goals were well stated and their titles well integrated. The students were doing the work
on their own, very independent of their teacher. Many were checking through the written material to make sure they were using the correct facts.

Roundhouse Diagram No. 10 Construction

The Case Study Group

Close-up Focus on Marian

Marian's goals were stated clearly. Her title was well integrated and covered all the concepts stated in the diagram. The diagram included the necessary key concepts in the material. The concepts were stated accurately. There was an icon in each segment. The enlarged wedge sheet added more detail to the diagram. The drawings were beautiful and the color added novelty to the aesthetically pleasing diagram. Marian's worksheet and paragraph indicated she understood the material.

Close-up Focus on Elizabeth

Elizabeth had trouble expressing her goals but the meaning was clear. Her title was well integrated although there were spelling errors. The title clearly covered the concepts stated in the diagram. The concepts were accurately stated. There was an icon for each segment which represented that concept. The enlarged wedge added detail and clarity to the diagram. Elizabeth's pictures were well done and the color added to her wonderful designs. Elizabeth still had some grammar problems as well, but she had improved remarkably since she first began with the Roundhouse diagram. Her worksheet and final paragraph indicated she understood this lesson on color.

Close-up Focus on Betty

Betty's goals were stated clearly. Her title was well integrated and covered the key concepts stated in the diagram. Only one of her concepts was not clearly stated or
defined. There was an icon in each segment which was representative of that concept. The enlarged wedge sheet was exceptionally well done. Her work was incredibly neat and the colors were delightful. Betty took her time and was absorbed in her work constructing this diagram. Her worksheet and her final paragraph indicated she understood the material.

**Close-up Focus on Collin**

Collin’s stated goals were a bit too complex and difficult to understand. His title was well integrated with related concepts, and he did cover all the key ideas stated in the diagram. His concepts were accurately stated. There was an icon to represent each concept. There were still some spelling errors, but overall, Collin constructed an excellent diagram. His use of color was slight but his pictures were interesting and well associated with related concepts. The enlarged wedge sheet was a nice addition. His final paragraph and worksheet were evidence he understood the material.

**Close-up Focus on Carla**

Carla’s goals were stated simply and directly. Her title integrated the concepts within the diagram and she covered all the key concepts. Her concepts were written concisely and stated clearly. Her icons were directly related to the concepts. The colors used added a nice touch to the diagram. The enlarged wedge sheet was beautifully done (see Appendix LL). Her final paragraph and diagram indicated she understood the material (see Appendix MM).

**Close-up Focus on Willy**

Willy’s goals were clearly stated. His title was well integrated and covered the necessary concepts. His ideas were accurately stated. There was an icon which
represented each concept. The pictures were well associated and the extra color made
the diagram aesthetically pleasing. His worksheet and his final paragraph indicated he
understood the material. His enlarged wedge sheet was clear and well constructed.

Reflections from the Researcher

The subject of light was an abstract concept for most students. The diagrams
were really helping the students understand the visible spectrum on a very basic level.
They were being confronted with new ideas and were restructuring the material through
the diagrams. These students had never thought about these concepts before. It was
causing them to be extremely inquisitive. The students seemed fascinated by color.
Questions were asked such as, “How does television pick up colors?” Their questions
were good and indicated they were thinking about these new concepts.

The teacher had to be ready for these higher order questions. She admitted to
me that she was enjoying teaching these students more now that they were involved. I
overheard the teacher telling another teacher about the Roundhouse diagram. All of her
comments were very positive.

Reflections from the Teacher

These comments were taken from the teacher’s journal:

Today we received life science packages for the students to study for the
standardized tests. I plan to have the students do a Roundhouse diagram on
plant and animal cells. They will not receive a class grade nor will they be
tested on this material for classroom purposes. The practice will strictly be
related to helping the students organize their thoughts for the testing this week.
The Roundhouse diagram will cover the parts and jobs of the plant and animal
cells. I am using this diagram to review. There are many ways this diagram can
be used.

Today, two of my lower level students proofread a sentence I had typed.
They never used to catch my typing mistakes. This shows me that they are
proofreading. The Roundhouse diagrams and the journaling has helped them
learn how to revise sentences. I think that is great!

**Reflections from the Outside Observer**

These comments were taken from the outside observer’s field notes:

The teacher had the students get their notebooks and list the main ideas
of the lesson. The class discussed these major points. She put a word bank on
the board to help the students be able to pull the main ideas out of the chapter.
She uses very good questioning techniques. She answers their questions. She
walks around and monitors the students, helping them where needed. She asked
the students if they clearly understood the lesson. She encouraged them to do
well by giving them positive comments.

The worksheet allowed the students to concentrate on the information
taught from the lesson. As the students answered the questions, it motivated
them to ask more questions. They were very curious. The teacher walked
around checking their work. She helped them to explain the lesson in their own
words.

This worksheet put the responsibility of exploring and explaining what is
being taught on the learner. The diagrams force the teacher to go to each
student’s desk and check on comprehension. If the teacher can catch what they
do not understand now, they will do better on the test later. The diagrams look
wonderful. This can be used for other subjects. Test scores have shown
improvements.

**Reflections from the Students**

The student evaluation checklist on Roundhouse diagram No. 10 established
positive feedback from the students. The greatest problem areas seemed to be with
chunking and using their own words when rewriting their sentences (see Table 5).

**Table 5. Student Evaluation Checklist: Whole Class Results**

<table>
<thead>
<tr>
<th>Roundhouse Diagram No. 10</th>
<th>Yes</th>
<th>No</th>
<th>Sometimes</th>
<th>Most of the Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning Tasks</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enjoyment</td>
<td>17</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Organization</td>
<td>13</td>
<td></td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

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Table 5 continued

<table>
<thead>
<tr>
<th>Learning Tasks</th>
<th>Yes</th>
<th>No</th>
<th>Sometimes</th>
<th>Most of the Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to Chunk</td>
<td>12</td>
<td>-</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Uses time wisely</td>
<td>17</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Works well independently</td>
<td>15</td>
<td>-</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Works well with others</td>
<td>14</td>
<td>1</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Uses own words</td>
<td>10</td>
<td>-</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Ability to link pictures</td>
<td>12</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Creativeness</td>
<td>17</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Improves understanding</td>
<td>15</td>
<td>1</td>
<td>2</td>
<td>-</td>
</tr>
</tbody>
</table>

Two questions were asked at the end of each student evaluation sheet:

1. The most important things I’ve learned constructing the Roundhouse diagram were: the subject matter (6), better grades (3), to study (3), paraphrasing (3), it is fun, draw pictures.

2. Did you encounter any problems constructing your Roundhouse diagrams? chunking (2), no problems (13), link pictures.

A table has been provided with the meaningful concepts learned by the case study group based on Roundhouse diagrams No. 10 (see Appendix NN).
Sound and Light

Description of Science Concept

Comparison of sound waves and light waves: Sound waves are compressional waves, while on the other hand, light waves are transverse waves. Sound waves cannot travel through empty space; light waves can travel through empty space. Sound waves travel 340 meters per second; light waves travel 300,000,000 meters per second. Sound waves move back and forth along the path they travel; the waves that make up light “vibrate” at right angles to the path they travel.

Places where air molecules are squeezed together are called compressions, while places where air molecules spread farther apart are called rarefactions. Rarefactions can be compared to the troughs of a water wave. The distance from any place on a wave to a similar place on the next wave is called one wavelength. Sound waves occur when vibrations created by a vibrating object squeeze together and spread apart its transmitting medium (air, water, steel).

Sound vibrations traveling through the air are captured by the external ear and travel down a tube called the ear canal. The sound vibrations hit the eardrum at the end of the ear canal and cause the eardrum to vibrate. Vibrations get stronger in the middle ear. In the inner ear, these sound vibrations change to electrochemical messages. The auditory nerve carries these messages to the brain where the message is interpreted.
The Whole Class

The teacher began the lesson by having the students open their textbooks and read orally. The objective of this lesson was to compare sound waves and light waves. The teacher reviewed the students on what they had learned on lights so they would be refreshed before making the comparisons. The teacher lit a candle. She took a two-liter bottle with one end cut off and covered with plastic wrap. She patted her hand on the plastic which made a sound and caused the flame to flicker. This presentation was to represent a simulation of sound.

The students recorded their main ideas from the board. The teacher gave them an additional handout to use when constructing their diagrams. These students still needed guidance, but they had become much more independent than when they first started constructing the Roundhouse diagrams. They immediately began working through the worksheets. The students were very familiar with the process and jumped right in without delay or hesitation.

As I walked around the room, I noticed a few students having trouble with the idea of making a comparison. The teacher had to go back to the board and explain to them to think in terms not only of sound, but relating the same idea to light as well. This was a difficult task for them. Eventually they all caught on. The Roundhouse diagram involves many learning processes and comparing is one of them.

I noticed many of the students were integrating their titles using the "and" and "of" words. The students were able to work at a pace fast enough to complete a diagram in one class period. This was a tremendous improvement.
Roundhouse Diagram No. 11 Construction

The Case Study Group

**Close-up Focus on Marian:**

Marian’s goals were stated clearly. Her title was well integrated and covered the concepts stated in the diagram. The concepts were accurately stated. There was an icon in each segment which was clearly associated with that concept. Marian’s pictures were not only creative but very well drawn. The diagram was clear, direct, and thoughtful. Marian’s work had gone from good to excellent. Her grades had remained consistently above average. Her worksheet, paragraph, and diagram showed that she understood the material in this lesson (see Appendix 00).

**Close-up Focus on Elizabeth**

Elizabeth’s goals were written with good intentions but sounded very confusing. She wrote too much information and too many concepts. The title was well integrated, but she stated that rarefaction was a wave when actually it is a wave characteristic. Elizabeth had difficulty saying what she meant at times, but her grades indicated that she was improving her understanding of science concepts. Elizabeth’s diagram did include the necessary key concepts covered in the material. There was an icon in each segment which represented that concept. The diagram appeared to be overcrowded although at the same time she had included meaningful details. Elizabeth had made a great amount of improvement over time.

**Close-up Focus on Betty**

Betty left light out of her goals and just stressed sound, when actually she was comparing the two. Her title was well stated and well integrated. Her diagram included
the necessary key concepts. Most of her concepts were well stated. She drew a picture of a parallel sound wave, but she did not draw a picture of a transverse wave which travels at right angles. Her diagram did not indicate that she totally understood this. There was an icon in each segment except for this one. The other concepts were accurate. Betty had the potential to do well when she applied herself. She had shown improvement although I believe she was capable of doing better than she was doing.

Close-up Focus on Collin

Collin stated his goals clearly. His title was well integrated and well stated. The diagram included the necessary key concepts. Collin’s concepts were stated accurately. He continued to have minor spelling errors. There was an icon in each segment, representative of each concept. Collin’s pictures were well thought out and associated directly with his statements. This representation had helped his grades to increase. He had told me on numerous occasions that this was why he remembered his diagrams so well. His details were meaningful. Meaningful learning occurs when it is nonarbitrarily related to ideas already existing in the cognitive structure of the learner (Ausubel, 1968). Collin had improved with this method.

Close-up Focus on Carla

Carla’s goals were well written. Her title was well integrated and stated directly. Her title covered all the necessary key concepts in the diagram. Her concepts were stated accurately. There was an icon in each segment which was representative of that concept. The diagram was extremely neat and well drawn. Carla’s strength was that she was able to chunk effectively which helped her diagrams remain clear, concise, and meaningful. This characteristic aids in the encoding process so that it can be retrieved.
easily (Hohn, 1995; Searleman & Herrmann, 1994). Her diagrams had gone from good to excellent. Her strength in language arts had helped her.

**Close-up Focus on Willy**

Willy’s goals were stated clearly. The title was well integrated and well written. His title covered the concepts related in the diagram. The concepts were accurately stated. There was an icon in each segment which represented that concept. Willy included many details in his drawings. Willy had greatly improved with this method. He had problems chunking and putting sentences into his own words, but he did well in this diagram.

**Reflections from the Researcher**

The teacher has continued to model metacognitive learning strategies for these students. The goal of every science teacher should be to engage learners in meaningful instruction which will transfer from subject to subject and eventually to real-life situations (AAAS, 1989). She had shown them how to re-read their material in order to check for the main ideas. She had shown them how to establish relationships within their diagrams. She had helped to train them to recognize parts of a whole concept and to think from the general to the specific. She had helped them to plan, revise, restructure, and question themselves about their concepts. She had also established their prior knowledge before each lesson and had attended to their needs if they happened to have misconceptions within their diagrams. It had been a learning experience for the teacher as well as for the students. I had seen both teacher and students transform as this research study had continued to transform me as well.
The students had learned how to evaluate their own work. They were questioning their statements and making decisions about what they wanted to put in their own diagrams. They have continued to create their own experience with the construction of the Roundhouse diagram. They continued to learn other strategies such as writing, paraphrasing, and comparing. They had become inquisitive, active, meaningful learners.

Reflections from the Teacher

These comments were taken from the teacher’s journal:

The students have told me that they want to do the Roundhouse diagram until the end of the year. I find they are retaining more. I administered a review question on their last test and they were able to recall the information. The students are working more independently.

Before the Roundhouse diagram study, my science tests consisted of science vocabulary with word bank, multiple choice, and true/false questions. I always provided a word bank for this class on the tests because they did very poorly without one.

I taught each lesson, had hands-on activities, and provided notes in outline form. Many students did not study or take responsibility for their own learning. Many were passively functioning in the class and scoring low average to below average. They never asked questions on their own. I always had to ask questions myself and probe for answers. When I asked if anyone had questions, no one ever responded as though they understood or maybe they didn’t know what question to ask. These students also hated writing. I actually cringed when I told them they were going to have to write something because of their faces and groans of discontentment.

When the students began writing the Roundhouse diagramming method they were having a hard time. They found it very difficult to write, find main ideas, and think for themselves. They were being required to be responsible for their learning and they did not like it. A few of them let me know how unhappy they were with this situation.

After two or three diagram cycles were completed (by this I mean the teaching, the completed diagram, and the test) attitudes began to change. Students were becoming more proficient at coming up with their titles, relationships of things, chunking the information, and writing. I began to see grades go up. Students’ self-esteem began to rise as a result. Students were enjoying doing the diagram and were so pleased with their improved test scores.
Their writing skills improved. I no longer saw discontentment when it was time to write. I began to hear many inquisitive questions from this group. We looked in encyclopedias to find answers to their questions and did further research on topics in which they were interested. I began to feel like they were truly interested in science.

I noticed a difference in my attitude as well. I am now enjoying teaching science to this class. We explore new concepts and enjoy doing it. I seem to have higher expectations of my students. I can see that they have higher expectations for themselves. I heard from a child that was not interested in learning science and did not study say how she had studied with one of her classmates the night before the science test. She smiled proudly when she saw her test grade.

Before the Roundhouse diagrams, when I assigned the study-guide questions in the back of the science book, students had to search for the answers in the lesson. I often wondered why. I felt as though I had taught the lesson well and that they should have known many of these answers without looking back at anything. They had not retained much of the lesson and had not studied the material. After they did the diagrams, as a review, I verbally asked them the questions in the back of the book without them knowing prior to this or looking at them first. They could answer the questions for me now without having to look back. This proved to me that they had retained the material that I had taught them now.

In conclusion, I have found only positive effects from using the Roundhouse diagram. I feel as though it has helped my students in science, English, and reading. My students enjoy learning this way and I will definitely continue using the diagram each year.

Reflections from the Students

The student evaluation checklist for Roundhouse diagram No. 11 established positive feedback from the students. They indicated high levels of creativity, since they were allowed to integrate color into their lesson (see Table 6). Creative thinking strategies are being incorporated where students are being asked to think rather than memorize (Starko, 1995).
### Table 6. Student Evaluation Checklist: The Whole Class Results

<table>
<thead>
<tr>
<th>Learning Tasks</th>
<th>Yes</th>
<th>No</th>
<th>Sometimes</th>
<th>Most of the Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enjoyment</td>
<td>15</td>
<td>1</td>
<td>2</td>
<td>--</td>
</tr>
<tr>
<td>Organization</td>
<td>15</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Ability to chunk</td>
<td>13</td>
<td></td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Uses time wisely</td>
<td>15</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Works well independently</td>
<td>12</td>
<td></td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Works well with others</td>
<td>10</td>
<td></td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Uses own words</td>
<td>7</td>
<td>1</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Ability to link pictures</td>
<td>11</td>
<td></td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Creativeness</td>
<td>16</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Improves understanding</td>
<td>15</td>
<td>1</td>
<td></td>
<td>--</td>
</tr>
</tbody>
</table>

Two questions were asked at the end of each student evaluation sheet:

1. The most important things I’ve learned constructing the Roundhouse diagrams were:
   - subject matter (2), improves grades (3), organization, understanding, fun, chunking (2)
   - studying more.

2. Did you encounter any problems while constructing your Roundhouse diagrams?
   - drawing pictures (2), none (13), chunking (2), linking the pictures to the icons (2), main
     ideas of each type of angle.

A table has been provided with the meaningful concepts learned by the case study group based on Roundhouse diagram No. 11 (see Appendix PP).
Quantitative Evidence of Student Performance

To examine the potential use of the Roundhouse diagram method for classroom learning in the middle school, a major research question was posed: Does constructing and using Roundhouse diagrams affect the meaningful learning of science concepts by middle school students?

I had presented evidence from the case study group and the whole class which addressed issues relating to meaningful learning of science concepts, as seen in six test scores during the 10-week duration of study. Mastery of technique was also monitored and graded over all of the 11 diagrams for the case study group. Student evaluation checklists were investigated in order to determine student problems as well as their reflections on the overall Roundhouse diagram process. Triangulation of sources was used to check for consistency and patterns which accumulated throughout the case study evidence which was previously presented. Triangulation of methods was used to compare the qualitative data to the quantitative data in order to thoroughly answer the major research question. The documentation of available statistical data included the 1st through 5th six-weeks grade-point averages (see Appendix QQ) and the Roundhouse diagram scores which were recorded lab grades in the 5th six-weeks grading period (see Appendix Q). Various comparisons were made using a paired t-test on a defined pre-score and a defined post-score. The hypothesis this researcher tested for using the paired t-test was: Ho: D ≤ 0; Ha: D > 0. The null hypothesis states there is no difference. The alternative hypothesis states the difference of the two scores is going to be positive which indicates the post-score is higher than the pre-score.
Although not all of the paired t-tests were significant, in particular for the case study group (because of the small sample size), all of the post-averages were higher than the pre-averages in both the case study group and the whole class. In order to be comprehensive, various comparisons were made using a paired t-test on a defined pre- and a defined post-score (see Tables 7 through 18).

Test 1 (case study group) and Test 2 (whole class), with diagram scores, examined six-weeks averages pre- and post-Roundhouse diagramming methods. Average post-scores were higher than average pre-scores for both groups, but the paired t-test was significant only for the whole class (probably due to the small sample size). The pre-scores include 1st through 4th six-weeks averages. The post-score includes the 5th six-weeks average (see Tables 7 and 8).

Table 7. Test 1

| Variable | \( n \) | Mean | Std Dev | Min | Max | T | Prob>|T| | \( \Delta \) |
|----------|-------|------|---------|-----|-----|---|----------|-------|
| PRE      | 6     | 85.71| 6.45    | 77  | 92.5|   |          |       |
| POST     | 6     | 89.17| 11.27   | 73  | 98  |   |          |       |
| DIFF     | 6     | 3.46 | 2.83    |     |     | 1.22| 0.28    | 0.54  |

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Table 8. Test 2

| Variable | N | Mean | Std Dev | Min | Max | T  | Prob>|T| | Δ |
|----------|---|------|---------|-----|-----|----|--------|---|
| PRE      | 19| 84.64| 6.29    | 73.5| 92.5|    |        |  |
| POST     | 19| 87.74| 8.32    | 73  | 98  |    |        |  |
| DIFF     | 19| 3.09 | 1.12    | 73  | 98  | 2.76| *0.01  | 0.49 |

*p < .05

Test 3 (case study group) and Test 4 (whole class), with diagram scores, yielded the same results as Test 1 and Test 2 except the 4th six-weeks grading period was left out of the scoring because it was a transitional period. The pre-score included the first three tests of the 4th six-weeks period. The post-score included the last test of the 4th six-weeks period and the first two tests of the 5th six-weeks period. The researcher entered the classroom in the middle of the 4th six-weeks period (see Tables 9 and 10).

Table 9. Test 3

| Variable | n | Mean | Std Dev | Min  | Max | T  | Prob>|T| | Δ |
|----------|---|------|---------|------|-----|----|--------|---|
| PRE      | 6 | 85.61| 5.79    | 78.67| 92  |    |        |  |
| POST     | 6 | 89.17| 11.27   | 73   | 98  |    |        |  |
| DIFF     | 6 | 3.56 | 2.88    | 73   | 98  | 1.23| 0.27   | 0.61 |
Table 10. Test 4

| Variable | N | Mean | Std Dev | Min | Max | T  | Prob>|T| | Δ |
|----------|---|------|---------|-----|-----|----|-------|---|
| PRE      | 19| 84.93| 5.86    | 73.67| 92  |     |       |   |
| POST     | 19| 87.74| 8.32    | 73  | 98  |     |       |   |
| DIFF     | 19| 2.81 | 1.16    |      |     | 2.41| *0.03 | 0.48|

*p < .05

Test 5 (case study group) and Test 6 (whole class), with no diagrams, examined the first three tests pre-Roundhouse diagram training and the first three tests post-Roundhouse diagram training. The post-scores for both groups were higher than the pre-scores, with the case study groups average being significantly higher than the pre-averages. It could be argued that the whole class post-scores were also significantly higher (see Tables 11 and 12).

