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AN ANALYSIS OF SECONDARY STUDENTS' OPINIONS
OF THE TYPE OF SCIENCE INSTRUCTION
WHICH RESULTS IN CONCEPTUAL ADJUSTMENT OR FORMATION

MASTER'S THESIS

Submitted to the Department of Teacher Education,
University of Dayton, in Partial Fulfillment
of the Requirements for the Degree
Master of Science in Education

by

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April, 1999

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ACKNOWLEDGEMENTS

First and foremost I would like to thank my husband and children for their support and patience while I completed course work for my Master's degree.

Secondly, I would like to thank my mom for all of the editing of papers, emotional support, and encouragement she provided me during the process of completing my Master's degree work.

I would also like to thank my principal for his support and help with gathering research.

Finally, I would like to thank Dr. Fuchs for being my academic advisor and for agreeing to be my thesis advisor. You have made a daunting process much more achievable with your guidance and support.

CHAPTER 1

INTRODUCTION

Background of the Problem

Learning is a natural process of pursuing personally meaningful goals. It is active, volitional, and internally mediated; it is a process of discovering and constructing meaning from information and experience and is filtered through the learner's unique perceptions, thoughts, and feelings (McCombs, 1997). The actual construction of meaning appears to be a generative process that occurs in short-term memory which serves as a working interface between sensory input and long-term memory and where unprocessed information is rapidly lost (Holden & Yore, 1996). Holden and Yore (1996) stated that the constructed meanings are then stored in long-term memory by integrating these new ideas into existing knowledge structures or by reorganizing knowledge structures to accommodate new ideas. The entire process is orchestrated by the learners' metacognition, habits of mind, or epistemic disposition (Holden & Yore, 1996). While there is still much to be discovered about learning, it is known that knowledge must be acquired by the individual and that previous knowledge influences the acquisition of new knowledge (Novak, 1985).

In the past two decades, educational research in most discipline areas, including science, has focused on cognitive research. In science the research pertains to how students learn and make meaningful connections of new or misunderstood concepts to their existing scientific knowledge base (Anderson & Lee, 1998). The result of this research has been an impetus for teaching with instructional techniques which will produce

conceptual change in science knowledge. More recently research has begun to focus on students' attitudes and opinions toward instruction and science (Kobella Jr., 1989). The student is a crucial factor is the construction of his/her own knowledge. Related to this research is an area of psychology termed "metacognition". Metacognition refers to the process of a learner learning how to learn and develop a repertoire of thinking processes which can be applied to solve problems (Blakey & Spence, 1990).

Regarding conceptual change, the crucial goal in science pedagogy is to encourage and provide opportunity for learners to form correct conceptual understanding. Concepts, the essential units of human thought, that do not have multiple links with how a student thinks about the world are not likely to be remembered or useful. Or, if they do remain in memory, they will be tucked away in a drawer labeled, for example, "biology course, 1995," and will not be available to affect thoughts about any other aspect of the world (American Association for the Advancement of Science [AAAS], 1990). Concepts are most concretely understood when they are encountered in a variety of contexts and expressed in a variety of ways for that ensures that there are more opportunities for them to become embedded in a student's knowledge system (AAAS, 1990).

Cognitive research reveals that even with what is considered to be good instruction many students including academically talented ones understand less than educators think they do (AAAS, 1990). Jovanovic and Dreves (1998) concluded, after their study of students' opinions about science as a subject before and after using performance based instruction, that "If we are to ensure

the effectiveness of the science education reform effort, we need to better understand what happens to students when they learn science over a long period of time in a context where active performance is a daily expectation" (p. 245).

Metacognition, a respect for the activity of the learner's mind, is a part of "cognitive" or conceptual change learning (Ausubel, 1968). Although basic principles of learning, motivation, and effective instruction apply to all learners, learners have different capabilities and preferences for learning mode and strategies. Thus an understanding of the significant role of metacognition in the accomplishment of conceptual change is essential. Metacognition includes theory and research that focus upon one's thinking about thinking (Holden & Yore, 1996). Metacognition can be defined in a variety of ways, but it encompasses the idea of the learner thinking about their thinking and learning process (Blakey & Spence, 1990).

Significance of the Research

According to Novak (1985) the learner chooses to learn superficially or meaningfully, enhancing existing cognitive structure, and part of the task of teachers is to help the learner choose powerful meaningful learning approaches (Novak, 1985). Metacognitive strategies are strategies that empower the learner to take charge of his/her own learning (Novak, 1985). Holden and Yore (1996) found a significant association between prior conceptual knowledge and metacognitive self-management which supported their finding that self-directed learners more effectively construct and retain knowledge.