Table 11. Test 5

| Variable | n | Mean | Std Dev | Min | Max | T   | Prob>|T| | Δ |
|----------|---|------|---------|-----|-----|-----|-------|---|
| PRE      | 6 | 78.83| 13.50   | 61.67| 91.67|     |       |   |
| POST     | 6 | 85.33| 14.37   | 66  | 99.33|     |       |   |
| DIFF     | 6 | 6.5  | 1.20    |      |     | 5.41| *0.003| 0.48|

*p < .05

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Table 12. Test 6

| Variable | N | Mean | Std Dev | Min  | Max  | T    | Prob>|T| | Δ   |
|----------|---|------|---------|------|------|------|-------|-----|-----|
| PRE      | 18| 79.22| 10.75   | 61.67| 92.67|      |       |     |     |
| POST     | 19| 83.88| 13.77   | 58   | 99.33|      |       |     |     |
| DIFF     | 18| 4.87 | 2.40    |      |      | 2.03 | 0.06  | 0.43|

Test 7 (case study group) and Test 8 (whole class), without diagram scores, examined the three tests pre-Roundhouse diagram training and all the tests post-Roundhouse diagram training of the 5th six-weeks including the last test of the 4th six-weeks (see Tables 13 and 14).

Table 13. Test 7

| Variable | n | Mean | Std Dev | Min  | Max  | T    | Prob>|T| | Δ   |
|----------|---|------|---------|------|------|------|-------|-----|-----|
| PRE      | 6 | 78.83| 13.50   | 61.67| 91.67|      |       |     |     |
| POST     | 6 | 87.44| 12.33   | 69.33| 97.83|      |       |     |     |
| DIFF     | 6 | 8.61 | 1.92    |      |      | 4.48 | *0.007| 0.64|

*p < .05

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Table 14. Test 8

| Variable | N  | Mean   | Std Dev | Min   | Max   | T    | Prob>|T| | Δ  |
|----------|----|--------|---------|-------|-------|------|-------|----|----|
| PRE      | 18 | 79.22  | 10.75   | 61.67 | 92.67 |      |       |    |    |
| POST     | 19 | 85.81  | 10.25   | 68.67 | 97.83 |      |       |    |    |
| DIFF     | 18 | 6.46   | 1.84    |       |       | 3.51 | *0.003| 0.61|

*p < .05

Test 9 (case study group) and Test 10 (whole class), without diagram scores, examined the 1st through 4th six-weeks averages pre-Roundhouse diagram training to the 5th six-weeks average post-Roundhouse diagram training. It could be argued that the whole class post-scores were also significantly higher (see Tables 15 and 16).

Table 15. Test 9

| Variable | n   | Mean   | Std Dev | Min   | Max   | T    | Prob>|T| | Δ  |
|----------|-----|--------|---------|-------|-------|------|-------|----|----|
| PRE      | 6   | 83.92  | 7.58    | 75.75 | 91.50 |      |       |    |    |
| POST     | 6   | 87.37  | 12.73   | 68.80 | 97.40 |      |       |    |    |
| DIFF     | 6   | 3.45   | 2.85    |       |       | 1.21 | 0.28  | 0.46|    |

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Table 16. Test 10

| Variable | N  | Mean | Std Dev | Min  | Max  | T     | Prob>|T| | Δ  |
|----------|----|------|---------|------|------|-------|--------|-----|
| PRE      | 18 | 83.22| 6.71    | 72.08| 91.50|       |        |     |
| POST     | 19 | 86.22| 9.68    | 68.80| 97.40|       |        |     |
| DIFF     | 18 | 2.78 | 1.39    |       |       | 1.99  | 0.06   | 0.45|

Test 11 (case study group) and Test 12 (whole class), without diagram scores, examined the 1st through 3rd six-weeks averages pre-Roundhouse diagram training to the 5th six-weeks average post-Roundhouse diagram training (see Tables 17 and 18).

Table 17. Test 11

| Variable | N  | Mean | Std Dev | Min  | Max  | T     | Prob>|T| | Δ  |
|----------|----|------|---------|------|------|-------|--------|-----|
| PRE      | 6  | 85.61| 5.79    | 78.67| 92   |       |        |     |
| POST     | 6  | 87.37| 12.73   | 68.80| 97.40|       |        |     |
| DIFF     | 6  | 1.76 | 3.49    |       |       | 0.50  | 0.64   | 0.30|

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### Table 18. Test 12

| Variable | N | Mean | Std Dev | Min | Max | T | Prob>|T| | \( \Delta \) |
|----------|---|------|---------|-----|-----|---|------|-----|-----|
| PRE      | 19| 84.93| 5.86    | 73.67| 92  |   |      |     |     |
| POST     | 19| 86.22| 9.68    | 68.80| 97.40|   |      | 0.90| 0.38| 0.22 |
| DIFF     | 19| 1.29 | 1.43 \( \text{std error} \) |  |     | 0.90 | 0.38 | 0.22 |

### Case Study Group

In conclusion, for all tests, all post-averages were higher than pre-averages, but only tests 5 and 7 (which compared the first three tests of the 4th six-week [pre-Roundhouse diagramming] with the first three tests [post-Roundhouse diagramming], and all six tests during the Roundhouse diagramming method, with no diagram scores included) were significantly higher. Failure to reject in the remaining tests of the case study group may be due, in part, to the small size and the intentional but disproportional make-up of the case study group with respect to science proficiency.

### Whole Class

The same paired t-tests, when performed using data from the whole class, were significant in all but Test 12. In a test comparing the 1st through 3rd six-weeks period averages (pre) to the 5th six-weeks period average with diagram scores excluded (post), leaving out the 4th six-weeks period and considering it as a transitional period, the 5th six-weeks average is higher, but its not significantly higher. However, if we include the 4th six-weeks average (excluding the diagram grade) in the post-average, the difference
does become significant. (Note: In tests 9 through 11, the variables P4T1 and P4T2 were not available for student No. 19. Since the students' 4th six-weeks average did not include estimates for the missing test grades and we used this value in other tests. She was at another school and these grades were not available. Hence the tests were run using 18 students, leaving No. 19 out.)

**Analysis of Variance: Average Test Scores**

An Analysis of Variance (ANOVA) was performed to examine the average test scores for the case study group and the whole class. To determine if grades increased during the 10-week period, the Roundhouse diagramming method was used. For both the case study group and the whole class, the average score did not have a strong trend upward. ANOVAs for both groups were not significant (case study group, \( p = 0.312 \); whole class, \( p = 0.287 \)) resulting in no significant difference between all test averages.

In summary, the whole class revealed a stronger trend upward, showing an increase in test score averages, although the results were not significant (see Tables 19 and 20).

**Table 19. Case study group Average Test Scores for all Six Tests**

<table>
<thead>
<tr>
<th>Variable</th>
<th>( n )</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>P4T4</td>
<td>6</td>
<td>87.83</td>
<td>11.13</td>
<td>72.00</td>
<td>100.00</td>
</tr>
<tr>
<td>P5T1</td>
<td>6</td>
<td>83.50</td>
<td>19.42</td>
<td>53.00</td>
<td>106.00</td>
</tr>
<tr>
<td>P5T2</td>
<td>6</td>
<td>84.67</td>
<td>16.12</td>
<td>56.00</td>
<td>100.00</td>
</tr>
<tr>
<td>P5T3</td>
<td>6</td>
<td>94.00</td>
<td>7.90</td>
<td>84.00</td>
<td>100.00</td>
</tr>
<tr>
<td>P5T4</td>
<td>6</td>
<td>84.33</td>
<td>19.45</td>
<td>52.00</td>
<td>100.00</td>
</tr>
<tr>
<td>P5T5</td>
<td>6</td>
<td>90.33</td>
<td>9.67</td>
<td>76.0</td>
<td>100.00</td>
</tr>
</tbody>
</table>

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Table 20. Whole Class Average Test Scores for all Six Tests

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>P4T4</td>
<td>19</td>
<td>83.74</td>
<td>15.78</td>
<td>54.00</td>
<td>100.00</td>
</tr>
<tr>
<td>P5T1</td>
<td>19</td>
<td>82.32</td>
<td>17.87</td>
<td>45.00</td>
<td>106.00</td>
</tr>
<tr>
<td>P5T2</td>
<td>19</td>
<td>85.58</td>
<td>13.37</td>
<td>50.00</td>
<td>100.00</td>
</tr>
<tr>
<td>P5T3</td>
<td>19</td>
<td>88.74</td>
<td>86.69</td>
<td>72.00</td>
<td>100.00</td>
</tr>
<tr>
<td>P5T4</td>
<td>19</td>
<td>86.68</td>
<td>14.24</td>
<td>52.00</td>
<td>100.00</td>
</tr>
<tr>
<td>P5T5</td>
<td>19</td>
<td>87.79</td>
<td>8.68</td>
<td>75.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>

A graph of average test scores for the case study group and the whole class are on the following page (see Figure 4).
Figure 4. Average Test Scores
Analysis of Variance: Average Diagram Scores

An analysis of variance (ANOVA) was performed to examine the average diagram score for the case study group and the whole class. A comparison of average diagram scores for the case study group as well as the whole class were also examined to determine an increase over the 10-week period of the Roundhouse diagramming method. A graph of the students’ average diagram scores can be found in Figure 5.

A comparison of diagram scores resulted in significant differences for both groups, as ANOVAs were significant (case study group, \( p = 0.03 \); whole class, \( p = 0.02 \)). Hence significant differences between average diagram scores exist, and since the average increases over time, conclusions indicate that diagram scores did improve during the 10-week session (see Tables 21 and 22).

Table 21. Case study group Roundhouse Diagram Average Scores

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>6</td>
<td>17.50</td>
<td>1.52</td>
<td>15.00</td>
<td>19.00</td>
</tr>
<tr>
<td>D2</td>
<td>6</td>
<td>18.17</td>
<td>2.23</td>
<td>15.00</td>
<td>20.00</td>
</tr>
<tr>
<td>D3</td>
<td>6</td>
<td>18.67</td>
<td>1.63</td>
<td>16.00</td>
<td>20.00</td>
</tr>
<tr>
<td>D4</td>
<td>6</td>
<td>18.00</td>
<td>2.28</td>
<td>14.00</td>
<td>20.00</td>
</tr>
<tr>
<td>D5</td>
<td>6</td>
<td>19.67</td>
<td>0.82</td>
<td>18.00</td>
<td>20.00</td>
</tr>
<tr>
<td>D6</td>
<td>6</td>
<td>18.33</td>
<td>1.86</td>
<td>16.00</td>
<td>20.00</td>
</tr>
<tr>
<td>D7</td>
<td>6</td>
<td>19.67</td>
<td>0.82</td>
<td>18.00</td>
<td>20.00</td>
</tr>
<tr>
<td>D8</td>
<td>6</td>
<td>19.17</td>
<td>1.33</td>
<td>17.00</td>
<td>20.00</td>
</tr>
<tr>
<td>D9</td>
<td>6</td>
<td>20.00</td>
<td>0</td>
<td>20.00</td>
<td>20.00</td>
</tr>
</tbody>
</table>
(Table 21 continued)

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
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<tr>
<td>D10</td>
<td>6</td>
<td>19.500</td>
<td>0.84</td>
<td>18.00</td>
<td>20.00</td>
</tr>
<tr>
<td>D11</td>
<td>6</td>
<td>19.17</td>
<td>1.33</td>
<td>17.00</td>
<td>20.00</td>
</tr>
</tbody>
</table>

Table 22. Whole Class Roundhouse Diagram Average Scores

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>D6</td>
<td>19</td>
<td>18.47</td>
<td>2.06</td>
<td>13.00</td>
<td>20.00</td>
</tr>
<tr>
<td>D7</td>
<td>19</td>
<td>18.42</td>
<td>1.57</td>
<td>15.00</td>
<td>20.00</td>
</tr>
<tr>
<td>D8</td>
<td>19</td>
<td>18.63</td>
<td>1.54</td>
<td>15.00</td>
<td>20.00</td>
</tr>
<tr>
<td>D9</td>
<td>19</td>
<td>19.74</td>
<td>0.65</td>
<td>18.00</td>
<td>20.00</td>
</tr>
<tr>
<td>D10</td>
<td>19</td>
<td>19.16</td>
<td>1.12</td>
<td>16.00</td>
<td>20.00</td>
</tr>
</tbody>
</table>

Three subquestions were asked in order to fully answer the major research question:

1. How do students' science concepts change as they become more proficient in constructing Roundhouse diagrams?

2. What problems do students encounter in mastering the technique associated with construction of Roundhouse diagrams?

3. How do students' choices and drawings of iconic images affect their progress in meaningfully learning science concepts as they construct a series of Roundhouse diagrams?
Figure 5. Average Diagram Scores
Subquestion No. 1

In order to answer the first subquestion, this researcher examined the relationship between the mastery of technique scores or the five lab grades in the 5th six-weeks period and the corresponding test scores. Roundhouse diagram Nos. 6 (What is light?) and 7 (the electromagnetic spectrum) corresponded with Test 2 in the 5th six-weeks grading period. Roundhouse diagrams No. 8 (reflection) and No. 9 (refraction) corresponded with Test 3 in the 5th six-weeks grading period. Each mastery of technique score was paired with its corresponding test score, and a Pearson’s correlation coefficient was calculated on all diagram-test pairs for the case study group and the whole class. For the case study group, $r = 0.55$ ($p = .0004$) and is significant. For the whole class data, $r = .08$ and is not significant ($p = 0.5433$). The whole class was graded on five Roundhouse diagrams (mastery of technique sheets) by the researcher and the teacher collaboratively. These scores were used as lab grades in the 5th six-weeks. The combined lab grades made up one test score toward the final six-weeks’ average. The case study group, on the other hand, was graded on all Roundhouse diagrams using mastery of technique sheets for monitoring purposes. There were 11 total mastery of technique sheets, lab grades, examined for the case study group (see Appendix R).

Correlation

A Pearson’s $r$ correlation coefficient was calculated on all diagram-test pairs for the case study group and the whole class. For the case study group, $r = 0.55$ ($p = .0004$) and is significant. For the class data, $r = .08$ ($p = 0.5433$) and is not significant.
Correlation coefficients were also calculated for diagram-test pairs for each test. For the case study group, five out of six coefficients were above .50, although only one was significant (see Table 23). For the whole class data, none of the three correlation coefficients were above .50 and none were significant.

Table 23. Correlation—Case study group

<table>
<thead>
<tr>
<th>Statistics</th>
<th>P4 Test 4</th>
<th>P5 Test 1</th>
<th>P5 Test 2</th>
<th>P5 Test 3</th>
<th>P5 Test 4</th>
<th>P5 Test 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corr</td>
<td>0.71</td>
<td>0.77</td>
<td>0.64</td>
<td>0.04</td>
<td>0.60</td>
<td>0.92</td>
</tr>
</tbody>
</table>
| Prob>|r| | 0.11      | 0.08      | 0.17      | 0.94      | 0.21      | *0.01 *

Note. * indicates significantly different from 0 under Ho: Rho = 0.

Table 24. Whole Class

<table>
<thead>
<tr>
<th>Statistics</th>
<th>P5 Test 2</th>
<th>P5 Test 3</th>
<th>P5 Test 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corr</td>
<td>-0.14</td>
<td>0.14</td>
<td>0.22</td>
</tr>
<tr>
<td>Prob&gt;</td>
<td>r</td>
<td></td>
<td>0.57</td>
</tr>
</tbody>
</table>

Note. In Table 24, none of the Pearson r correlation coefficients are significantly different from 0.

For the case study group, evidence indicates that there is a positive relationship between diagram scores and test scores, since r = 0.55 (see Tables 25 and 26), although this does not confirm that if diagrams are constructed more effectively the test scores will improve. In this study, diagram scores do explain 30.25% of the variance in test scores (r² = .3025).
As for the entire class, \( r = .08 \) and is not significantly different from 0 under Ho: Rho = 0 (\( p = 0.5433 \)). This lack of significant correlation may be due in part to the fact that there was low variation in the mastery of technique scores. The mastery of technique scores ranged from 13 to 20 but there was high variation in the test scores which ranged from 50 to 100.

For the whole class, the reason this insignificant correlation shows no relationship between diagram scores and test scores may be attributed to the following: (a) the whole class was graded on five mastery of technique scores and only three tests in the middle of the training period; and (b) diagram scores had little variation since they were based on 20 points. Had all diagram scores been included, as they were for the case study group, a stronger relationship may have been detected. In terms of future research, I would suggest basing the mastery of technique score on a 100-point system rather than a 20-point system so there would be more included variation when compared to the test score which was based on a 100-point system.

Table 25. Correlation Analysis—Case study group

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Sum</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagram</td>
<td>36</td>
<td>18.98</td>
<td>1.19</td>
<td>683.17</td>
<td>16.00</td>
<td>20.00</td>
</tr>
<tr>
<td>Test</td>
<td>36</td>
<td>87.44</td>
<td>14.12</td>
<td>3148.00</td>
<td>52.00</td>
<td>106.00</td>
</tr>
</tbody>
</table>

Pearson Correlation Coefficients / Prob > |R| under Ho: Rho = 0 / n = 36

Note. Correlation = .56 and Prob > |R| = 0.0004
Table 26. Correlation Analysis—Whole Class

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Sum</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagram</td>
<td>57</td>
<td>18.93</td>
<td>1.07</td>
<td>1079.00</td>
<td>16.00</td>
<td>20.00</td>
</tr>
<tr>
<td>Test</td>
<td>57</td>
<td>87.00</td>
<td>12.17</td>
<td>4959.00</td>
<td>50.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Pearson Correlation Coefficients / Prob > |R| under Ho: Rho = 0 / N = 57

Note. Correlation = 0.08 and Prob > |R| = 0.54

In terms of subquestion No. 1, qualitative evidence revealed that science concepts become more meaningful over time in terms of metacognition and include metalearning skills for some students from the case study group as the students became more proficient in constructing the Roundhouse diagrams. Meaningful learning of science concepts affected the case study group in various ways because of the stratified purposeful sampling procedures which incorporated different ability levels pre-Roundhouse diagram training.

Going back to the eye-brain system and the stages of visual information processing, neural impulses are transmitted in a massive parallel fashion into a network of cerebral neurons, where these impulses are combined with previously stored information for higher-order processing, including cognition and thought (Solso, 1994). It is in the associative cortex that numerous connections are made with other neurons and interpretation of visual signals is converted into meaningful thought. It is at this particular point that Ausubel’s Theory of Meaningful Learning becomes applicable (1968). Prior relevant knowledge and experience must be established before new
connections can be stabilized (Wandersee, 1985). In the sample of the low-ability students from the case study group, Betty and Elizabeth, lack of relevant prior knowledge greatly contributed to the difficulty in making new associations. Ausubel's Theory of Meaningful Learning requires three basic qualifications; (a) the material must have potential meaning; (b) the learner must have relevant prior knowledge, and (c) the learner must choose to incorporate this knowledge (Mintzes & Wandersee, 1998).

Meaningful learning is explained as the process of subsumption where new knowledge is less inclusive and is connected to the learner's existing cognitive structure (Novak & Gowin, 1984). In the case of these low-ability students, the existing cognitive structure is not well connected nor well represented with experience and associations derived from science content. Reteaching of concepts is necessary, but the learner must be willing to undergo this conceptual change. Many times, Betty and Elizabeth were unwilling to encounter the necessary reconstruction for this change to occur. Because of unfortunate circumstances of Betty's home life, which caused her to be tardy on numerous occasions and at times caused her duress, her grades and diagram scores suffered and resulted in irregular patterns. One day Betty would perform excellent work, and the next day she would appear apathetic. Elizabeth, on the other hand, worked diligently to overcome her lack of prior knowledge and understanding, which eventually paid off, although it was time consuming.

Due to poor associations, visual abilities were affected as well. Many times, both Elizabeth and Betty were unable to connect concepts to icons which were a representation of that concept. As a result, immediate misconceptions were discovered by the teacher and the researcher. On several occasions, when reteaching methods were
employed, these students did not do the extra work needed to establish new links.

Elizabeth was more receptive to this idea than Betty, which resulted in grade-point improvement.

The two average students, Willy and Carla, both improved immensely in mastering the technique of diagram construction as well as meaningfully learning the science content presented in class. Both students had stable, relevant, prior knowledge and both learners revealed metacognitive learning skills enabling them to undergo conceptual reconstruction (Wittrock, 1994). Willy struggled more with diagram construction and had problems with chunking, more toward the end of the 10-week period than in the very beginning. This was possibly due to the change in subject matter. The study of light was much more abstract than the beginning subjects such as food chains and food webs. The abstract nature of the subject matter caused him problems because he was unable to put terms into his own words and reduce the amount of details. Willy was challenged by these learning tasks and continued to persevere through his difficulties. His grades continued to improve and his willingness to accept this challenge aided in the reconstructive process which eventually led to conceptual change and meaningful learning (Ausubel, 1968; Wittrock, 1994).

Carla’s ability to chunk was established by diagram No. 3, and she had an amazing ability to be concise, direct, and to the point in the Roundhouse diagram constructive process. Her neatness, organizational skills, and ability to chunk efficiently aided in the encoding process which enabled her to retrieve information easily (Searleman & Herrmann, 1994). Carla’s grades continued to remain excellent throughout the 10-week period. Carla exhibited metalearning characteristics on her

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essay test answers and displayed metacognitive learning characteristics in class (Novak & Gowin, 1984). The strong associations and the ability to meaningfully learn the science content enabled Willy and Carla to possess strong visual skills. They were able to accurately understand the science content which, in turn, enabled them to link meaningful icons to their concepts (Paivio, 1986). In cases where students generate their own visual representations of the content, learners retain 40% more information than with students who did not create visual representations of the content (Levin et al., 1979).

The two high-ability students, Collin and Marian, both maintained their high averages throughout the 10-week research period. Both students excelled in meaningfully learning science concepts. Both students had strong, well-connected neural networks which resulted in strong associations and interpretation (Searleman & Herrmann, 1984). Marian's well-developed organizational qualities enhanced encoding which, in turn, resulted in high grade-point averages (Hohn, 1995). Collin's effective abilities to link his icons to his concepts helped him to mentally visualize his verbal learning material (Paivio, 1986). Both students were active participants in meaningful learning activities, which is a creative characteristic (Starko, 1995). Both students performed metalearning tasks when answering their essay questions on their assessment (Novak & Gowin, 1984). Marian was much more focused than most students in the class. Her capacity to concentrate for long periods of time helped her in terms of making strong connections. Collin's ability to link pictures with concepts and his ability to understand the content helped him to maintain a high grade-point average.
The iconic features of self-constructed Roundhouse diagrams significantly improved their science content recall (Wandersee, 1988).

Both the qualitative and quantitative data presented for subquestion No. 1 resulted in a positive relationship between students' meaningful science conceptions and mastering the technique of construction, over time, during this 10-week study. If students were taught these metacognitive skills from the beginning of the year, I think more students would begin to develop more responsibility and awareness over their own learning, which would, in turn, lead to conceptual change and higher grades (Wittrock, 1994). These results would definitely enhance self-esteem and motivation, especially at the middle school level where these characteristics are needed the most (Bybee, 1983).

Subquestion No. 2

Qualitative methodology was employed to accumulate data from observations which consisted of descriptions within fieldnotes characterizing Roundhouse diagram construction from the point of view of the researcher, the classroom teacher, the outside observer, and the students. Documentation was derived from qualitative inquiry during informal conversations, formal interview methods, student worksheets and student evaluations, field notes, and Roundhouse diagrams constructed by participants.

The major problems the overall class encountered in mastering the technique associated with the construction of the Roundhouse diagrams focused around the following learning tasks: the ability to extract the main ideas from textbook science-related content without teacher assistance, to think in terms of general to specific in relation to the parts of a system, the ability to integrate the title using the “and” and “of” words in order to cover the concepts within the diagram, drawing related icons to each
concept within the seven sections of the diagram, the ability to sequence events accurately, and the ability to chunk the main ideas of the content—not only reducing the amount of words without changing the meaning of the concept, but also putting the sentences into their own words. Most of the students were able to state their goals by the third diagram. For many students, it was difficult to think on their own without being dependent on the teacher for answers.

The students in this 6th-grade science classroom ranged from low to average, with a very few higher level abilities. These students were not accustomed to writing correctly, and most of them had a poor language background. The Roundhouse diagrams required writing the main ideas in complete sentences; then restructuring these sentences by paraphrasing accurately into concise, well-related statements. After the diagrams were completed, the students had to write a paragraph in order to explain their diagram in essay form. These students had not been exposed to this much writing before and, as a result, these skills were very difficult for them.

The major part of the subject matter that was incorporated in the Roundhouse diagram construction training was based on many abstract concepts. The lowest grade-point averages for the whole class and the case study group was based on the test material from Roundhouse diagram Nos. 4 and 5 on the nitrogen cycle and the carbon-dioxide-oxygen cycle. The lowest diagram score for the case study group was the first diagram they constructed, Roundhouse diagram Nos. 1 and 2. Students with little prior knowledge of the subject matter had a difficult time drawing icons to concepts that they did not understand.
The student evaluation sheets indicated that there were more problems toward the beginning of the 10-week study than toward the end of the duration. Three students in the case study group mastered the technique of diagram construction. The other three students continued to have problems related to finding the main ideas, chunking sentences, and relating concepts to icons. These students remained teacher dependent to some degree.

In terms of the case study group, each student revealed progress over the 10-week Roundhouse diagram training period in terms of mastering the technique. In regard to the meaningful learning of science concepts, only one student did not show improvement.

Betty's grades did not improve over time as the other case study group members' grades improved. Toward the end of the 10-week Roundhouse diagram training period, Betty was still very inconsistent in her work. As indicated earlier, these problems were most likely not indicative of her potential, but outside influences greatly affected her classwork. She continued to reveal misconceptions throughout her diagrams, due to lack of studying and weak associations in her neural network (Searleman & Herrmann, 1994). This made it difficult for her to interpret science content properly. The icons in her diagrams were not related to the concepts well, indicating misconceptions. She had many language problems as well, which indicated these learning problems transferred to other subject areas. She often produced poor test grades, incomplete diagrams, unrelated concepts, and applied little effort to correct these difficulties. Betty's off-task attention pattern dropped midway through the
10-week diagramming period but greatly improved toward the end (see Figure 6). This inconsistency was characteristic of her grades, as well.

Elizabeth's grades consistently improved over time during the 10-week diagram training period. She also had very poor language skills which made it difficult at times to understand her meanings. She paid attention in class, which helped her greatly in terms of encoding (Hohn, 1995). She rarely studied outside of class, which was not to her advantage. She remained very dependent on her group members for correct answers, and also communicated to the teacher when she needed assistance. Elizabeth's persistence with this method paid off in terms of test scores. Her major problems centered around weak prior knowledge and understanding the science content. She was unable to express in words how she interpreted the information. She continued to leave out icons due to her inability to associate meanings. The most important thing students can bring to class is their concepts (Wandersee, 1987). In the Roundhouse diagramming method, if these concepts are faulty, they are immediately detected. Elizabeth's grades increased but her attention level dropped throughout the 10-week period (see Figure 6).

Willy's grades continued to improve because he put a tremendous amount of effort into the Roundhouse diagram construction method. He did remain teacher dependent because he genuinely struggled with paraphrasing abstract subject matter in the science content. Willy's inquisitive nature caused his attention level to excel and keep him interested (see Figure 6). I think he learned a great deal in this area and will benefit from the paraphrasing experience in higher grade levels. Willy had strong relevant knowledge of science content before the Roundhouse diagram training,
although his grades were average. I think the novelty of the Roundhouse diagram method stimulated his attention and kept him motivated to succeed (Wittrock, 1994). The reconstruction process awakened his curiosity, and he often asked higher-order questions related to science content. His greatest problem area centered on chunking and putting concepts into his own words.

Carla adapted quickly to the Roundhouse diagram construction method. Her grades immediately began to improve. After the first diagram, she had overcome many of the obstacles the rest of the class was still facing. She had problems integrating her title using the “and” and “of” words up until diagram No. 9. After that point, she mastered the Roundhouse diagramming technique completely. Her attention level remained high but dropped slightly toward the end of the 10-week study, probably due to the fact that she had mastered the Roundhouse diagramming technique and was familiar with the process (see Figure 6). The novelty of the process had kept her attention level high in the beginning of the research study.

Collin adjusted to the Roundhouse diagram method right from the start. His first diagram was perfect, other than not using the “and” and “of” words in the title. This challenging task was so new and different from their ordinary routine that very few students were able to accomplish the integration of the title until the end of the 10-week training session. Collin had problems with this particular task up until diagram No. 6. Collin’s major problem centered around his attention deficit disorder. He continued to have spelling difficulties and handwriting problems throughout most of his diagrams, which is normal with students who possess this disorder. Collin’s quick adaptability to
the Roundhouse diagramming method combined with his attention deficit is probably why his attention level dropped throughout the research study (see Figure 6).

Marian mastered the technique of the Roundhouse diagramming construction after diagram No. 4. Her only problem was a dependency on the teacher, which also ceased after diagram No. 4. This teacher dependency was a result of her wanting to be sure her answers were correct. Marian had fewer problems than any other student in the classroom. Marian was also group dependent until her confidence grew enough for her to work on her own. Her attention level remained above 90% throughout the diagram study (see Figure 6).

**Subquestion No. 3**

In order to answer subquestion No. 3 quantitatively, this researcher established a relationship between the meaningful science concept scores and icon scores. A Pearson's $r$ correlation coefficient was calculated on icon scores paired with meaningful concept scores for the case study group. Evidence indicates a positive relationship between icon scores and meaningful concept scores since Pearson's correlation coefficient $r = .556$, although this does not confirm a cause-effect relationship. Note in Table 27 that $r = .55$ and is significant under Ho: Rho = 0; ($p = .0004$). This correlation was established with all six tests and with all 11 diagrams only for the case study group.

In order to answer subquestion No. 3 qualitatively, there is strong evidence within the case study group to indicate that visual literacy is an important issue and strong indicator of production in the Roundhouse diagramming method. This use of
Table 27. Correlation Analysis on 6 tests with 11 diagrams- Case study group

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Sum</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Icon</td>
<td>36</td>
<td>93.44</td>
<td>8.20</td>
<td>3364.00</td>
<td>75.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Concept</td>
<td>36</td>
<td>84.81</td>
<td>15.33</td>
<td>3053.00</td>
<td>50.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Pearson Correlation Coefficients / Prob > |R| under Ho: Rho = 0 / n = 36

drawing pictures and icons and linking them to concepts helps to develop visual thinking abilities and mental representations within the learner’s cognitive structure (Launey, 1995). One major strength of the Roundhouse diagram is that when a student is unable to link a picture to a concept, the teacher is able to detect the alternative conception immediately. The Roundhouse diagram indicates an estimate of what the learner knows about a particular subject, and therefore reveals conceptual problems within the learner’s cognitive structure (Wandersee, 1987).

Within the case study group, Marian, Carla, and Collin mastered the technique of linking icons with their concepts after Roundhouse diagram No. 4. All three of these students exhibited metalearning skills on their test papers where they mentally visualized their constructed diagrams in answering their questions (Novak & Gowin, 1984). Research indicates that students who use illustrations in order to recall...
information outperform students who had no pictures to help them recall the data (Hohn, 1995; Levin et al., 1979).

Going back to the eye-brain system, students who have well-connected and well-represented associations are able to link new information more easily with a more established knowledge base (Searleman & Herrmann, 1994). The average and high students performed well on their test scores because of strong, relevant, prior knowledge of the science content. This quality enabled them to link concepts to pictures with less difficulty.

Betty and Elizabeth, the low-ability students, both exhibited problems linking icons to concepts. These problems were due to the lack of relevant prior knowledge and their unwillingness to learn the needed material in order to evaluate, revise, and restructure their present conceptual structures (Wittrock, 1994). Over time, this task did improve with both of these students due to the constant effort of the teacher in the classroom work sessions. Visual representations within the memory allow one to answer questions. If students have little relevant knowledge, this representation cannot be established (Hohn, 1995). This is one reason why these students' grades remained lower than the rest of the case study group.

Learning involves mental organization. Learner's develop schemas which are stored in the long-term memory (Hohn, 1995). Roundhouse diagramming helps to develop schemas based on science content learned in the classroom by connecting concepts to pictures related to the science content. Icon scores for all of the students in the case study group improved, with the exception of the low-ability students. Willy mastered connecting icons to concepts by Roundhouse diagram No. 8. Carla had no
problems connecting icons to concepts after diagram No. 6. Collin left out icons only on
diagram No. 2 and after that point, connected his ideas very creatively. Marian never
had any problems connecting icons to concepts after the first Roundhouse diagram was
constructed. Betty was still having problems relating icons to concepts until
Roundhouse diagram No. 9, and Elizabeth had problems relating icons to concepts
throughout all 11 diagrams.

Meaningful learning implies that information is well connected in the long-term
memory. Memory involves a series of interrelated mental processes (Hohn, 1995;
Searleman & Herrmann, 1994). Students with well-connected neural networks, such as
Marian, Collin, and Carla, are able to transfer these connections to other areas, such as
linking icons to concepts which are well connected in their cognitive structure.

Betty and Elizabeth both have very weak associations related to classroom
science content. This lack of prior knowledge makes it difficult for them to connect
concepts to icons even in an effective learning environment such as this one. Effective
learning could require the student totally to discard his or her previous concepts within a
topic. Research suggests the best method for correcting a misconception is to identify
the missing associations in such a way that the student is able to visualize the missing
concepts (Novak & Gowin, 1984). If these misconceptions are not recognized, the
learner is unable to make new associations (Wandersee, 1987). Teaching skills, such as
constructing Roundhouse diagrams, helps learners to become metacognitive thinkers.
Many times, I was able to look at students’ faces and see them thinking about what
icons they could link to their concepts. The Roundhouse diagram is a metacognitive
tool that students can use to visualize new connections which directly link to their prior
knowledge (Novak & Gowin, 1984). Before metacognition can take place, the learner must have knowledge that is relevant to the subject matter or learning task (Bonds et al., 1992). This is one reason the low-ability students had problems linking icons to the meaningful learning of concepts.

All of the students were attracted to the drawings of icons, and this additional novelty of drawing pictures, helped them to direct their attention, which aids in the encoding process (Hohn, 1995). When students were unable to link icons to concepts it was because they never learned the material in the first place. The brain is a model builder, and linking icons to concepts helps to construct a knowledge base (Wittrock, 1994). Imagery is a visual way of organizing content. When recall is required, mental visualization of the icons occurs with those students who have well-represented cognitive structures. Conceptual models, such as the Roundhouse diagram, are excellent tools to help students who lack prior knowledge (Hohn, 1995).

Relating icons to concepts is a creative task which requires thinking. This process involves arranging details, solving problems, and elaborating on ideas, which establish strong connections in the neural network of the brain. Creative strategies, such as linking icons to concepts, help students to think instead of memorize (Starko, 1995).

**On-Task / Off-Task**

After the first two weeks of Roundhouse diagram training, this researcher took 35mm photographs of the case study group during Roundhouse diagram construction times. Pictures were taken every ten minutes during three different time periods during the research study. The number of observed times varied because student activities varied. Each child's picture was calculated either on-task for one point or off-task for
zero points, then converted to a percentage. The results were inconclusive and each child’s level of concentration varied. The graphs were created according to percentages (see Figure 6).

Table 28. On-Task / Off-Task

<table>
<thead>
<tr>
<th>Percent On-Task</th>
<th>Based on Interval Photographs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marian</td>
<td>Collin</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>91</td>
<td>83</td>
</tr>
<tr>
<td>100</td>
<td>67</td>
</tr>
</tbody>
</table>

Table 29. On-Task / Off-Task Based on Interval Photographs

<table>
<thead>
<tr>
<th>On-Task / Off-Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marian</td>
</tr>
<tr>
<td>Time Periods</td>
</tr>
<tr>
<td>1st time period</td>
</tr>
<tr>
<td>2nd time period</td>
</tr>
<tr>
<td>3rd time period</td>
</tr>
<tr>
<td>Totals</td>
</tr>
<tr>
<td>Percentage of time off task</td>
</tr>
</tbody>
</table>

Marian’s attention level stayed high and she maintained a high grade-point average. Collin’s attention level went down, but he still maintained an “A” average for the 5th six-weeks period. Note that Collin was an attention-deficit student. Carla’s average level of attention remained high and her grade-point average increased. Billy’s level of
attention increased and so did his grades. Elizabeth’s attention span decreased but her grades increased. Betty’s attention span was inconsistent, just as her grades were.

This graph represents three different time periods in which 35mm photographs were taken during diagram construction times (see Table 30). The total number of pictures was converted into a percentage and is illustrated on the following graph.

Table 30. On-Task Percentages.

<table>
<thead>
<tr>
<th>Time Periods</th>
<th>Marian</th>
<th>Collin</th>
<th>Carla</th>
<th>Willy</th>
<th>Elizabeth</th>
<th>Betty</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Time Period</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>57</td>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td>2nd Time Period</td>
<td>91</td>
<td>83</td>
<td>100</td>
<td>75</td>
<td>73</td>
<td>64</td>
</tr>
<tr>
<td>3rd Time Period</td>
<td>100</td>
<td>67</td>
<td>89</td>
<td>100</td>
<td>61</td>
<td>89</td>
</tr>
</tbody>
</table>

A graphic representation of this analysis has been developed for the reader and appears on the following page (see Figure 6).
Figure 6. On-Task/Off-Task Photographs
CONCLUSIONS

Introduction

The purpose of the present research study was to explore the effects of Roundhouse diagram construction and apply the meaningful learning of science concepts in a 6th-grade science classroom. This researcher examined three sub-questions using qualitative and quantitative methods. An elaborate case study investigation was established in the previous chapter in order to examine how the students' science concepts changed as they became more proficient in constructing the diagrams, what problems they encountered while constructing the Roundhouse diagrams, and how their choices of drawings and icons affected their progress in meaningfully learning science concepts as they constructed a series of Roundhouse diagrams. A timeline progression series of the case study group has been included as a summary of how these students developed over this 10-week research study on the Roundhouse diagramming method.

Timeline Progression Series

Table 31. Willy’s Progress

<table>
<thead>
<tr>
<th>Roundhouse Diagram</th>
<th>Masters Technique</th>
<th>Growth</th>
<th>Needs Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>• goals clear</td>
<td>• grades improved</td>
<td>• left out icons</td>
</tr>
<tr>
<td></td>
<td>• accurate sequence</td>
<td></td>
<td>• group dependent</td>
</tr>
<tr>
<td></td>
<td>• paraphrases well</td>
<td></td>
<td>• no use of “and”/“of”</td>
</tr>
<tr>
<td></td>
<td>• neat</td>
<td></td>
<td>• teacher dependent</td>
</tr>
<tr>
<td>No. 2</td>
<td>• goals clear</td>
<td>• icon score</td>
<td>• teacher dependent</td>
</tr>
<tr>
<td></td>
<td>• accurate sequence</td>
<td>• grades improved</td>
<td>• group dependent</td>
</tr>
<tr>
<td></td>
<td>• paraphrases well</td>
<td>• lab score</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• neat</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• uses “and”/“of”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roundhouse Diagram</td>
<td>Masters Technique</td>
<td>Growth</td>
<td>Needs Improvement</td>
</tr>
<tr>
<td>--------------------</td>
<td>------------------</td>
<td>--------</td>
<td>------------------</td>
</tr>
<tr>
<td>No. 3</td>
<td>- goals clear</td>
<td>- grades improved</td>
<td>- a concept unclear</td>
</tr>
<tr>
<td></td>
<td>- accurate sequence</td>
<td>- asks good questions</td>
<td>- icon repeated</td>
</tr>
<tr>
<td></td>
<td>- paraphrases well</td>
<td></td>
<td>- teacher dependent</td>
</tr>
<tr>
<td></td>
<td>- neat</td>
<td></td>
<td>- misconceptions</td>
</tr>
<tr>
<td></td>
<td>- uses “and”/“of”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 4</td>
<td>- goals clear</td>
<td>- details</td>
<td>- teacher dependent</td>
</tr>
<tr>
<td></td>
<td>- accurate sequence</td>
<td>- clarity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- paraphrases well</td>
<td>- icon score</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- neat</td>
<td>- lab score</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- uses “and”/“of”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 5</td>
<td>- goals clear</td>
<td>- asks good questions</td>
<td>- icons left out</td>
</tr>
<tr>
<td></td>
<td>- accurate sequence</td>
<td>- icons related</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- paraphrases well</td>
<td>- paraphrasing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- neat</td>
<td>- teacher dependent</td>
<td>- off balance</td>
</tr>
<tr>
<td></td>
<td>- uses “and”/“of”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 6</td>
<td>- goals clear</td>
<td>- grades improved</td>
<td>- icon not related</td>
</tr>
<tr>
<td></td>
<td>- uses “and”/“of”</td>
<td>- asks good questions</td>
<td>- paraphrasing</td>
</tr>
<tr>
<td></td>
<td>- good wedge</td>
<td></td>
<td>- teacher dependent</td>
</tr>
<tr>
<td></td>
<td>- sequences</td>
<td></td>
<td>- handwriting</td>
</tr>
<tr>
<td>No. 7</td>
<td>- goals clear</td>
<td>- asks good questions</td>
<td>- icon not related</td>
</tr>
<tr>
<td></td>
<td>- uses “and”/“of”</td>
<td>- paraphrases</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- sequences</td>
<td>- teacher dependent</td>
<td>- handwriting</td>
</tr>
<tr>
<td>No. 8</td>
<td>- goals clear</td>
<td>- grades improved</td>
<td>- icon not related</td>
</tr>
<tr>
<td></td>
<td>- uses “and”/“of”</td>
<td>- asks good questions</td>
<td>- paraphrases</td>
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<td></td>
<td></td>
<td></td>
<td>- teacher dependent</td>
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<tr>
<td>No. 9</td>
<td>- goals clear</td>
<td>- grades improved</td>
<td>- handwriting</td>
</tr>
<tr>
<td></td>
<td>- uses “and”/“of”</td>
<td>- icons related</td>
<td>- paraphrases</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- asks good questions</td>
<td>- teacher dependent</td>
</tr>
<tr>
<td>No. 10</td>
<td>- goals clear</td>
<td>- grades improved</td>
<td>- handwriting</td>
</tr>
<tr>
<td></td>
<td>- paraphrases</td>
<td>- icon score</td>
<td>- teacher dependent</td>
</tr>
<tr>
<td></td>
<td>- uses “and”/“of”</td>
<td>- asks good questions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- good wedge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 11</td>
<td>- icons well related</td>
<td>- grades improved</td>
<td>- paraphrases</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- icon score</td>
<td>- teacher dependent</td>
</tr>
</tbody>
</table>
Willy's grades continued to improve throughout the 10-week Roundhouse diagram training period. He began as an average science student in terms of grades, but I think he had much more potential than he exhibited in a traditionally taught science class. Through the Roundhouse diagram training sessions, he was very teacher dependent as well as group dependent. Willy's hand was always raised asking for assistance. He indicated on his student evaluation sheet that he really enjoyed the Roundhouse diagramming method, but he was struggling a bit with this new metacognitive strategy. The beginning diagrams on food chains and food webs which contained concrete subject matter were easier for him to diagram although the unfamiliarity of the method caused him a few problems relating icons to concepts. His pictures became very detailed, indicating his creativity and his ability to elaborate. His love for science and his inquisitiveness were sparked by the restructuring of information, and he became quite adept with metacognitive learning skills. The training of metacognitive thought processes increases constructive thinking (Wittrock, 1994). His lack of confidence with this method kept him in close contact with his teacher and his peers. He struggled with paraphrasing and putting information into his own words throughout the 10-week period. Billy's grades continued to improve, as did his attention level in class. The challenge of the Roundhouse diagram method helped him to become an above-average science student.
<table>
<thead>
<tr>
<th>Roundhouse Diagram</th>
<th>Masters Technique</th>
<th>Growth</th>
<th>Needs Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>• neat</td>
<td>• grades improved</td>
<td>• goals unclear</td>
</tr>
<tr>
<td></td>
<td>• accurate sequence</td>
<td></td>
<td>• no use of “and”/“of”</td>
</tr>
<tr>
<td></td>
<td>• paraphrases</td>
<td></td>
<td>• teacher dependent</td>
</tr>
<tr>
<td></td>
<td>• good pictures</td>
<td></td>
<td>• icon left out</td>
</tr>
<tr>
<td>No. 2</td>
<td>• goals clear</td>
<td>• goals</td>
<td>• spelling and grammar</td>
</tr>
<tr>
<td></td>
<td>• uses “and”/“of”</td>
<td>• uses “and”/“of”</td>
<td>• teacher dependent</td>
</tr>
<tr>
<td></td>
<td>• neat</td>
<td></td>
<td>• icon not related</td>
</tr>
<tr>
<td></td>
<td>• accurate sequence</td>
<td></td>
<td>• unable to paraphrase</td>
</tr>
<tr>
<td></td>
<td>• icon in each section</td>
<td></td>
<td>• low self-esteem</td>
</tr>
<tr>
<td>No. 3</td>
<td>• neat</td>
<td>• lab score</td>
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</tr>
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<td></td>
<td>• accurate sequence</td>
<td></td>
<td>• misconceptions</td>
</tr>
<tr>
<td></td>
<td>• uses “and”/“of”</td>
<td>• grades</td>
<td>• poor grammar</td>
</tr>
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<td>• paraphrases</td>
<td>• confidence</td>
<td>• teacher dependent</td>
</tr>
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<td>• icons better related</td>
<td></td>
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<td>• better</td>
<td>• goals unclear</td>
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<td>• accurate sequence</td>
<td></td>
<td>• no use “and”/“of”</td>
</tr>
<tr>
<td></td>
<td>• good pictures</td>
<td>• paraphrasing</td>
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<td></td>
<td></td>
<td>• confidence</td>
<td>• left out one icon</td>
</tr>
<tr>
<td></td>
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<td>• more unique</td>
<td>• group dependent</td>
</tr>
<tr>
<td>No. 5</td>
<td>• goals clear</td>
<td>• goals</td>
<td>• poor grammar</td>
</tr>
<tr>
<td></td>
<td>• uses “and”/“of”</td>
<td></td>
<td>• grades down</td>
</tr>
<tr>
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<td>• neat</td>
<td></td>
<td>• misconceptions</td>
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<td>• accurate sequence</td>
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<td>• teacher dependent</td>
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<td>• goals</td>
<td>• no use of “and”/“of”</td>
</tr>
<tr>
<td></td>
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<td>• grades up</td>
<td>• poor grammar</td>
</tr>
<tr>
<td></td>
<td>• accurate sequence</td>
<td></td>
<td>• teacher dependent</td>
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<tr>
<td></td>
<td>• good wedge</td>
<td>• confidence</td>
<td>• repeated icons</td>
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<td>• paraphrases</td>
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<td></td>
</tr>
<tr>
<td>No. 7</td>
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<td>uses “and”/“of”</td>
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</tr>
<tr>
<td>No. 8</td>
<td>goals clear</td>
<td>concepts related to icons</td>
<td>neat</td>
</tr>
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<td>No. 9</td>
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<td>neat</td>
<td>paraphrases</td>
</tr>
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<td>No. 10</td>
<td>uses “and”/“of”</td>
<td>paraphrases</td>
<td>neat</td>
</tr>
<tr>
<td>No. 11</td>
<td>uses “and”/“of”</td>
<td>clear goals</td>
<td>confident</td>
</tr>
</tbody>
</table>

Elizabeth’s grades began to improve immediately after the Roundhouse diagramming method was employed. She went from making “Ds” and “Fs” to “Cs.” She dropped in performance and made her only “F” when addressing the nitrogen cycle, which was difficult for her to grasp in terms of sequence of events. She had a weak
science background, and traditional methods of learning textbook material from one point of view did not effectively motivate Elizabeth to perform well in class (Wittrock, 1994). Metacognitive learning skills helped her to monitor her own learning and thus extend her thinking capabilities. This method was very challenging for her and she required much assistance. Students who have little prior knowledge about a subject area often resort to rote methods in order to pass, but very little of this material is actually retained (Mintzes & Wandersee, 1998). The Roundhouse diagram focuses on less content and more relationships and connections to the content in order for learning to become meaningful. Elizabeth indicated on her student evaluation sheets that she was attracted to this method of learning but that she was struggling in areas such as relating concepts to icons and paraphrasing information, both of which require skills involving deep understanding to the subject matter. Elizabeth had problems integrating her title and thinking from general to specific, but with training, she progressed. Conceptual change is a time-consuming process, but I think this method is excellent for students with weak cognitive connections in terms of science. Elizabeth had very poor language skills, which made it difficult for her to communicate what she was thinking. She was able to overcome many learning problems and advanced to become an average-level student by the end of the 10-week research training period.
<table>
<thead>
<tr>
<th>Roundhouse Diagram</th>
<th>Masters Technique</th>
<th>Growth</th>
<th>Needs Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>• neat</td>
<td>• grades improved</td>
<td>• left out icons</td>
</tr>
<tr>
<td></td>
<td>• accurate sequence</td>
<td></td>
<td>• no use of “and”/“of”</td>
</tr>
<tr>
<td></td>
<td>• paraphrases</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>• aesthetic</td>
<td></td>
<td>• teacher dependent</td>
</tr>
<tr>
<td>No. 2</td>
<td>• icons well related</td>
<td>• icons in each section</td>
<td>• teacher dependent</td>
</tr>
<tr>
<td></td>
<td>• goals clear</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• uses “and”/“of”</td>
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<td></td>
<td>• neat</td>
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<td>• paraphrases</td>
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<tr>
<td></td>
<td>• aesthetic</td>
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</tr>
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<td>No. 3</td>
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<td>• artistic</td>
<td>• group dependent</td>
</tr>
<tr>
<td></td>
<td>• goals clear</td>
<td></td>
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<tr>
<td></td>
<td>• accurate sequence</td>
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<td></td>
<td>• uses “and”/“of”</td>
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<td></td>
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<td>• paraphrase</td>
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<td></td>
<td>• aesthetic</td>
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</tr>
<tr>
<td>No. 4</td>
<td>• icons related</td>
<td>• good vocabulary</td>
<td>• goals unclear</td>
</tr>
<tr>
<td></td>
<td>• goals clear</td>
<td>• movement</td>
<td>• no use of “and”/“of”</td>
</tr>
<tr>
<td></td>
<td>• accurate sequence</td>
<td>• arrows</td>
<td>• poor grammar</td>
</tr>
<tr>
<td></td>
<td>• uses “and”/“of”</td>
<td>• higher-order thinking</td>
<td>• left out one icon</td>
</tr>
<tr>
<td></td>
<td>• neat</td>
<td>• independent</td>
<td>• group dependent</td>
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<tr>
<td></td>
<td>• paraphrases</td>
<td>• metalearning (Novak &amp; Gowin, 1984)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• aesthetic</td>
<td>• higher-order thinking</td>
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<tr>
<td>No. 5</td>
<td>• icons well related</td>
<td>• grades improved</td>
<td>• thinking general to specific</td>
</tr>
<tr>
<td></td>
<td>• goals clear</td>
<td>• good vocabulary</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• uses “and”/“of”</td>
<td>• movement</td>
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<td>• neat</td>
<td>• arrows</td>
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<tr>
<td></td>
<td>• accurate sequence</td>
<td>• higher-order thinking</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• paraphrases</td>
<td>• independent</td>
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</tr>
<tr>
<td></td>
<td>• aesthetic</td>
<td>• metalearning (Novak &amp; Gowin 1984)</td>
<td></td>
</tr>
</tbody>
</table>

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(Table 33 continued)

<table>
<thead>
<tr>
<th>No. 6</th>
<th>icons well related</th>
<th>goals clear</th>
<th>uses “and”/“of”</th>
<th>neat</th>
<th>accurate sequence</th>
<th>paraphrases</th>
<th>aesthetic</th>
<th>grades improved</th>
<th>good vocabulary</th>
<th>movement</th>
<th>arrows</th>
<th>higher-order thinking</th>
<th>independent</th>
<th>metalearning (Novak &amp; Gowin, 1984)</th>
<th>faster</th>
<th>more independent</th>
<th>no use of “and”/“of”</th>
<th>poor grammar</th>
<th>teacher dependent</th>
<th>repeated icons</th>
</tr>
</thead>
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</tr>
<tr>
<td>No. 7</td>
<td>icons well related</td>
<td>goals clear</td>
<td>uses “and”/“of”</td>
<td>neat</td>
<td>accurate sequence</td>
<td>paraphrase</td>
<td>aesthetic</td>
<td>good sequence</td>
<td>grades improved</td>
<td>good vocabulary</td>
<td>movement</td>
<td>arrows</td>
<td>higher-order thinking</td>
<td>independent</td>
<td>metalearning (Novak &amp; Gowin, 1984)</td>
<td>thinking general to specific</td>
<td>faster</td>
<td>more independent</td>
<td>helping others</td>
<td>teacher dependent</td>
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<tr>
<td>No. 8</td>
<td>goals clear</td>
<td>concepts related to icons</td>
<td>neat</td>
<td>paraphrases</td>
<td>icon scores</td>
<td>grades up</td>
<td>independent goals</td>
<td>confidence</td>
<td>more unique</td>
<td>grammar</td>
<td>paraphrases</td>
<td>good understanding</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>no use of “and”/“of”</td>
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</tbody>
</table>
Carla began as an average student in science, but she had a strong background in language skills which accommodated the Roundhouse diagramming method. Her attention level was very strong and her interest in the new method was high, which helped her encode information easily (Hohn, 1995). Carla exhibited many
metacognitive learning skills and the Roundhouse diagram helped her to visualize new connections in order to link previous knowledge (Gunstone & Mitchell, 1998). She was extremely talented in artistic abilities and her neatness and beautiful handwriting made her Roundhouse diagrams very attractive to the eye. Her icons were always very thoughtfully connected to her concepts, which contributed greatly to her being able to remember what she had created. Research indicates that images enhance the memory (Hohn, 1995). The Roundhouse diagram helped students to transform abstract concepts into concrete information. Paivio discovered that concrete information is remembered more easily than abstract information (1986). Carla’s answers in her classroom assessments indicated metalearning skills which exhibited exact wording and organization which transferred from her diagrams to her test pages (Novak & Gowin, 1984). Carla’s ability to be concise and direct helped her to diagram information effectively. Carla progressed from being an average science student to being above average in science over the 10-week training period.

Table 34: Collin’s Progress

<table>
<thead>
<tr>
<th>Roundhouse Diagram</th>
<th>Masters Technique</th>
<th>Growth</th>
<th>Needs Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>• goals clear</td>
<td>• improved grades</td>
<td>• does not use “and”/“of”</td>
</tr>
<tr>
<td></td>
<td>• concise</td>
<td></td>
<td>• handwriting</td>
</tr>
<tr>
<td></td>
<td>paraphrasing</td>
<td></td>
<td>• teacher dependent</td>
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<tr>
<td></td>
<td>• icons well related</td>
<td></td>
<td></td>
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<td></td>
<td>• sequences</td>
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<td>• neat</td>
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<td>• arrows used to</td>
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<td>enhance</td>
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</tr>
<tr>
<td>No. 2</td>
<td>• goals clear</td>
<td>• independent</td>
<td>• left out icons</td>
</tr>
<tr>
<td></td>
<td>• concise</td>
<td></td>
<td>• spelling</td>
</tr>
<tr>
<td></td>
<td>paraphrasing</td>
<td></td>
<td>• handwriting</td>
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<tr>
<td></td>
<td>• icons well related</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>icons well related</td>
<td>concise paraphrasing</td>
<td>sequences</td>
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<td>7</td>
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</tbody>
</table>
Collin began the Roundhouse diagram training period as a “B-average” student. He is a very intelligent, serious-minded learner who has the potential to be an excellent student. Collin is the type of student who needs to be challenged, and traditional methods of teaching science did not seem to stimulate him to perform to his maximum ability level. Collin adapted easily to the new Roundhouse diagramming method. His thinking was stimulated and the work became challenging. His spelling and handwriting problems were trivial to him. At one point, I suggested to him to change the word on “food chane” to “c-h-a-i-n.” He told me how to correctly spell the word...
before I even finished my sentence. To him, this part seemed unimportant. The metacognitive learning skills Collin was deriving from the Roundhouse diagramming method were stimulating him and helped him pay attention in the beginning. Studies have been performed using novelty of new methods with attention-deficit students. It has been found that novelty aids in mindful attention and thus enhances performance (Langer, 1997). The Roundhouse diagram is metacognitive in nature because it involves the learner making decisions which result in the development of a learning experience (Gunstone & Mitchell, 1998). Collin’s grades progressed from “Bs” to “As” with the exception of one test near the end of the study. His attention levels began to drop as well, which suggested to me that he had probably mastered this technique. It is always helpful not to overwork any one teaching method (White, 1998). Collin’s test papers exhibited metalearning and visual representations of the diagrams (Novak & Gowin, 1984). Collin’s well-connected neural network and his strong, relevant prior knowledge helped provide a strong anchor in order to connect new information (Mintzes & Wandersee, 1998).

Table 35. Marian’s Progress

<table>
<thead>
<tr>
<th>Roundhouse Diagram</th>
<th>Masters Technique</th>
<th>Growth</th>
<th>Needs Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>• goals clear</td>
<td>• grades improved</td>
<td>• teacher dependent</td>
</tr>
<tr>
<td></td>
<td>• uses “and”/“of”</td>
<td></td>
<td>• left out icon</td>
</tr>
<tr>
<td></td>
<td>• neat</td>
<td></td>
<td>• group dependent</td>
</tr>
<tr>
<td></td>
<td>• accurate sequence paraphrases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 2</td>
<td>• goals clear</td>
<td>• creative</td>
<td>• teacher dependent</td>
</tr>
<tr>
<td></td>
<td>• uses “and”/“of”</td>
<td>• all icons</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• accurate sequence paraphrases</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• icons well related</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>No.</th>
<th>Goals Clear</th>
<th>Uses “and”/“of”</th>
<th>Neat</th>
<th>Accurate Sequence</th>
<th>Paraphrases</th>
<th>Good Wedge</th>
<th>Outside References</th>
<th>Leader in Group</th>
<th>Direct</th>
<th>Concise</th>
<th>Creative</th>
<th>Independent</th>
<th>Metalearning (Novak &amp; Gowin, 1984)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 3</td>
<td>• goals clear</td>
<td>• uses “and”/“of”</td>
<td>• neat</td>
<td>• accurate sequence</td>
<td>• paraphrases</td>
<td>• icons well related</td>
<td>• asks good questions</td>
<td>• icons well related</td>
<td>• creative</td>
<td>• teacher dependent</td>
<td>• group dependent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 4</td>
<td>• goals clear</td>
<td>• uses “and”/“of”</td>
<td>• neat</td>
<td>• accurate sequence</td>
<td>• paraphrases</td>
<td>• icons well related</td>
<td>• thinking general to specific</td>
<td>• organized</td>
<td>• high concentration</td>
<td>• more independent</td>
<td>• metalearning (Novak &amp; Gowin, 1984)</td>
<td>• group dependent</td>
<td></td>
</tr>
<tr>
<td>No. 5</td>
<td>• goals clear</td>
<td>• uses “and”/“of”</td>
<td>• neat</td>
<td>• accurate sequence</td>
<td>• paraphrases</td>
<td>• leader in group</td>
<td>• concise</td>
<td>• creative</td>
<td>• independent</td>
<td>• metalearning (Novak &amp; Gowin, 1984)</td>
<td>• uses outside references</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 6</td>
<td>• goals clear</td>
<td>• uses “and”/“of”</td>
<td>• neat</td>
<td>• accurate sequence</td>
<td>• paraphrases</td>
<td>• good wedge</td>
<td>• leader in group</td>
<td>• direct</td>
<td>• concise</td>
<td>• creative</td>
<td>• independent</td>
<td>• metalearning (Novak &amp; Gowin, 1984)</td>
<td></td>
</tr>
<tr>
<td>No. 7</td>
<td>• goals clear</td>
<td>• uses “and”/“of”</td>
<td>• neat</td>
<td>• accurate sequence</td>
<td>• paraphrases</td>
<td>• good wedge</td>
<td>• nice symbols</td>
<td>• faster</td>
<td>• more focused</td>
<td>• independent</td>
<td>• uses outside references</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Marian began the Roundhouse diagramming method as a high-level student and maintained her high achievement level. She was challenged by the new method and was very focused, producing high attention levels in class. The Roundhouse diagram provided novelty by using stimuli that she had never encountered. This novel quality helped to hold her attention. Marian already possessed good organizational skills, but the Roundhouse diagram helped her to organize material according to meaning. She had an amazing ability to chunk information. George Miller (1986) suggested that learning occurs as a result of restructuring knowledge in an attempt to discover the most significant relationships (Bruer, 1993). When recall is required, most learners try to organize information into some form easy to memorize (Hohn, 1995). Marian
possessed metalearning skills which enhanced her mental visualization of the material exactly as it appeared in the diagram (Novak & Gowin, 1984). Organizing material into a single unit such as the Roundhouse diagram helps to transform verbal content into a mental image so that the learner is able to retrieve it easily (Paivio, 1986). Marian had fewer problems than any of the case study group members, but she also maintained the highest average of all the students before the training began.

Table 36: Betty’s Progress

<table>
<thead>
<tr>
<th>Roundhouse Diagram</th>
<th>Masters Technique</th>
<th>Growth</th>
<th>Needs Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>• neat • goals clear • paraphrases • sequences</td>
<td>• grades improved</td>
<td>• left out icons • grammar • teacher dependent • icon not related • no use of “and”/“of” • misconceptions</td>
</tr>
<tr>
<td>No. 2</td>
<td>• goals clear • paraphrases • sequences • uses “and”/“of”</td>
<td></td>
<td>• not complete • icons not related • spelling and grammar • teacher dependent</td>
</tr>
<tr>
<td>No. 3</td>
<td>• icons related • goals clear • uses “and”/“of” • icon in each segment • good sequence</td>
<td>• good detail • good icons • grades up</td>
<td>• poor grammar • repeated icons • teacher dependent • group dependent</td>
</tr>
<tr>
<td>No. 4</td>
<td>• paraphrases • sequences</td>
<td></td>
<td>• no goals • no title • no icons • no effort • icons not related • grades</td>
</tr>
</tbody>
</table>
| No. 5 | • paraphrases  
• goals clear  
• sequences  
• neat  
• uses “and”/“of” | • good detail  
• good icons |  |
| No. 6 | • goals clear  
• paraphrases | • no use of  
“and”/“of”  
• repeated icons  
• misconceptions  
• incomplete concepts  
• little effort |  |
| No. 7 | • neat  
• sequences  
• paraphrases  
• uses “and”/“of”  
• goals clear | • more effort  
• independent | • repeated icons  
• poor grammar  
• grades low  
• inconsistent |
| No. 8 | • uses “and”/“of”  
• paraphrases  
• good pictures  
• goals clear | • effort  
• independent | • misconception  
• icons not related  
• poor grammar |
| No. 9 | • uses “and”/“of”  
• paraphrases  
• good pictures  
• goals clear | • effort  
• grades improved  
• independent | • icons unrelated  
• poor grammar |
| No. 10 | • uses “and”/“of”  
• paraphrases  
• good pictures  
• goals clear | • great icons  
• good color  
• grammar  
• independent | • grades dropped  
• inconsistent |
| No. 11 | • uses “and”/“of”  
• icons in each  
• segment  
• goals clear | • details  
• independent | • grades improved  
• inconsistent  
• overcrowded  
• paraphrasing |

Betty’s grades did not improve with the Roundhouse diagramming method. The restructuring process of evaluating the material, revising the information, and diagramming was much more work than Betty was willing to do. I do think she definitely had the potential to perform better work. Outside problems interfered with
her concentration levels and consistency of grades in the learning environment. She possessed weak associations with science content and was unable to make new connections without the willingness to relearn the material she missed in the first place (Wandersee, 1987). There were repeated signs of misconceptions within her diagrams. Her poor language background made it difficult for her to communicate her ideas which were often faulty in the first place. In the past, with traditional methods, Betty probably was able to rely on rote learning methods in order to pass, but in a meaningful learning environment, she found herself helpless (Mintzes & Wandersee, 1998). Students who are able to succeed with memorizing facts are often unable to transfer this knowledge to other contexts (Langer, 1997). There were times when her diagrams were good and her attention level was high. Those times did show an increase in grade-point improvement.

Overall, the time line progression series revealed some generalizations about the different performance levels. The low-ability students, Betty and Elizabeth, began the Roundhouse diagramming method with weak prior knowledge structures. Learners who develop well-represented cognitive structures are meaningful learners, and those students who have relied on rote learning are unable to develop these structures and transfer their learning to other learning contexts (Novak, 1998). The Roundhouse diagram did help both students in terms of constructing knowledge and thinking on their own, but without the willingness to undergo conceptual change, meaningful learning cannot occur (Mintzes & Wandersee, 1998). On-task/off-task behavior plots (see Figure 6) indicated inconsistent levels of concentration and the inability to stay on-task over the 10-week time period. Oftentimes, as educators we must create an environment where students are able to succeed. Many times, low-ability students formulate a
negative perception about themselves which greatly affects their self-esteem and their motivation in school. Self-esteem is a crucial factor in learning, especially at the middle school level (Bruer, 1993; Barman et al., 1982).

The average learners, Carla and Willy, both had very high potential to do well before the Roundhouse diagram training, but both students were apparently unstimulated using traditional learning methods where information is presented from a single perspective and there is little room for creativity (Langer, 1997). The middle school student needs to learn facts but needs to make connections and assimilate these facts into their cognitive structure. The Roundhouse diagram aided in this connectionist development for these students and created a network for them within which they could be creative. Both Willy and Carla had strong prior knowledge, but neither of them applied themselves before exposure to this method. Both students exhibited metacognitive learning skills such as re-reading, asking questions, and elaboration (Bonds et al., 1992). Both students exhibited creative details in their work indicating they understood the material being learned (Starko, 1995). Carla portrayed higher-order thinking skills by creating mental models of the diagrams which transferred to her test answers (Novak & Gowin, 1984). Willy showed higher-order thinking skills by his inquisitive nature and questioning techniques exhibited in the classroom. Willy's concentration level continued to excel throughout the same time period. Carla exhibited a high level of concentration throughout the 10-week study. I think most average students have more potential than meets the eye. More educators need to study the principles of cognition and apply what they learn to how information is presented to students (Bruer, 1993).
The high-level students, Marian and Collin, have developed well-organized knowledge structures and have produced meaningful learning in this science classroom environment (Novak, 1998). Both students were able to integrate and assimilate their scientific factual knowledge in an organized unit using the Roundhouse diagrams. Storing knowledge into a structure which allows mental visualization of the information aids in increasing the relationship between thinking and information processing (Paivio, 1986). When information is presented in a manner which promotes connections, learning becomes a powerful process (Bruer, 1993). Meaningful learning increases the ability to store and access information. Our knowledge is represented in patterns due to neural activation of numerous interconnected brain cells (Solso, 1994). If a learner possesses strong connections which are determined by experience and learning, interpretation of this prior knowledge will yield greater understanding (White, 1998).

For learners who have a strong knowledge base, such as Marian and Collin, meaningful learning activities challenge their potential, resulting in creative critical thinking strategies. Both of these students perform well in problem-solving situations and learning transfers from subject to subject as well as to environments outside of the classroom. Marian has a much longer attention span probably due to the fact that Collin has an attention-deficit disorder (see Figure 6). This quality may have contributed to her higher grade-point average pre-Roundhouse diagram training. Both students had acquired skillful visual abilities, which aided in the metalearning process exhibited on their test answers (Novak & Gowin, 1984). It appeared that the Roundhouse diagramming method had motivated both students to enhance their learning of science.
content and perform metacognitive learning skills which helped to facilitate conceptual change.

*Comparative Case Study Analysis*

Stratified purposeful sampling was used in this research study in order to choose the case study group (see Appendix M). Collin and Marian had the highest overall grade-point averages in the class. Marian's overall average was the highest and Collin was a "B-average" student. Carla and Willy represented the average students based on their overall grade-point averages and science grades. Betty and Elizabeth were the low-level students in this group.

In the beginning of the 10-week Roundhouse diagram research study, all of the students achieved their lowest diagram construction grades because this was a new skill. All of their grades improved on the first test over their first two Roundhouse diagrams. Willy, Collin, Marian, and Betty were able to state their goals clearly on their first diagrams. Collin was the only student who did not leave any icons out on the first diagrams. He clearly related each icon to each concept and he began to improve immediately. All of the students were teacher dependent through the first few diagrams with the exception of Collin. Right from the start he connected to this learning method in a very positive manner.

Carla and Marian had mastered the Roundhouse diagram technique and had become less teacher dependent by diagram No. 3. Carla, Marian, and Collin all exhibited "metalearning" characteristics on their test papers (Novak & Gowin, 1984). They mentally pictured their diagrams and their test papers exhibited indications of this quality. Marian’s essay answer exhibited numbers one through seven as if she were
envisioning her diagram section by section. (see Appendix EE). They also exhibited creative characteristics portrayed by details and uniqueness of ideas. Willy’s progress with the diagram was slow because of the teacher dependency he exhibited in class, but his test grades began to really improve. By diagram No. 5, Willy had mastered all of the learning tasks the diagram required with the exception of chunking.

Betty and Elizabeth had many problems with misconceptions through diagram No. 9. They both had little or no prior knowledge of the science subject matter taught in class. They both were not willing to take responsibility to find out what their definitions meant, so that they were capable of linking icons to their concepts. Despite this characteristic, Betty’s test scores and diagram scores continued to be very inconsistent. She would do really well one day and poorly the next. Nevertheless, progress was being made in some areas including her ability to write paragraphs. Both girls had a very poor language arts backgrounds and many grammar problems. Elizabeth continued to try her best even with her difficulties in learning and her grades continued to improve. All of the students’ grade-point averages went up over this 10-week period except for Betty.

Willy continued to have specific problems related to chunking after the 5th diagram. Elizabeth and Betty continued to have language problems. Collin continued to have spelling problems. Marian and Carla mastered the technique.

Collin, Carla, and Marian achieved “A” averages their 5th six-weeks grading period. Willy attained a “B” overall average for the 5th six-weeks. Elizabeth improved with a “C” overall average, and Betty’s grades went down from a “C” to a “D” for the 5th six-weeks period (see Appendix P).
Various statistical tests were performed in order to answer the major research question, Does constructing and using Roundhouse diagrams affect the meaningful learning of science concepts by middle school students?

A paired t-test was performed on several pre/post-scores using data from the case study group and the whole class. For the case study group, all post-averages were higher than the pre-averages but only test Nos. 5 and 7 were significantly higher. These tests specifically compared the first three tests of the 4th six-weeks period (pre-Roundhouse diagramming method) with the first three tests of the 5th six-weeks period (post-Roundhouse diagramming method), with no diagram scores included.

For the whole class, the same paired t-tests, when performed using data, were significant in all but one case. In a test comparing the 1st through 3rd six-weeks period average with diagram score excluded (post-Roundhouse diagramming method) leaving out the 4th six-weeks period, and considering it as a transitional period, the 5th six-weeks average was higher, but it was not significantly higher. However, if we include the 4th six-weeks average (excluding the diagram grade) in the post-average, the difference does become significant. No matter how the grades were combined, the post-averages were higher than the pre-averages, and in most case, post-averages were significantly higher. It appears that overall grades during the Roundhouse diagram training period were higher for the whole class as a unit than the grades were in the previous part of the year. I think this is due to the meaningful learning of science content acquired through using and constructing Roundhouse diagrams in order to break down difficult science concepts. The Roundhouse diagram helps learners to organize, evaluate, and revise
expository information and has proven to be a successful learning strategy (Trowbridge & Wandersee, 1998). However, I do acknowledge that, in part, the Hawthorne effect may have been operative, based on the fact that the participants were aware that they were involved in a research study, and were receiving special attention. There is a great deal of positive evidence indicating that the Roundhouse diagram is in need of follow-up research studies and is, indeed, worthy of recommended research.

An Analysis of Variance (ANOVA) was performed in order to examine the average test scores for the case study group and the whole class in order to determine if grades increased during the 10-week duration. ANOVAs for both groups were not significant (case study group, p=0.312; whole class, p=0.287) resulting in no significant difference between all test averages. The whole class revealed a stronger trend of an upward increase than the case study group, although the results were not significant. These results may be attributed, in part, to the small size of the case study group.

After the 10-week Roundhouse diagram training period, an Analysis of Variance was performed to examine the increase in test scores and diagram scores as the students improved in the Roundhouse diagramming method. The test scores did not reveal a strong trend upwards and the ANOVA was not significant. There was no significant difference between any pairs of average test scores. This result may be attributed to the fact that the material covered on each test was different, with some concepts being more difficult and more abstract than others. Another point to consider is that the format of the tests varied from one test to the next. The classroom teacher had previously used multiple choice, true-false questions, and fill-in-the-blank tests using a word bank. This type of test is generally used in rote memorizing strategies. About mid-way through the
Roundhouse diagram method, the teacher began to use more essay-type testing procedures based on the fact that the Roundhouse diagram covered a general-to-specific-type of thinking and would be more accurately measured in terms of essay-type answers.

An Analysis of Variance (ANOVA) was performed in order to examine the average diagram scores for the case study group and the whole class. A comparison of diagram scores resulted in significant differences for both groups as ANOVAs were significant (case study group, $p=0.027$; whole class, $p=0.016$). Hence significant differences between average diagram scores existed, and since average scores were increasing over time, conclusions indicated diagram scores did improve during the 10-week Roundhouse diagramming session. Therefore, constructing and using Roundhouse diagrams did affect meaningful learning of science concepts by middle school students.

The Analysis of Variance performed on the diagram scores did increase and the ANOVA was significant. I think this increase was attributed to a greater understanding of the diagramming method on the students' part over the 10-week period. The format of the diagram and the method of grading was consistent for all diagrams, and thus an improvement in diagramming was clearly reflected in a higher score.

Three subquestions were asked to help make these conclusions stronger: subquestion No. 1—How do students’ science concepts change as they become more proficient in constructing Roundhouse diagrams? In quantitative terms, the researcher examined the relationship between the mastery of technique scores (lab grades in the 5th six-weeks) and the corresponding test scores. The mastery of technique scores indicated
a measure of how well the students mastered the technique of constructing the
Roundhouse diagrams based on 10 predetermined qualifications. The corresponding
test scores represented how meaningfully the students learned the science content.
There were five mastery of technique lab grades but they corresponded with only three
test grades for the whole class. A Pearson’s correlation coefficient was calculated on
all diagram test pairs for each test. For the whole class, $r = .08$ ($p = 0.5433$) and was not
significant.

The case study group was graded on all 11 diagrams (even though only five
calculated as lab grades). A Pearson’s correlation coefficient was calculated on all
diagram test pairs for each test, so 11 diagrams were compared to six test scores. For
the case study group, $r = 0.55$ ($p = .0004$) and was significant. In conclusion, to
subquestion No. 1, it appeared that students’ science concepts changed as they became
more proficient in constructing Roundhouse diagrams, for the case study group using all
diagram and all test scores.

An inherent problem in calculating the Pearson’s correlation coefficient was
the small scale for the diagram scores. The scale of 0 - 20 made it difficult to detect
differences when paired with test scores on a 0 - 100 scale. For the whole class,
diagram scores ranged from 16 - 20 and were mostly whole numbers, whereas test
scores ranged from 52 - 106. The near-0 value of the Pearson’s $r$ reflects the lack of
linear relationship between diagram scores and test scores, which I think is due mainly
to the small scale for the diagram scores. The Pearson’s correlation coefficients for
the test-diagram pairs for the case study group were positive and, in some cases,
significant. So there exists a positive relationship between diagram scores and test
scores for the case study group. However, confounded in this coefficient were the three different academic levels of the students. High-achieving students do well on the diagrams and on the tests due to their strong, relevant prior knowledge, whereas low-achieving students do not do as well on the diagram and test scores due to weak associations resulting in weak interpretation. A good linear relationship existed and hence a positive, significant Pearson's $r$ correlation coefficient. When considering a student individually, there was not enough variation in the diagram scores to be a good indicator of how well he or she would do on a test. In terms of future research, a larger scale for diagram scores would give us more insight into the diagram/test relationship.

After thoroughly analyzing the case study group and examining their progress over the 10-week Roundhouse diagram training period, all of the students' grades, with the exception of one, improved using this method. Most of the case study group exhibited metacognitive learning skills such as re-reading, checking back, asking questions, working on their own, listening and following directions, revising their work, evaluating, analyzing, and making decisions as to what to add or delete from their diagrams. This type of strategy leads to conceptual change within all ability levels (Wittrock, 1994). The Roundhouse diagramming method provided opportunities for creativity as well as problem solving rather than focusing on rote memorization. Meaningful learning involves information processing and mental/visual abilities affecting how learners encode, interpret, and acquire new associations (Mintzes & Wandersee, 1998).

For subquestion No. 2—What problems do students encounter in mastering the technique associated with construction of Roundhouse diagrams? According to student
evaluation sheets throughout this research study and triangulation of sources, the major
problems associated with the construction of Roundhouse diagrams were: extracting the
main ideas from the textbook science lesson without teacher assistance, reasoning from
general to specific in relation to integrating the title using the “and” and “of” words,
chunking sentences effectively, and sequencing events in an accurate order.

The students in the 6th-grade science class were traditionally taught to read their
textbooks, answer questions in the back of the chapter, memorize their facts, and to
perform assessments on the end of the chapter questions. Students were rarely asked to
think on their own or to share a part in evaluating their own progress within a learning
situation. I think this additional personal, individual responsibility is important at the
middle school level. Metacognitive learning is a time-consuming process, but
eventually results in an informed, self-directed approach (Wittrock, 1994). Learners
become responsible whenever they have control over their own thought processes
during learning (Gunstone, 1994). Strategies such as these increase confidence,
decision making, and eventually, self-esteem, which is most needed at the middle
school level.

The students who had the most problems with meaningfully learning science
concepts were the low-ability students. This was due to the fact that there were very
weak associations due to their lack of experience and thought previous to interpretation
(Searleman & Herrmann, 1994). Students without relevant prior knowledge must be
willing to relearn the material in a meaningful manner in order to make connections to
new information (Mintzes & Wandersee, 1998.)
For subquestion No. 3—How do students’ choices and drawings of iconic images affect their progress in meaningfully learning science concepts as they construct a series of Roundhouse diagrams? A Pearson’s r correlation coefficient was calculated on icon scores paired with meaningful concept scores for the case study group. A coefficient $r = 0.56$ which indicates that the greater the icon score, the greater the concept score. Note, $r = .55$ is significant under $H_0: \rho = 0$ ($p = .0004$). In conclusion, this research study indicated that the more directly related the concept in the Roundhouse diagram was to an appropriate icon, the higher the icon score. Based on empirical evidence, when students generate their own visual representations, attention is facilitated, which is the first step in the encoding process (Hohn, 1995). Whenever verbal or written information is transformed into a visual form, the mental image includes things which are remembered. In the Roundhouse diagramming process, learners chunk scientific information and then link the restructured concept to an icon, which promotes a dual-coding function, which, in turn enhances recall, and results in meaningfully learning science concepts (Paivio, 1986). Overall, it appears that a positive relationship existed between the icon scores and the meaningful concept scores for the case study group.

The students in this 6th-grade science classroom were exposed to a hands-on method of learning pre-Roundhouse diagram training, but they still learned science from a single-track method of student-to-textbook, reading, memorizing, and testing-type of approach. The novelty of using a new kind of learning method stimulated many of these students within all of the learning ability levels, and stimulating attention enhances the encoding process (Hohn, 1995; White, 1988). The fact that the Roundhouse diagram was designed and based on research in neuroscience and visual
cognition also connected learning processes with memory and information processing (Trowbridge & Wandersee). My research study reveals that reconstructing and organizing knowledge in a Roundhouse diagram is an effective encoding strategy which enhances retrieval of information. The circular shape, the simple lines, the chunking of the concepts, and relating the concepts to icons are all useful in the process of forming a mental picture. Research indicates that mental representations of this sort, paired with the written or verbal information, reinforces a type of dual-coding functionality which stimulates greater recall (Paivio, 1986).

**Value and Knowledge Claims**

This research study of middle school science students’ participation in a 10-week research-based Roundhouse diagramming method supported the following knowledge claims. Rich, qualitative data has been inserted in between each of these knowledge claims in order for the reader to gain a greater understanding.

1. Middle school participants in the construction of Roundhouse diagrams gained a greater understanding of science concepts as well as enrichment of meaningful learning techniques.

   During one of the interviews, Marian said, “It was not a problem to chunk the sentences, it’s just finding the right sentences.” She was referring to the main ideas (see p. 200) She added, “The Roundhouse diagram forces you to think to find the main ideas” (p. 238). Collin said he liked the Roundhouse diagram because it provided a summary of the lesson to be learned (see p. 200). Carla said, “The Roundhouse diagram is fun and easy. It is helpful and it helps me to remember things” (p. 272).
2. Students gained an understanding of science concepts in terms of whole/part relationships.

I asked Elizabeth how the diagramming method was helping her to do better in class. She said, “Because it helps me to apply my information in shorter words where I can understand them, and pictures to see” (see p. 202). Another comment made by Marian was, “If you study the diagram, it’s like you’re studying the whole lesson, but only in few words” (see p. 238). Marian has the ability to break down concepts into their parts (see p. 214). Willy said, “The diagram helps me to break down stuff” (see p. 241).

3. Students developed mastery of technique in constructing Roundhouse diagrams. Betty said, “I’m starting to get the hang of it” (see p. 239). Collin said, “It’s coming from my head. I’m thinking and not someone else. The Roundhouse diagram is your creation” (see p. 240).

Marian told me that the Roundhouse diagramming method was getting easier for her, especially finding the main ideas and chunking sentences into her own words (see p. 237). She said chunking sentences was also helping her in reading. She said that doing the diagram was making it easier for her to write (see p. 237). Betty said, “It’s getting easier, but it’s like you gotta think even more about how you’re gonna break it down, or the seven ones you have to break down” (see p. 240).

4. Students demonstrated visual thinking abilities and organizational skills.

I asked Betty what she liked about the diagram and she said, “Because it can help you when you don’t understand something and you can just look and it kind of helps you know better.” She also added, “I learned that drawing pictures would help
you better understand" (see p 197). Willy said, "If you draw good pictures, you’ll be able to remember" (see p. 199). Carla said, "This is the best benefit—I can see my thoughts" (see p. 239). Collin said, "First, I think of the icons for the main ideas and once I get that, it’s really a breeze" (see p. 272). Elizabeth said, "So, like, if you have question on a test, if they don’t have a picture, I can remember it in my head to put down, to know that’s the answer" (see p. 239).

5. Students developed metacognitive learning skills necessary for conceptual change to occur.

Willy said the diagram made him think (see p. 199). Willy said he asked many questions in class (p. 198). Marian asked many questions during the process of building her connections (see p. 206).

6. Student interview tapes supported the idea that meaningful science learning was fostered by reconstruction of knowledge that was learned.

Marian said the diagram helped her to organize her ideas and to put things in order like the sequence of events (see p. 200). I asked Willy what was the biggest problem he had with the diagram. He said it was “hard to, like, after you break it down, it’s hard to figure out, like, how you paraphrase it and stuff, but if you draw good pictures, you’ll be able to remember it (see p. 199).

7. Students valued meaningful learning techniques as opposed to rote learning.

Collin said he easily remembered his diagram and felt the process worked well for him (see p. 201). Carla said, "It feels like we are in college" (see p. 221). Elizabeth said, "My thoughts about the Roundhouse diagram are good because it is helping me
because I am using my brain. It makes me think harder" (see p. 271). Marian felt the Roundhouse diagramming method was very helpful (see p. 270).

8. Student Roundhouse diagram and test score improvement correlated significantly over time.

Elizabeth had language problems, but she was learning science content. She said, “The pictures and how it’s helping me with my grades, ‘cause my grades is improving. I’m not using some else’s brain, it’s my brain” (see p. 239). Willy said drawing pictures helped him and that chunking was getting easier. He added, “I think it helped me with mysterious studying. It helped me to make better grades on my test” (see p. 241).

Emergent Themes

Two themes continued to emerge throughout the 10-week research study of the Roundhouse diagramming method. One constant issue which developed over time involved the changes which took place within the classroom teacher. The other point of interest involved the overall level of concentration within the learning environment as the students became more proficient with the Roundhouse diagramming method.

The teacher was very impatient with the Roundhouse diagramming process in the beginning. After teaching traditionally for many years, she was accustomed to reading the lesson in class with the students, having them participate in a hands-on activity to better understand the subject matter, and then spending a day or two each week answering questions in the back of the textbook. The part that had now changed was the answering questions in the textbook. The students were now doing the Roundhouse diagrams instead.
In the beginning, the Roundhouse diagram worksheets took an entire science period, and the next day would be used for the diagram construction. The teacher felt it was taking too much of valuable class time constructing the diagrams and worksheets. Then the students needed more time out of their usual schedules to evaluate their work and reflect on their diagrams by writing paragraphs in their journals.

After the first few diagrams were completed, she began to see some surprising changes. These slow, nonverbal, low-attention span students began to transform. They started asking questions because their minds were being stimulated. The teacher was constantly needing to research outside references to answer their questions. She noticed the students re-reading their textbooks to check for correct sequence of events. She noticed them re-checking their worksheets for accuracy before putting information into the diagrams. She was unaware of the literature on metacognition (Bonds et al., 1992; Gunstone, 1994; Mintzes & Wandersee, 1998; Wittrock, 1994), but she was pleasantly surprised these metacognitive behaviors were taking place. Her attitude began to change along with the students.

The teacher was most amazed at the fact that she was able to discover misconceptions the students were having prior to test material. Never before the Roundhouse diagram had she been able to see what the students were thinking. The students had become active learners, and she had become an active teacher.

She brought to my attention, on several occasions, that their writing abilities had changed for the better. These students had not been capable of writing sentences on their own and now they were writing paragraphs. Using a combination of the diagrams and the paragraphs, the teacher was able to discover their prior knowledge and their
present misconceptions about the science content. She was able to reteach the material when needed.

The teacher’s assessments changed as well. In the beginning she had given one-answer, fill-in-the-blank questions with word banks. Students could memorize words without knowing the meaning to answer these types of questions. She also gave true/false-type questions, which were not indicative of what a child knows. She had always feared giving essay questions because these students not only could not write, but she was afraid they would not be capable of thinking in general terms to see the whole picture regarding the subject matter. Much to her surprise, these students were beginning to think critically and make associations within the science content. She found out that they were retaining the subject matter and several students began to show evidence of “metalearning” (Novak & Gowin, 1984). They were answering their test questions exactly as they had completed their Roundhouse diagrams.

The other emergent theme was one that the teacher and I both noticed within these particular students. As the teacher commented in her journal notes, these students had very short attention spans and had not paid attention in class before using the Roundhouse diagramming method. Over the duration of this 10-week study, some students maintained excellent levels of concentration. I tried to capture this in the 35mm photographs I took in class, but I was very restricted and did not have the structure to statistically see this evidence. I was able to take the pictures only during the diagram construction times, which varied greatly from week to week. When I analyzed the pictures, it was difficult to tell, at times, if a child was just thinking, or if he or she was actually off-task.
Limitations of the Study

The results of this study were limited in several ways. First, the classroom-based design was not experimental, which required equivalent groups of subjects. The small sample size was not random, but specifically chosen from varying achievement levels in order to enhance the comparisons of the multiple case study evidence. There was no pre-test or post-test to determine students' ability levels. Instead, the classroom teacher deliberately picked these students based on overall grade-point averages, science grades, communication levels, and information richness (see Appendix M).

Second, the choice of classroom teacher and grade-level analysis was deliberate. I wanted to test this technique under optimal instructional conditions, but with a diverse and challenging set of students in a real classroom. This teacher was chosen, not only because of her science experience, but also because she was presently furthering her own education, and exposed to the latest trends in education as well as exposed to graphic organizers, since she was an Educational Specialist in the area of reading. Thus the selection of this teacher was intended to help create an information-rich environment for this particular type of study.

Third, the design also necessitated researcher decisions regarding content area, length of instructional units, and types of assessment materials. Finally, not all the participants were present every day of the 10-week period. Different findings may have been obtained if each student had been present and participating each day of the study. The length of the study was sufficient to determine whether the Roundhouse diagram necessitated further research, but not long enough to transform the low-achieving students into metacognitive learners.
Fourth, there was a high level of abstraction in the later units of science content (energy, forms of energy, and their theoretical behavior). There were additional problems such as, hard-to-observe curriculum topics added to gaining meaningful understanding—even with the use of the Roundhouse diagrams.

Given these limitations, the results of this study indicated that the use of Roundhouse diagrams did enhance the middle school students' science conceptions and meaningful learning. In addition, it appeared that, over time, the students' construction of Roundhouse diagrams did improve and the Roundhouse diagram became a creative tool which promoted metalearning (Novak & Gowin, 1984).

**Transformations in Student Learning**

**Case Study Group**

Based on the construction of 11 Roundhouse diagrams and three wedges, the entire case study group improved in mastery of technique of construction on the Roundhouse diagrams. All but one student improved on overall grade-point averages in science. The higher-achieving students and average-level students improved in area relating to creativity details and metacognition. The high-level and one average student exhibited metalearning traits on test answers (Novak & Gowin, 1984).

Marian was already a high-level student pre-Roundhouse diagram training, but she had never had to think on her own before. She had always been in a traditionally taught learning environment and was never truly challenged. This new method increased her present abilities to organize, paraphrase, sequence events, and to write paragraphs effectively. The new skills she encountered were integration of title and key concepts, making links to icons and concepts, writing goals, and chunking. She became
very detailed, creative, and she developed complexity in her visual thinking abilities. Marian exhibited metalearning characteristics on test answers (Novak & Gowin, 1984).

Collin was an above-average student pre-Roundhouse diagram training. He exhibited traits of a serious-minded student who was unchallenged by traditional teaching methods. He was capable of excellent work, but he made “Bs” in science. Due to his attention-deficit disorder combined with boredom in the classroom, he never met his true potential. The Roundhouse diagram method was novel to him and stimulated his attention (Hohn, 1995; Langer, 1997; Wittrock, 1994). Collin was transformed immediately into an “A-average” student post-Roundhouse diagram training. His ability to link icons to concepts helped him to create mental representations of his written and verbal material (Paivio, 1986). Collin exhibited metalearning traits on his test papers (Novak & Gowin, 1984). He became an active, creative problem solver and a meaningful learner (Starko, 1995).

Carla was an average science student pre-Roundhouse diagram training but she obviously had much more potential. The Roundhouse diagramming method challenged her and motivated her to become an “A” student. Her artistic, organizational skills, and ability to write neatly developed to their highest potential in the Roundhouse diagramming process. Carla took her time and was very thoughtful, which led to her aesthetically pleasing and meaningful diagrams. She exhibited metacognitive learning skills and metalearning traits on her test answers (Novak & Gowin, 1984). She became an integrative, creative thinker. She had incredible strengths in areas related to paraphrasing, chunking, being direct, concise, and putting sentences into her own words. Her diagrams were full of wonderful ideas, details, and complexities.
Willy was an average student pre-Roundhouse diagram training. He liked to play around in class and joke with his classmates. The Roundhouse diagram method captured his attention and was a novel experience for learning (Hohn, 1995; Wittrock 1994). His levels of concentration increased along with his motivation. His inquisitive nature was stimulated and he began asking many higher-order questions along with other metacognitive learning traits (Bonds et al., 1992). He went from average to excellent in his grades in science. He became a detailed, creative, thoughtful learner during the 10-week training period.

Elizabeth was a low-ability student pre-Roundhouse diagram training. Her lack of prior, relevant knowledge in science caused her to resort to rote memorization methods of learning, which rendered her helpless in the beginning of the Roundhouse diagram training period (Mintzes & Wandersee, 1998). Her lack of language skills hindered her ability to write and communicate what she was thinking. Elizabeth was very insecure and had low self-esteem because of her poor performance and low grades in school. Post-Roundhouse diagram training, Elizabeth's self-esteem improved as she became a "C-average" student. She was able to perform skills she was not able to perform prior to this method such as; writing paragraphs effectively, paraphrasing, sequencing events, integrating thoughts, and writing goals. Elizabeth struggled with this new method, but she tried hard and overcame many learning obstacles.

Betty was a low-ability student both pre- and post-Roundhouse diagram training. Her confidence was low due to poor grades and a unfortunate home life. Her self-image improved as did her mastery of technique in constructing the Roundhouse diagrams. She had much more potential than she applied. Her writing and thinking skills
improved. Betty’s grades fell as they had the six-weeks prior to this six-weeks period. She came from another school and was apparently not doing as well as she did at the other school. Outside influences were affecting her progress in this class.

**Whole Class**

The entire class exhibited traits involving the definition of creativity according to Starko (1995). Creativity is a form of problem solving, recognizing the problem, analyzing the problem, making suggestions, and making decisions of selective material in order to solve the problem. Creative ability is the ability to recognize a problem and build connections based on the kinds of information needed to solve it. The product of thinking is related to the Roundhouse diagram because of the discovery of relationships within the system. The students learned to think in terms of whole/part relationships. This process involved the ability to order, to arrange details, and to carry out steps in a reasonable sequence in order to achieve a final product.

The students in this class extended their learning by linking previous knowledge about a topic to new connections within the diagram (Gunstone & Mitchell, 1998; Novak & Gowin, 1984). The diagram allowed the learner to visualize new connections. As a result, metacognitive learning took place and students started to ask questions such as: What have I learned? Have I answered what is needed in order to complete my diagram? Have I integrated the ideas properly? What changes do I need to make? The students in this class began to exhibit strategies such as checking back, self-questioning, and re-reading (Bonds et al., 1992). They became involved to the point that they took charge and did what needed to be done without being told what to do.
The mastery of technique varied with subject matter. The Roundhouse diagrams dealt with a variety of subject matter of which most concepts were abstract. The students had a very difficult time with the nitrogen cycle and the carbon dioxide-oxygen cycle and "What is light?" but on the other hand did very well with reflection and refraction and "What is color?"

The entire class was transformed and became active instead of passive learners. They went from merely following directions to thinking on their own. It appeared that most students were on-task for longer periods of time. The students went from being teacher dependent to group dependent to independent in their work while constructing the Roundhouse diagrams. They all began to learn metacognitive skills, such as participating, questioning, and creating. Their work became creative, artistic, well planned, effective, thoughtful, and meaningful. Most of the students had undergone some level of conceptual change due to the restructuring process of evaluating, revising, and making decisions (Gunstone, 1994). They were operating at higher levels of thinking by problem solving and constructing meaningful learning, as opposed to rote memorization (Langer, 1997). The students went from being bored to being interested, from being quiet to being constructive and conversational, and from being fearful to being successful. Their visual abilities were developed, as well as their abilities to show relationships, connections, and to link new information. There were absolutely no behavior problems, which revealed high levels of interest and attention (Wittrock, 1994). Students' writing abilities improved as they became more skillful at writing paragraphs, paraphrasing, citing the main ideas, sequencing events, writing goals, breaking down concepts, and recalling their diagrams on tests.
The classroom teacher was transformed as well. She also went from being passive to being an active teacher. When the students asked questions, she researched the answers. She went from being doubtful to being confident regarding the Roundhouse diagramming process. She went from thinking the process was too time consuming to appreciating the results. The class went from being teacher centered to being student centered. The teacher went from being a lecturer to being a facilitator, helper, and listener. Her lessons went from being just hands-on experiences to being hands-on, minds-on, and reflective experiences.

Other transformations which took place were predicted prior to the research such as:

1. The transcripts of student responses to the construction of the Roundhouse diagrams became more elaborate and relaxed over time. The student responses were more developed and more on target.

2. The construction of the Roundhouse diagrams had more detail, more connectedness, and more uniqueness over time.

3. The student responses on the Roundhouse diagram worksheets were more direct and connected to the diagrams over time.

4. The students' attitudes and self-esteem improved because their grades increased.

5. The student responses to the mastery of technique were more confident due to the increase in scores.

6. The weekly Roundhouse diagram scores and science class scores revealed a moderate positive correlation.
7. The students' ability to link concepts to iconic images improved as indicated by icon score improvement.

8. The ability to use iconic images to help recall their Roundhouse diagram content improved as indicated by grade improvement.

Evidence of Student Involvement

Student evaluation sheets were written at the end of every teaching and assessment unit. Responses from the students when asked, “What were the most important things learned?” were written on each evaluation sheet. The most repeated comments were:

1. the subject matter
2. how to think
3. how to improve my grades
4. how to write a paragraph
5. how to paraphrase or chunk
6. how to put things in sequential order
7. how to study
8. how to link concepts to icons or drawings
9. how to organize my work
10. how to summarize

The construction of the Roundhouse diagrams stimulated imaginations and curiosity. These students learned that meaningful or mindful learning was much more valued than rote memorization. Learning by rote memorization has little personal meaning and ensures mediocrity (Langer, 1997). Students who generally find

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enjoyment from doing an activity are successful in their engagement with that activity. These students were able to successfully construct the Roundhouse diagrams, which greatly motivated their attention. "One could argue memory is the most meaningful measure of attention" (Langer, 1997, p. 41).

**Educational Implications**

It is a tremendous challenge to teachers as well as learners when strategies are incorporated into the classroom which enhance conceptual change (White, 1988). One way to help promote conceptual change in the science classroom is continually to encourage students to make sense out of their science content. The student who constructs the Roundhouse diagram not only reads the text but also must decide on priorities within the subject matter and think from general to specific as well as create relationships between concepts. The Roundhouse diagram is a visual illustration of a students' progress with understanding science content.

One of the main emphases in graphic organizer research is to elicit the students' prior knowledge and uncover students' alternative conceptions (Smith, 1990; Connor, 1990). Throughout the entire study, the classroom teacher was continually amazed at the amount of misconceptions students held even after the lesson was just presented. Without a visual illustration of the students' misunderstandings, the teacher would pass over the unlearned material and would continue to try to make new connections which would not be established (Wandersee, 1985).

Throughout the construction of the Roundhouse diagram series, the students were faced with making selections and decisions on what to include in their diagrams. "Metacognitive learning is the awareness and control over one's thought processes
during learning” (Wittrock, p. 30, 1994). Students learned how to share their thoughts as well as compare them to other students' thoughts and make decisions based on selecting the most appropriate pictures to link to their concepts. “Conceptual change involves the learner recognizing his/her existing ideas and beliefs, evaluating these ideas, and then personally deciding whether or not to reconstruct these ideas” (Gunstone, 1994, p. 132). The restructuring process in constructing the Roundhouse diagrams included extracting the main ideas, putting these ideas into their own words, connecting these ideas to other ideas, relating pictures to the concepts and then placing them within the diagram. Afterwards the students continued to evaluate their work and reflect upon what they had constructed by writing their summaries.

Furthermore, the construction of the Roundhouse diagram aids in assessing a students’ understanding of a particular concept. The teacher is able to determine if reteaching is necessary before trying to establish new relationships. The Roundhouse diagram provides an excellent tool for assessment purposes and could be used as an assessment tool instead of traditional testing methods which may not exhibit what the student actually knows.

The construction of the Roundhouse diagram parallels what the science standards try to promote. The students are active, not passive learners. They rely on higher-level thinking and metacognitive learning skills. More responsibility is placed on the learner in terms of making sense out of what they are learning.

**Future Research Implications**

Exploring the effects of Roundhouse diagram construction and use as a teaching approach on the meaningful learning of science concepts in the middle school remains
virtually unresearched and unexplored. Given Human Constructivism as an underlying theoretical framework, Roundhouse diagrams provide a meaningful method of instruction available to middle school teachers who base their curriculum on understanding and conceptual change. This is a substantial alternative to traditional methods which rely on rote learning of text-based content.

Traditional assessment such as fill-in-the blank questions, true/false questions, and multiple choice questions are clearly not indicative of what students can accomplish. So many students have been stifled by the system of education and dropped out because they were unable to test and learn according to narrow alternatives that many teachers provide. My research indicates that the Roundhouse diagram is a powerful assessment tool as well as learning tool which clearly illustrates exactly what the child is thinking and what he/she understands. It appears that interviewing, combined with construction of the Roundhouse diagram is a powerful way to develop conceptual change.

Research is needed in order to investigate long-term use of this strategy at the middle school level. The Roundhouse diagram not only enhances the learning of science-related material but also enhances language arts and reading skills. This method can be used integrating science and other subject matter. Because of the use of drawing in this technique, the artistic possibilities are endless.

Future research studies are needed to compare the Roundhouse diagram assessment with conventional forms of science assessment to see what information can be added about science knowledge, attitudes, and skills that this new diagnostic tool can provide. The on-task/off-task technique employed in this study needs to be refined as a
way to gather formative evaluation data when visual approaches such as Roundhouse
diagramming are used. Studies are needed to formalize, elaborate, expand, and research
the learning value added with the additional wedge construction extension of the
Roundhouse diagramming technique that was pioneered in this study.

Studies are needed which explore and develop metacognitive teaching and
learning skills. Science educators must recognize and research the possibilities the
Roundhouse diagram possesses in establishing relationships among systems of science
concepts. “Human beings are meaning makers” (Mintzes & Wandersee, 1998). My
research study revealed that the Roundhouse diagram is a powerful tool for classroom
teachers who are prepared to explore meaningful learning and the building of
knowledge.

The most amazing component of researching effective science education
learning and instructional methods is the possibility that just maybe I can enlighten one
student and thus make a positive and constructive difference in educational reform
today. The most thrilling moment I experienced as an educator and as a researcher in
this particular study is when I asked Willy how he was most helped while using and
constructing the Roundhouse diagram, he replied, “I think it helped me with mysterious
studying” (see p. 241). It is that mystery in life that has sparked my sense of wonder, as
well. I think Albert Einstein would agree, as he once so stated, “One of the greatest
wonders and mysteries of the world, one of the things we don’t understand about the
world, is that it is understandable” (Singer, 1981, p. 40)
REFERENCES


Rowe, M. B., & Holland, C. (1990). The uncommon common sense of science. In Mary Budd Rowe (Ed.), *What research says to the science teacher: (Vol. 6)* The


APPENDIX A

GOWIN'S VEE DIAGRAM OF PROPOSED RESEARCH

WORLD VIEWS
Meaningful learning is the nonarbitrary, non-verbatim, substantive incorporation of new ideas into the learner's cognitive structure (Ausubel, 1968). The single most important factor influencing learning is what the learner already knows. Ascertain this and teach him [sic] accordingly (Ausubel, 1968). Learners who developed well-organized knowledge structures are meaningful learners (Novak, 1978). Cognitive research indicates the brain is a model builder (Wittrock, 1980). There is an active interplay between what we know and our new observations and knowledge claims (Gowin, 1977). Concepts are patterns or regularities in objects and events (Novak & Gowin, 1984). Knowledge is constructed (Novak, 1984). Metacognition increases transfer of science learning and facilitates conceptual change (White & Gunstone, 1989). The iconic features of self-constructed Roundhouse diagrams significantly improve science content recall (Wandersee, 1998).

THEORIES
Ausubel's Theory of Meaningful Learning
Novak's Theory of Human Constructivism
Gowin's Theory of Educating
Paivio's Dual Coding Theory of Visual-Verbal Memory

PRINCIPLES
*Meaningful learning is explained as the process of subsumption, where new knowledge, which is less inclusive, is connected to the learner's existing cognitive structure, which is more general or inclusive.

RESEARCH QUESTION
Does constructing and using Roundhouse diagrams affect the meaningful learning of science concepts by middle school students?

SUBQUESTIONS
How do student's science concepts change as they become more proficient in constructing Roundhouse diagrams?

What problems do students encounter in mastering the technique associated with construction of Roundhouse diagrams?

How do student's choices and drawings of iconic images affect their progress in meaningfully learning science concepts as they construct a series of Roundhouse diagrams?

VALUE CLAIMS
*Middle school participants in the construction of Roundhouse diagrams gained a greater understanding of science concepts as well as demonstrated meaningful learning habits.

KNOWLEDGE CLAIMS
Where appropriate, tables, correlation statistics, and excerpts were prepared that transformed the following data categories:
*Students gained understanding of science concepts in terms of whole/part relationships.
*Students developed mastery of technique in constructing Roundhouse diagrams.
*Students demonstrated visual thinking abilities and organizational skills.
*Students developed metacognitive learning skills necessary for conceptual change to occur.
*Student interview tapes supported the idea that meaningful science learning is fostered by reconstruction of knowledge to be learned.
*Students valued meaningful learning techniques as opposed to rote learning.
*Student Roundhouse diagrams and test score improvement correlated significantly over time.

TRANSFORMATIONS
*Transcripts of student responses to construction Roundhouse diagrams.
*Student products of constructed Roundhouse diagrams.
*Student responses on constructed Roundhouse diagram worksheets.
*Student attitude changes.
*Student responses to "mastery of technique" worksheets.

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Cognitive structure develops by progressive differentiation.
Cognitive structure develops by integrative reconciliation.
The goal of education is the construction of shared meanings.
Cognitive structure is organized according to levels of inclusiveness.

Weekly Roundhouse diagram scores and science Class scores showed moderate positive correlation.
Ability to link concepts with iconic images.
* Ability to use iconic images to help recall their Roundhouse diagram content.

CONCEPTS
- alternative conception
- associations
- case study
- chunking
- cognition
- cognitive structure
- concept map
- concepts
- conceptual change
- constructivism
- creativity
- elaboration
- encode
- generation
- graphic organizer
- icon
- integrative reconciliation
- metacognition
- misconception
- prior knowledge
- propositions
- Roundhouse diagram
- subsumption
- transfer

OBJECTS AND EVENTS
- Students practice and plan their diagrams.
- Students construct and use Roundhouse diagrams as an aid to help them learn science.
- Students evaluate their own graphic organizer construction work on student evaluation sheet.
- Students use the Roundhouse diagram checklist to be sure they have completed their assigned tasks.
- Students work in groups.
- Students work individually.
- Students were assessed using essay-type tests to evaluate students' tendency toward making spontaneous, valid, written connections of the science material they were studying to their construction and use of Roundhouse diagrams.
- The classroom teacher graded students' regular science assignments and tests.
- The researcher or her trained representative took field notes while the science instruction unfolds.
- The researcher and teacher collaboratively graded students' Roundhouse diagrams.
- The researcher interviewed students about their science learning and their Roundhouse diagramming experiences.
- The researcher compared the mastery of technique score with the test grades.
- The researcher compared the icon scores with the meaningful concept scores.

RECORDS
- Students' Roundhouse diagram worksheets.
- Students' evaluation sheets.
- Students' recorded construction of Roundhouse diagrams.
- Tape recorded interviews and transcripts with case study participants.
- Videotapes of students in progress, constructing their Roundhouse diagrams.
- Teacher's science grades.
- Researcher's Roundhouse diagram grades.
- Researcher and teacher ratings of student work using checklists.
- Researcher's "mastery of technique" sheets for student diagrams.
- On-task/off-task 35mm photos of students constructing Roundhouse diagrams and doing regular science activities.
- Each diagram received an icon score.
- Each test received a meaningful concept score.

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APPENDIX B

FLOW CHART OF RESEARCH STUDY

June, 1998
- Literature Search:
  Educational Psychology: A
  Cognitive View: Learning How to
  Learn: The Content of Science:
  Memory from a Broader
  Perspective: Cognition and the
  Visual Arts. Teaching Science for
  Understanding.

World Views: Ausubel 1968
  Novak 1977, Gowin 1977,
  Wittrock 1980, White &

Theoretical Base:
  Ausubel, Novak,
  Gowin, and Paivio

November, 1998 -
January, 1999
- Preparation for Research Study:
  development of student
  Roundhouse diagram
  worksheets, student evaluation
  sheets, mastery of technique
  sheets, student checklists and
  icon clip art books

Pilot Study: six-week study with
  middle school
  science students

November, 1998
- Preparation and
  approval of
  General Exams

February - April, 1999
- Students
  Student generated data: Construction of Roundhouse diagrams, completion of Roundhouse
  diagram worksheets and evaluation sheets, daily journaling activities, completion of
  Roundhouse diagram checklists, working in groups, working individually, completion of
  assessment tasks on science content (six post-Roundhouse diagrams),
  performance of regular science activities

Researcher: direct observation,
  participant observation, collects all
  student generated data, takes field
  notes, grades mastery of technique
  sheets, interviews case study
  group, transcribes tapes,
  videotapes students, takes 35 mm
  photos of students, analyzes data

Outside observer: observes students,
  takes field notes, informally
  interviews students

Teacher: teaches science content,
  observes students, takes field
  notes, grades mastery of technique
  sheets, grades regular science
  assignments and science tests, informally interviews students

Data Collection

Research Study:
  10 week
  study

Preparation, presentation,
  and approval of prospectus

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Final analysis from the researcher encompassing mixed methodologies

Qualitative Analysis

a. Triangulation of sources was used to build explanations using multiple perspectives for purposes of pattern-matching and case study analysis.

b. Multiple perspectives were used to create thick description of student Roundhouse diagram construction, focusing on the case study group, and creating a timeline progression series characterizing mastery of technique, specific patterns of growth and areas indicative of needed improvement.

c. Mastery of technique sheets acknowledge student improvement of Roundhouse diagram construction, accuracy in sequencing events, and understanding of key scientific concepts being investigated.

d. Multiple data sources were used comparing observational data with interview data, comparing what students said to classmates with what students said to observers, comparing the perspectives of people from different points of view and cross-checking consistency of data derived from different time periods.

e. Student evaluation checklists were examined in terms of student feedback regarding their perspective of improvement, what they valued most in terms of experience with constructing the Roundhouse diagrams, and what problems they encountered during the diagramming process. Evaluation checklists indicated progress of student abilities based 10 characteristics.
Quantitative Analysis

1. Various comparisons were made using a paired t-test on a defined pre-score and a defined post-score.

   a. Test 1 (case study group) and Test 2 (whole class), with diagram scores, examined six-week averages pre- and post-Roundhouse diagramming methods. Average Post-scores were higher than average pre-scores for both groups, but the paired t-test was significant only for the whole class (probably due to the small sample size). The post-score includes the 1st through 4th six-week averages. The post-score includes the 5th six-week average.
   \[ t = 2.76 \text{ and } p = 0.0129 \text{ for the whole class} \]
   \[ t = 1.22 \text{ and } p = 0.2767 \text{ for the case study group} \]
   *p < .05

   b. Test 3 (case study group) and Test 4 (whole class), with diagram scores, yielded the same results as Test 1 and Test 2 except the 4th six-weeks grading period was left out of the scoring because it was a transitional period. The post-score included the 1st three tests of the 4th six-weeks. The post-scores included the last test of the 4th six-weeks and the 1st two tests of the 5th six-weeks period. The researcher ensured the classroom in the middle of the 4th six-weeks period.
   \[ t = 1.23 \text{ and } p = 0.2724 \text{ for the case study group} \]
   \[ t = 2.41 \text{ and } p = 0.0267 \text{ for the whole class} \]
   *p < .05

   c. Test 5 (case study group) and Test 6 (whole class), without diagram scores, examined the first three tests pre-Roundhouse diagramming training and the first three tests post-Roundhouse diagramming training. The post-scores for both groups were higher than the pre-scores, with the case study group’s average being significantly higher than the pre-averages. It could be argued that the whole class post-scores were also significantly higher.
   \[ t = 3.41 \text{ and } p = 0.0029 \text{ for the case study group} \]
   \[ t = 2.03 \text{ and } p = 0.0548 \text{ for the whole class} \]
   *p < .05

   d. Test 7 (case study group) and Test 8 (whole class), without diagram scores, examined the three tests pre-Roundhouse diagramming training of the 5th six-weeks and all the tests post-Roundhouse diagramming training.
   \[ t = 4.48 \text{ and } p = 0.0005 \text{ for the case study group} \]
   \[ t = 3.51 \text{ and } p = 0.0027 \text{ for the whole class} \]
   *p < .05

   e. Test 9 (case study group) and Test 10 (whole class), without diagram scores, examined the 1st through 4th six-weeks averages pre-Roundhouse diagramming training to the 5th six-weeks average post-Roundhouse diagramming training.
   \[ t = 1.21 \text{ and } p = 0.2802 \text{ for the case study group} \]
   \[ t = 1.99 \text{ and } p = 0.0625 \text{ for the whole class} \]

   f. Test 11 (case study group) and Test 12 (whole class), without diagram scores, examined the 1st through 3rd six-weeks average pre-Roundhouse diagramming training to the 3rd six-weeks average post-Roundhouse diagramming training.
   \[ t = 0.50 \text{ and } p = 0.6361 \text{ for the case study group} \]
   \[ t = 0.90 \text{ and } p = 0.3781 \text{ for the whole class} \]

Summary

In conclusion for all the tests:

All post-averages were higher than the pre-averages, but only Tests 5 and 7 were significantly higher for the case study group. All of the tests for the whole class were significantly higher except for Test 12 leaving out the 4th six-weeks period and did not include diagram scores of the 5th six-weeks.

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An Analysis of Variance was performed to examine average test scores for the case study group and the whole class during the 10-week Roundhouse diagram training period. ANOVAs for both groups were not significant. The whole class revealed a stronger trend upward showing an increase in test scores averages, although the results were not significant.

Case study group: $F = 1.32$  \hspace{1cm} p = 0.287

Whole Class: $F = 1.21$  \hspace{1cm} p = 0.312

An Analysis of Variance was performed to examine average diagram scores for the case study group and the whole class to determine an increase in grades over the 10-week Roundhouse diagram training. A comparison of diagram scores resulted in significant differences for both groups.

Case study group: $F = 2.50$  \hspace{1cm} p = 0.0160

Whole class: $F = 2.93$  \hspace{1cm} p = 0.0266

Six test scores were examined during the 10-week research study which were compared to corresponding Roundhouse diagram mastery of technique scores. The case study group had scores from all 11 diagrams. The whole class was only graded on five diagrams (used as class lab grades). A Pearson's r correlation coefficient yielded a positive relationship for the case study group.

Case study group—r = 0.55 (p = .0004); Whole class—r = 0.08 (p = 0.5433)

Meaningful learning concept scores were determined based on how many questions were answered correctly on each test. The icon score was paired with the corresponding meaningful concept scores and a Pearson's r correlation coefficient was calculated yielding a positive relationship for the case study group (only the case study group was given icon scores on the diagrams).

Case study group—n = 36 (6 tests and 6 students)

$\rho = .55$ is significant under Ho: $\rho = 0$ (p = .0004)

On-task/off-task photographs were taken of the case study group in order to determine if levels of concentration increased over time. Percentages of on-task time over three separate time periods were examined and the results were inconclusive (videotaping is suggested for future research with a set time frame for each child in order to determine if the child was on-task or off-task. More time is needed to ascertain this decision).
APPENDIX C

LETTER OF PERMISSION FOR ROUNHOUSE DIAGRAM

Professor James H. Wandersee
Louisiana State University
Graduate Studies In Curriculum & Instruction
Room 223-F Peabody Hall
Baton Rouge La 70803

May 4, 1999

Ms. Robin Ward
1456 Chretien Point Road
Sunset, Louisiana 70584

Dear Ms. Ward,

You hereby have my permission to reproduce my Roundhouse Diagram template illustration in your Ph.D. dissertation.

Best wishes.

James H. Wandersee, Ph.D.
UEIT Professor of Biology Education
Louisiana State University
Goals: (4th Grade)
To use a Hands On/Minds On approach to critical thinking and problem solving in both Science and Math. I would like to learn and use more Authentic Assessment strategies to evaluate student knowledge.
APPENDIX E

ROUNDHOUSE DIAGRAM WORKSHEET

1. What is the main idea (or ideas) you are exploring? (Include all of your thoughts.)

2. Write out your title in different ways using the “and” and “of” words if possible.

3. Write down the goals or objective you have for this particular idea. What are you trying to learn by doing this diagram?

4. Take your entire concept and break it down into seven parts (if possible). If you have 2 less or 2 more, it is okay. List your most important parts in complete sentences.

1. ___________________________

2. ___________________________

3. ___________________________

4. ___________________________

5. ___________________________

6. ___________________________

7. ___________________________
3. ____________________________________________________________
   ____________________________________________________________
4. ____________________________________________________________
   ____________________________________________________________
5. ____________________________________________________________
   ____________________________________________________________
6. ____________________________________________________________
   ____________________________________________________________
7. ____________________________________________________________
   ____________________________________________________________

5. Take your seven parts and reduce the amount of written material by paraphrasing or "chunking" each sentence. Now list your parts again.
1. ____________________________________________________________
   ____________________________________________________________
2. ____________________________________________________________
   ____________________________________________________________
3. ____________________________________________________________
   ____________________________________________________________
4. ____________________________________________________________
   ____________________________________________________________
5. ____________________________________________________________
   ____________________________________________________________
6. ____________________________________________________________

7. If you need an enlarged wedge sheet to expand a section, they are available. Ask for one.

8. Now you are ready to place your ideas on your Roundhouse diagram. Rules:
   1. Ask for help if you need it.
   2. Use your time wisely.
   3. Be creative.
   4. Keep your diagram clear.
   5. Neatness is expected.
   6. Write dark.
   7. Use your best writing.
   8. Print if you want.
   9. Clip art books are available.
  10. Read index on books first
APPENDIX F

BLANK ROUNDHOUSE DIAGRAM

© 1994, James H. Wandersee

Goals:
APPENDIX G

ROUNDDHOUSE DIAGRAM CHECKLIST

1. Are the goals clearly stated at the bottom of the sheet?  
   Yes _ No _ N/A _ Needs Work _

2. Does the title clearly cover the concepts stated in the diagram?  
   Yes _ No _ N/A _ Needs Work _

3. Does the diagram include the necessary key concepts covered in the material?  
   Yes _ No _ N/A _ Needs Work _

4. Are there 5 to 7 concepts clearly defined in the diagram?  
   Yes _ No _ N/A _ Needs Work _

5. Are the concepts accurately stated?  
   Yes _ No _ N/A _ Needs Work _

6. Is there an “icon” in each segment which is representative of that concept?  
   Yes _ No _ N/A _ Needs Work _

7. Is there a sequence of events; is it accurate?  
   Yes _ No _ N/A _ Needs Work _

8. If a segment is enlarged for more detail, is the “wedge” sheet included with the diagram?  
   Yes _ No _ N/A _ Needs Work _

9. Is the diagram too crowded? Is the space well used?  
   Yes _ No _ N/A _ Needs Work _

10. Is the design aesthetically pleasing (considering balance, lettering, clarity, technique, “icon”)?  
    Yes _ No _ N/A _ Needs Work _
APPENDIX H

BRENDA'S ROUNDHOUSE DIAGRAM ON DRAWING

Goals: The goal was to show my procedure when drawing.
**APPENDIX J**

**SAMPLE ROUNDHOUSE DIAGRAM**

**Goals:** To show what occurs during photosynthesis.
APPENDIX K
EXAMPLE OF A ROUNDHOUSE DIAGRAM WORKSHEET
(Photosynthesis)

1. What is the main idea you are exploring? (Include all of your thoughts.)

   This idea includes the way in which green plants trap the sun’s energy and use it to change carbon dioxide and water into sugar and oxygen.

2. Write out your title in different ways using the “and” and “of” words if possible.

   Photosynthesis of Plants
   plants carbon dioxide sugar
   and and and
   sun’s energy water oxygen

3. Write down the goals or objectives for this particular idea. What are you trying to learn by doing this diagram?

   To discuss what occurs during the process of photosynthesis.

4. Take your entire concept and break it down into seven parts (if possible). If you have one less or two more, it is okay. List your most important parts in complete sentences.

   1. Plants get their energy from the sun.
   2. A material called chlorophyll in these cells traps light energy.
   3. Plants need the oxygen in the air before they can use the trapped energy.
   4. Plants use carbon dioxide from the air.
   5. The plant’s roots bring in water from the soil.
   6. Veins in the roots carry water to the leaves.
   7. Plants use light energy to change carbon dioxide and water into sugar and oxygen.

5. Take your seven parts and reduce the amount of written material by paraphrasing or chunking each sentence. Now list your parts again.

   1. Plants get energy from the sun.
   2. Chlorophyll traps sunlight.
   3. Plants need air.
   4. Plants use carbon dioxide in air.
   5. Roots bring water from soil.
   6. Veins carry water to leaves.
   7. Sunlight + carbon dioxide + water \(\rightarrow\) sugar + oxygen
6. Decide what icon you can use to help you to remember each chunk of information. Keep it simple. Draw them.

8. Now you are ready to place your ideas on your Roundhouse diagram.

   Rules:
   1. Ask for help if you need it.
   2. Use your time wisely.
   3. Be creative.
   4. Keep your diagram clear.
   5. Neatness is expected.
   6. Write dark.
   7. Use your best writing.
   8. Print if you want.
   9. Clip art books are available.
   10. Read the index on books first.
APPENDIX L

STUDENT EVALUATION CHECKLIST

1. Did I enjoy working through my Roundhouse diagram project?
   (1) yes  (2) no  (3) sometimes  (4) most of the time

2. Did I answer the questions about my topic on the Roundhouse diagram worksheet well?
   (1) yes  (2) no  (3) sometimes  (4) most of the time

3. Did I find useful sources, and did I use them well? (textbook, notes, clipart books)
   (1) yes  (2) no  (3) sometimes  (4) most of the time

4. Did I collect all the necessary information?
   (1) yes  (2) no  (3) sometimes  (4) most of the time

5. Did I organize and plan for my diagram well?
   (1) yes  (2) no  (3) sometimes  (4) most of the time

6. Was I able to paraphrase and “chunk” effectively?
   (1) yes  (2) no  (3) sometimes  (4) most of the time

7. Did I present my information in an interesting and effective manner?
   (1) yes  (2) no  (3) sometimes  (4) most of the time

8. Did I use my time wisely?
   (1) yes  (2) no  (3) sometimes  (4) most of the time

9. Was I able to work independently?
   (1) yes  (2) no  (3) sometimes  (4) most of the time

10. Was I able to work well with others?
    (1) yes  (2) no  (3) sometimes  (4) most of the time

11. Did I write everything in my own words?
    (1) yes  (2) no  (3) sometimes  (4) most of the time

12. Was I able to link the pictures with the concepts well?
    (1) yes  (2) no  (3) sometimes  (4) most of the time

13. Was I creative?
    (1) yes  (2) no  (3) sometimes  (4) most of the time
14. Did I find the Roundhouse diagram to be a helpful learning tool?
   (1) yes    (2) no    (3) sometimes    (4) most of the time

15. Do I prefer using the Roundhouse diagram better than taking notes?
   (1) yes    (2) no    (3) sometimes    (4) most of the time

16. Do I think the Roundhouse diagram method will help improve my understanding of scientific concepts?
   (1) yes    (2) no    (3) sometimes    (4) most of the time

The most important things I have learned doing this Roundhouse diagram are

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Did I encounter any problems in constructing my Roundhouse diagram? If so, what were they?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

On a scale of 1 to 10, I would rate my overall work on this Roundhouse diagram as a _______.
## APPENDIX M

### STUDENT LEVELS FOR SAMPLING PROCEDURE

<table>
<thead>
<tr>
<th>Name</th>
<th>Level of Attention</th>
<th>Level of Activity</th>
<th>Communication Skills</th>
<th>Level of Participation</th>
<th>Best subject(s)</th>
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<td>C/88</td>
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<td>A/100</td>
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<th>Level of Participation</th>
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Student Levels for Sampling Procedure

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<th>No.</th>
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<th>Overall Grade Point Average</th>
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<th>Reading Grade</th>
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(Appendix M continued)

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<td>M</td>
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**Note.**

- A = 95-100
- B = 89-94
- C = 76 - 88
- D = 70 - 75

L = Language Score on LEAP Test (L Range 500 - 597)  Passing: 549

M = Math Score on LEAP Test (M Range 500 - 598)  Passing: 549

Subjects:
- Sp = Spelling
- R = Reading
- E = English
- SS = Social Studies
- S = Science

Symbols:
- (minus) indicates low
- (plus) indicates high
- Av = Average
- * = focus group
### Roundhouse Diagram Checklist

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<tr>
<th>No.</th>
<th>Question</th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Needs Work</th>
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<tr>
<td>1.</td>
<td>Are the goals clearly stated at the bottom of the sheet?</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2.</td>
<td>Does the title clearly cover the concepts stated in the diagram?</td>
<td></td>
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</tr>
<tr>
<td>3.</td>
<td>Does the diagram include key concepts covered in the material?</td>
<td></td>
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<tr>
<td>4.</td>
<td>Are there 5 to 7 concepts clearly integrated in the diagram?</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>5.</td>
<td>Are the concepts accurately stated?</td>
<td></td>
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<tr>
<td>6.</td>
<td>Is there an icon in each segment which is representative of that concept?</td>
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<tr>
<td>7.</td>
<td>If there a sequence of events, is it accurate?</td>
<td></td>
<td></td>
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<tr>
<td>8.</td>
<td>If a segment is enlarged for more detail, is the “wedge” sheet included with the diagram?</td>
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<td>9.</td>
<td>Is the diagram too crowded? Is the space well-used?</td>
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<tr>
<td>10.</td>
<td>Is the design aesthetically pleasing (considering balance, lettering, clarity, technique, icon)?</td>
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# APPENDIX O

## 4TH SIX-WEEKS GRADES

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Tests
Pre-Roundhouse Diagramming  Post-Roundhouse Diagramming

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Tests 1, 2, 3 before Roundhouse diagram

Test 4: Test on Food Chains and Food Webs, post-Roundhouse diagram

Test 5: Roundhouse diagram on Water Cycle

* indicates focus group
<table>
<thead>
<tr>
<th>Students (* = case study group)</th>
<th>5&lt;sup&gt;th&lt;/sup&gt; Six-weeks Test Scores</th>
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Diagrams constructed for test:

| RHD #3 | RHD #4 | RHD #5 | Decomposer - Wedge | RHD #6 | RHD #7 | RHD #8 | RHD #9 | Angles - Wedge | RHD #10 | Color, white, black & white Wedge | RHD #11 |

*Test subject matter:

1. Nitrogen, carbon dioxide-oxygen cycle
2. What is light?
3. Reflection and refraction
4. How do we see color?
5. Sound and light waves

*All tests are post-Roundhouse diagramming method.
### POST-ROUNDBHOUSE DIAGRAM LAB GRADES

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(Appendix Q continued)

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<tr>
<td>18  Blake</td>
</tr>
<tr>
<td>19  Melissa</td>
</tr>
</tbody>
</table>

*Lab grades are based on five Roundhouse diagram constructions using Mastery of Technique sheets.

1. Parts of a wave
2. Electromagnetic spectrum
3. Reflection
4. Refraction
5. How we see color

*Each diagram was based on 20 points.
APPENDIX R

ROUNDHOUSE DIAGRAM LAB GRADES—CASE STUDY GROUP

<table>
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<tr>
<th>Students</th>
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<td>Collin</td>
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<td>18</td>
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</table>

*Roundhouse diagrams #1 through 5 were not used for grades.

*Scores were collaborated between teacher and researcher.

*Scores were used for statistical comparisons to see if grades improved as mastery of technique improved over time.
APPENDIX S

INSTITUTIONAL REVIEW BOARD FORMS

Application for Exemption from IRB (Institutional Review Board)
Oversight for Studies Conducted in Educational Settings
LSU COLLEGE OF EDUCATION

Title of Study: **The Effects of Roundhouse diagrams on Meaningful Learning in the Middle School Classroom**

Principal Investigator: **Robin E. Ward**

Faculty Supervisor: **James H. Wandersee**

Dates of proposed project period: From **2-1-99** To **5-1-99**

<table>
<thead>
<tr>
<th>ITEM</th>
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<th>NO</th>
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</tr>
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<td>✔</td>
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<td>5.</td>
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<td>✔</td>
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<tr>
<td>6.</td>
<td></td>
<td>✔</td>
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<tr>
<td>7.</td>
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<td>✔</td>
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<td>11.</td>
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<td>✔</td>
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<tr>
<td>12.</td>
<td></td>
<td>✔</td>
</tr>
</tbody>
</table>

Attach an abstract of the study and a copy of the consent form(s) to be used. If your answer(s) to numbers 6 and/or 7 is(are) YES, attach a copy of any surveys, interview protocols, or other procedures to be used.

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ASSURANCES

As the principal investigator for the proposed research study, I assure that the following conditions will be met:

1. The human subjects are volunteers.
2. Subjects know that they have the freedom to withdraw at any time.
3. The data collected will not be used for any purpose not approved by the subjects.
4. The subjects are guaranteed confidentiality.
5. The subjects will be informed beforehand as to the nature of their activity.
6. The nature of the activity will not cause any physical or psychological harm to the subjects.
7. Individual performances will not be disclosed to persons other than those involved in the research and authorized by the subject.
8. If minors are to participate in this research, valid consent will be obtained beforehand from parents or guardians.
9. All questions will be answered to the satisfaction of the subjects.
10. Volunteers will consent by signature if over the age of 6.

Principal Investigator Statement:

I have read and agree to abide by the standards of the Belmont Report and the Louisiana State University policy on the use of human subjects. I will advise the Office of the Dean and the University's Human Subject Committee in writing of any significant changes in the procedures detailed above.

Signature ______________________ Date ____________

Faculty Supervisor Statement (for student research projects):

I have read and agree to abide by the standards of the Belmont Report and the Louisiana State University policy on the use of human subjects. I will supervise the conduct of the proposed project in accordance with federal guidelines for Human Protection. I will advise the Office of the Dean and the University's Human Subject Committee in writing of any significant changes in the procedures detailed above.

Signature ______________________ Date ____________

Reviewer, recommendation:

✓ exemption from IRB oversight. (File this signed application in the Dean's Office.)

expedited review for minimal risk protocol. (Follow IRB regulations and submit 2 copies to the Dean's Office.)

full review. (Follow IRB regulations and submit 13 copies to the Dean's Office.)

Signature ______________________ Date ____________
February 1, 1999

Letter from: Mrs. Teacher

To: Parents or Guardians of Students

This letter is to inform you that your child will be participating in a research study in science education. The learner will be working on study skills and instructional methods which relate directly to the subject matter being taught in my science class at the present time. Your child has the right to withdraw from this study at any time.

I have been preparing for this research for many years and now I feel it is time for me to begin testing my science education research with sixth grade science students. I am working on my Ph.D. in science education and I am presently on Sabbatical leave to do this study and write my dissertation.

The planned activities with your child will include using graphic organizers in order to break down and clarify scientific concepts so that your child can improve understanding of the subject matter studied in the science classroom. Hopefully this instructional tool called the Roundhouse diagram will help to increase grades in science. This method is designed to improve study skills and may prove to be useful in other subject areas as well. Your child's progress will remain confidential. All records will remain anonymous. You are welcome to call me at any time to ask questions. (Home: 662-7229 School: 942-3130.)

This letter has been written to inform you of my study and to get permission to work with your child. This study may involve tape recorded interviews as well as video taped classroom work sessions. Thank you for this opportunity to work with your child. There are additional forms attached from Louisiana State University and the Internal Review Board which need to be signed, since your child is a minor and will be interviewed. The interview questions are strictly related to science content in order to enhance comprehension of science materials. Thank you.

Sincerely,

Robin Ward
Researcher/Interviewer
INTERVIEWEE RELEASE FORM

Tapes and Transcripts

I, ______________________, do hereby give to the T. Harry Williams Center at LSU all right, title or interest in the tape-recorded interviews conducted by ______________________ on _______. I understand that these interviews will be protected by copyright and deposited in the LSU Libraries for the use of future scholars. I also understand that the tapes and transcripts may be used in public presentations including but not limited to audio or video documentaries, slide-tape presentations, or exhibits. This gift does not preclude any use that I myself may want to make of the information in these recordings.

CHECK ONE:

- Tapes and transcripts may be used without restriction _______.
- Tapes and transcripts are subject to the attached restrictions _____.

________________________________________  ______________________
Signature of Interviewee                      Date

________________________________________
Address

________________________________________
Telephone Number
## APPENDIX V

### ROUNDHOUSE DIAGRAM THEMATIC UNITS

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<th>Roundhouse Diagram Number</th>
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<td></td>
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<td></td>
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<td></td>
<td><strong>Note:</strong> No Roundhouse Diagrams were completed</td>
<td></td>
<td></td>
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<tr>
<td>1</td>
<td><strong>Thematic Unit:</strong> Food Chains</td>
<td>2/5/99</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td><strong>Thematic Unit:</strong> Food Webs</td>
<td>2/10/99</td>
<td>2</td>
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<tr>
<td>2</td>
<td><strong>Thematic Unit:</strong> Water Cycle (diagram test)</td>
<td>2/17/99</td>
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<tr>
<td>3</td>
<td><strong>Thematic Unit:</strong> Carbon dioxide-oxygen cycle</td>
<td>2/22/99</td>
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<td><strong>Thematic Unit:</strong> Nitrogen cycle</td>
<td>2/25/99</td>
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<tr>
<td>5</td>
<td><strong>Thematic Unit:</strong> Decomposer</td>
<td>3/1/99</td>
<td>Wedge</td>
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<tr>
<td>3</td>
<td><strong>Thematic Unit:</strong> Light waves</td>
<td>3/3/99</td>
<td>6</td>
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<td>4</td>
<td><strong>Thematic Unit:</strong> Electromagnetic spectrum</td>
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<td><strong>Thematic Unit:</strong> Black, white, color</td>
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<td>Wedge</td>
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<tr>
<td>6</td>
<td><strong>Thematic Unit:</strong> Light/sound waves</td>
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<td>11</td>
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</table>
Goals:
Expret the food chane
APPENDIX X

WILLY'S FOOD WEB

Goals: To learn about food webs, energy pyramids and how people affect communities.

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## APPENDIX Y

### MEANINGFUL LEARNING SCIENCE CONCEPTS

(FOOD CHAINS AND FOOD WEBS)

<table>
<thead>
<tr>
<th>Concepts:</th>
<th>Elizabeth</th>
<th>Betty</th>
<th>Carla</th>
<th>Marian</th>
<th>Collin</th>
<th>Willy</th>
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</tr>
<tr>
<td>2 Producer</td>
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<td>+</td>
<td>+</td>
<td>+</td>
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<td>+</td>
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<td>+</td>
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<td>12 Two ways people affect communities</td>
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<td>-</td>
<td>+</td>
<td>+</td>
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<td>13 Describe amount of energy at beginning</td>
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<td>-</td>
<td>+</td>
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<td>14 Producers, first organisms in a sequence</td>
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<td>17 Food chains have 2 to 4 links</td>
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### Concepts:

<table>
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<tr>
<th>Concepts</th>
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<th>Caria</th>
<th>Marian</th>
<th>Collin</th>
<th>Willy</th>
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<tbody>
<tr>
<td>18 Most energy is at top of a pyramid</td>
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<td>19 Why are plants called producers?</td>
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<td>+</td>
<td>+</td>
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<tr>
<td>20 Explain a food chain in correct sequence</td>
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<table>
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<tr>
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<th>80/C</th>
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<th>95/A</th>
<th>100/A</th>
<th>97/A</th>
<th>83/C</th>
</tr>
</thead>
</table>

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APPENDIX Z

BETTY'S WATER CYCLE

Goals: how a water cycle works.
APPENDIX AA

CARLA'S CARBON DIOXIDE-OXYGEN CYCLE

Goals: To learn about the carbon dioxide oxygen cycle

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APPENDIX BB
BETTY'S NITROGEN CYCLE

Goals: To explore the nitrogen cycle.
APPENDIX CC
MARIAN'S DECOMPOSER WEDGE

1. Hyphae absorb water and nutrients from the surrounding environment.
2. Spores are released and may germinate to form new hyphae.
3. Mushrooms grow from their surroundings.
4. Mushrooms have gills that contain micromycelial reproductive structures.
5. Mushrooms reproduce with spores.
6. Mushrooms make food for fungi.

Decomposers
### APPENDIX DD

**MEANINGFUL LEARNING OF SCIENCE CONCEPTS**

+ = learned concept  
− = missed concept

#### Roundhouse Diagrams #3, #4, #5, and Wedge

<table>
<thead>
<tr>
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<td>4 oxygen</td>
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<td>5 respiration</td>
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<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>13 plants take in CO₂</td>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>14 bacteria release CO₂</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
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<tr>
<td>15 explain in full carbon dioxide-oxygen cycle</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
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</tr>
<tr>
<td>16 explain in full nitrogen cycle</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
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<td>+</td>
</tr>
<tr>
<td>17 Bonus +3: how do mushrooms digest?</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Concepts:</td>
<td>Marian</td>
<td>Elizabeth</td>
<td>Betty</td>
<td>Carla</td>
<td>Willy</td>
<td>Collin</td>
</tr>
<tr>
<td>-----------</td>
<td>--------</td>
<td>-----------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>--------</td>
</tr>
<tr>
<td>18 Bonus +3: how do mushrooms reproduce?</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>91/B</td>
<td>53/F</td>
<td>70/D</td>
<td>98/A</td>
<td>83/C</td>
<td>106/A+</td>
</tr>
</tbody>
</table>
15. Explain the carbon dioxide cycle.

1) Carbon dioxide-oxygen cycle works in many ways.
2) Plants take in carbon dioxide during photosynthesis.
3) Plants release oxygen.
4) Humans and animals take in oxygen.
5) Humans and animals release carbon dioxide.
6) Decomposers also release carbon dioxide.
7) Carbon dioxide-oxygen cycle is endless.

16. Explain the nitrogen cycle in detail.

1) 30% of the atmosphere is nitrogen.
2) Bacteria and lightning break the gas into compounds.
3) Plants break nitrogen into proteins.
4) Proteins pass through organisms through a food web.
5) Organisms die and bacteria decompose and convert it to ammonia.
6) Ammonia is used by plants but most goes back into the atmosphere as gas.
7) Nitrogen cycles don't end; it restarts.

"Bonus" Decomposers -
1) They absorb the dead material
2) When mushrooms die, thousands of spores are released.
Goals: The concepts for the transverse waves.
APPENDIX GG

ELIZABETH'S ELECTROMAGNETIC WAVES

Goals: To learn about the electromagnetic spectrum.
# APPENDIX HH

## MEANINGFUL LEARNING SCIENCE CONCEPTS

+ = learned concept  
- = missed concept

<table>
<thead>
<tr>
<th>Concept</th>
<th>Roundhouse Diagram Nos. 6 and 7</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Marian</td>
</tr>
<tr>
<td>1 transverse wave</td>
<td>+</td>
</tr>
<tr>
<td>2 energy</td>
<td>+</td>
</tr>
<tr>
<td>3 speed of light</td>
<td>+</td>
</tr>
<tr>
<td>4 parts of a wave</td>
<td>+</td>
</tr>
<tr>
<td>5 crest</td>
<td>+</td>
</tr>
<tr>
<td>6 trough</td>
<td>+</td>
</tr>
<tr>
<td>7 amplitude</td>
<td>+</td>
</tr>
<tr>
<td>8 wavelength</td>
<td>+</td>
</tr>
<tr>
<td>9 gamma rays</td>
<td>+</td>
</tr>
<tr>
<td>10 light rays</td>
<td>+</td>
</tr>
<tr>
<td>11 ultraviolet rays</td>
<td>+</td>
</tr>
<tr>
<td>12 microwaves</td>
<td>+</td>
</tr>
<tr>
<td>13 infrared rays</td>
<td>+</td>
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<tr>
<td>14 waves</td>
<td>+</td>
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<tr>
<td>15 x-rays</td>
<td>+</td>
</tr>
<tr>
<td>16 radio waves</td>
<td>+</td>
</tr>
<tr>
<td>17 ultraviolet rays</td>
<td>+</td>
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<td>Concept</td>
<td>Marian</td>
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<tr>
<td>----------------------</td>
<td>--------</td>
</tr>
<tr>
<td>18 Gamma rays</td>
<td>+</td>
</tr>
<tr>
<td>19 electromagnetic</td>
<td>+</td>
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<tr>
<td>20 light waves</td>
<td>+</td>
</tr>
<tr>
<td>21 frequency</td>
<td>+</td>
</tr>
<tr>
<td>22 speed of light</td>
<td>+</td>
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<table>
<thead>
<tr>
<th></th>
<th>Marian</th>
<th>Elizabeth</th>
<th>Betty</th>
<th>Carla</th>
<th>Collin</th>
<th>Willy</th>
</tr>
</thead>
<tbody>
<tr>
<td>100/A+</td>
<td>80/C</td>
<td>56/F</td>
<td>95/A</td>
<td>95/A</td>
<td>82/C</td>
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</tr>
</tbody>
</table>

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Goals: To explore about reflection.
Goals: To learn about refraction.
## APPENDIX KK

### MEANINGFUL LEARNING SCIENCE CONCEPTS

<table>
<thead>
<tr>
<th>Concepts:</th>
<th>Marian</th>
<th>Elizabeth</th>
<th>Betty</th>
<th>Collin</th>
<th>Carla</th>
<th>Willy</th>
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</thead>
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<td>+</td>
</tr>
<tr>
<td>2 refraction</td>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>3 parts of a wave</td>
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<tr>
<td>10 why image is normal in smooth, flat mirror</td>
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<td>-</td>
<td>+</td>
<td>+</td>
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<td>12 kind of lens in your eye</td>
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| Roundhouse Diagram Nos. 8 and 9 | 96/A | 84/C | 84/C | 100/A | 100/A | 100/A |

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Why Do We See White, Black, and Colors?

We see white because all the colors of the spectrum reflect at the same time.

We see color because that color will reflect to our eyes and the rest are absorbed.

We see black because all of the colors of the spectrum are absorbed and none reflect to our eyes.
Goals:
To explore the colors of light.

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APPENDIX NN

MEANINGFUL LEARNING SCIENCE CONCEPTS

+ = learned concept    - = missed concept

<table>
<thead>
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<th>Concepts</th>
<th>Marian</th>
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<th>Betty</th>
<th>Collin</th>
<th>Carla</th>
<th>Willy</th>
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<tr>
<td>3  white light</td>
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<td>-</td>
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<td>+</td>
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<td>4  prism</td>
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<td>6  rainbow</td>
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</tbody>
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100/A  76/C  52/F  78/C  100/A  100/A

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Goals: to learn about sound waves.
## APPENDIX PP

### MEANINGFUL LEARNING SCIENCE CONCEPTS

+ = learned concept  - = missed concept

<table>
<thead>
<tr>
<th>Concepts</th>
<th>Marian</th>
<th>Elizabeth</th>
<th>Betty</th>
<th>Collin</th>
<th>Carla</th>
<th>Willy</th>
</tr>
</thead>
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<tr>
<td>3 astronauts in space</td>
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<td>-</td>
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<tr>
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### APPENDIX QQ

#### SIX-WEEKS GRADE-POINT AVERAGES

<table>
<thead>
<tr>
<th>Students (* = focus group)</th>
<th>1998-1999 Six-weeks Grading Patterns</th>
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</thead>
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<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>1 Willy</td>
<td>86</td>
</tr>
<tr>
<td>2 Keith</td>
<td>94</td>
</tr>
<tr>
<td>3 Bobby</td>
<td>94</td>
</tr>
<tr>
<td>4 Meghan</td>
<td>89</td>
</tr>
<tr>
<td>5 Tremain</td>
<td>86</td>
</tr>
<tr>
<td>6 David</td>
<td>86</td>
</tr>
<tr>
<td>7 Lance</td>
<td>89</td>
</tr>
<tr>
<td>8 Tom</td>
<td>81</td>
</tr>
<tr>
<td>9 Joanie</td>
<td>77</td>
</tr>
<tr>
<td>10 *Collin</td>
<td>94</td>
</tr>
<tr>
<td>11 Diane</td>
<td>86</td>
</tr>
<tr>
<td>12 *Carla</td>
<td>91</td>
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<td>13 *Elizabeth</td>
<td>75</td>
</tr>
<tr>
<td>14 *Marian</td>
<td>91</td>
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<tr>
<td>15 Donna</td>
<td>93</td>
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<td>16 Sandra</td>
<td>90</td>
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<td>17 *Betty</td>
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<tr>
<td>Students (* = focus group) (continued)</td>
<td>1998-1999 Six-weeks Grading Patterns</td>
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<tr>
<td>---------------------------------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td>18 Blake</td>
<td>(1) 84  (2) 68  (3) 69  (4) 73  (5) 80</td>
</tr>
<tr>
<td>19 Melissa</td>
<td>(1) 95  (2) 90  (3) 90  (4) 85  (5) 91</td>
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</tbody>
</table>

*The Roundhouse diagrams began in the middle of the 4th six-weeks period (the last two tests).

*All of the 5th six-weeks period is post-Roundhouse diagram.

*1st, 2nd, 3rd six-weeks periods are pre-Roundhouse diagram.
VITA

Robin Eichel Ward was born October 10, 1950 in Atlanta, Georgia. She was the youngest of three children born to Florence and Al Eichel. She graduated with her bachelor of science degree in Art Education, grades 1 - 12 and Elementary Education, grades 1 - 8, from the University of Tennessee in the summer of 1973. She worked in Nashville, Tennessee, in her family’s business, D & P Custom Lights, performing administrative duties as well as art and design work for the company.

Robin moved to Opelousas, Louisiana, to be with her present husband in 1989. She married Eugene Ward November 27, 1993. She taught science and math to 4th-grade students and commuted to Baton Rouge to continue her education in Curriculum and Instruction at Louisiana State University. Professor Jim Wandersee became her major professor in 1994 and supervised her studies throughout her master’s program in 1995 and Educational Specialist degree in science education in 1997.

During these years, Robin became deeply committed to science education within Saint Landry Parish. She was chosen by a local lumber company to attend the California Redwood Forest Conference in Eureka, California, to learn about forest management, endangered species laws, and protection of waterways in the northwestern part of the United States. When she returned to Louisiana, she became actively involved in forestry programs developed in and around where she taught school. She began doing workshops for her local parish as well as local, state, and national science conventions. She also gave workshops at Science Saturday in Baton Rouge, Louisiana, and the Environmental Symposium in Alexandria, Louisiana.
She was chosen by her parish science supervisor to go to Phoenix, Arizona, and work on science assessment in the elementary and middle school levels for the National Assessment of Educational Progress. She was selected to represent her parish and write the science curriculum for Saint Landry and Lafayette Parish schools.

Over the last few years, she has been involved with some very challenging projects. One of these projects involved presenting a proposal to her present employer in her parish to incorporate inclusion into their elementary school. These plans involved some realistic activities which included the entire faculty and students, as well as the community.

The other project involved working with students from McKinley High School in Baton Rouge, Louisiana, in order to incorporate a part of Louisiana history which had been neglected. The 1953 bus boycott led by Reverend Jemison was a successful and positive effort on behalf of the civil rights movement in Baton Rouge, Louisiana. Reverend Jemison designed plans with the assistance of Martin Luther King, Junior so that the black community could still get to work by devising the "Free Ride System." Her participation this project included interviewing the people who lived during this time period and recording their experiences. She also designed a web page for the oral history department at Louisiana State University with this recorded history.

Robin continued her education at Louisiana State University and was greatly influenced by Professor Wandersee's classes in photography and concept mapping, which involved integrating her science knowledge as well as her artistic interests. This influence and the willingness to seek out this type of education led to her decision to earn the degree of Doctor of Philosophy in August, 1999.
DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Robin Eichel Ward

Major Field: Curriculum and Instruction

Title of Dissertation: The Effects of Roundhouse Diagram Construction and Use on Meaningful Science Learning in the Middle School Classroom

Approved:

[Signature]

Major Professor and Chairman

[Signature]

Dean of the Graduate School

EXAMINING COMMITTEE:

[Signature]

Co-chair

[Signature]

[Signature]

[Signature]

Date of Examination: June 16, 1999