Conceptual change and metacognitive awareness are tied together in that both promote the importance of connecting new

information to former knowledge (Hennessey & Beeth, 1993). According to Hennessey and Beeth, in order to promote conceptual change learning it is necessary for the students to continually engage in metacognition. A long term understanding of concepts cannot be expected to be produced if students fail to examine their conceptual understanding and cognitive processes. According to Garner (1992) metacognitive knowledge refers to the knowledge about the self as learner, the task, and the strategies used to complete the task. Holden and Yore (1996) concluded after their study of learning style characteristics and science achievement, that metacognitive learner characteristics produced positive influences on science learning. In their research, Holden and Yore (1996) found that students with high metacognitive awareness and metacognitive self-management consistently made greater gains in conceptual knowledge than did those students with low metacognitive awareness and metacognitive self-management.

In the creation of a metacognitive environment, teachers monitor and apply their knowledge, deliberately modeling metacognitive behavior to assist students to become aware of their own thinking. Teachers must become alert to these strategies and consciously model them for students (Blakey & Spence, 1990). The challenge of teaching is to help students develop skills which will not become obsolete. Metacognitive strategies enable students to successfully cope with new situations (Blakey & Spence, 1990). Metacognitive strategies also help the learner understand that meaning derives from concepts, conceptual relationships already learned, and new relationships which are assimilated into an existing knowledge framework (Novak, 1985).

This study analyzed the opinions secondary science students about science instruction which resulted in their conceptual adjustment or change. It is incumbent upon the teacher to provide an appropriate intellectual environment in which metacognitive reflection can take place (Blakey & Spence, 1990). Hennessey and Beeth (1993) also supported this recommendation in explaining that it is imperative to explicitly promote metacognitive activities within the science classroom in order to create an intellectual environment in which the learners willingly engage in the type of critical reflection and discussion that are necessary to promote evaluation of their own conceptions. Metacognitive talk serves to bring cognition into consciousness (Astington, 1998). By asking students to become aware of and form an opinion of their learning preferences, this study engaged the student's in activities which promoted metacognitive awareness and produced an understanding about what students believe about their instruction.

The Research Problem

Based on research on metacognition, it appears that it is important for students to recognize what they believe contributes to their conceptual change. The purpose of this study was to analyze the opinions of secondary students about the type of science instruction which resulted in their conceptual adjustment or change.

Assumptions of the Study

The methodology and research design carries these assumptions:

1. Subjects analyzed and recorded their conceptual clarity in a reliable manner.
2. Subjects explained their opinions of instruction which

produced their conceptual change in a reliable manner.

Limitations of the Study

Issues which may limit the applicability of the study to the general population include:

1. Subjects were chosen from a non-probability sample.
2. Self-report data are subject to known limitations, and with student issues, students may have been reluctant to be honest regarding their opinions due to a concern that their grade might have been affected.
3. Conclusions were based on a small number of participants.

Definitions of Terms

Concepts

Concepts can be defined as the essential units of human thought.

Conceptual adjustment

The cognitive correction of prior false scientific understanding defines conceptual adjustment.

Conceptual formation

Conceptual formation is defined as the cognitive formation of scientific understanding.

Metacognition

The process of students forming an awareness and reflecting on their own learning process defines metacognition.

Secondary students

Secondary students are those students in grades 10 through grades 12.

CHAPTER II

REVIEW OF THE RELATED LITERATURE

A review of the literature related to this study includes theories about conceptual change, metacognition, and science instructional techniques.

Theories Regarding Metacognition

The term metacognition has a wide variety of definitions. According to McCombs (1997) metacognition is a term which comes from both the educational and psychological fields. It relates learning to the construction of meaning from information and experience as it is filtered through the learner's unique perceptions, thoughts, and feelings. McCombs' definition most widely encompasses all other meanings of the term metacognition. As defined by Blakey and Spence (1990) metacognition is the process of the learner thinking about his or her learning process.

In their article describing the importance of metacognition, Blakey and Spence (1990) recommended that teachers must become alert to metacognitive strategies and consciously model them for students. They iterate that it is incumbent upon the teacher to provide an appropriate intellectual environment in which metacognitive reflection can take place. Garner (1992) suggested that metacognitive knowledge refers to knowledge about the self as learner, the task, and the strategies used to complete the task. Students must gain practice in reflective analysis of their own learning to become life long learners.

The usefulness of metacognitive strategies in learning is explained by Novak (1985). According to Novak (1985) metacognitive strategies empower the learner to take charge of his/her own learning. Novak explained that metalearning

strategies help the learner understand that meaning derives from the concepts and concept relationships already in place and new relationships which are assimilated into existing knowledge frameworks (Novak, 1985). This understanding can encourage the learner to become more conscious of how new material relates to previous material. A learner who has knowledge organized into large, integrated frameworks can assimilate more related knowledge in less time and with greater usefulness. The role of the teacher then is to help the learner to choose powerful meaningful learning approaches to enable the learner to form lifetime knowledge and habits of mind.

It is essential that an understanding is developed of the significant role of metacognition in the accomplishment of conceptual change (AAAS, 1990). In their case study of elementary science students, Hennessey and Beeth (1993) drew on data collected from three related case studies to substantiate their claim of the relationship between conceptual change and metacognition. Hennessey and Beeth (1993) discussed their reasoning for their belief that it is imperative to explicitly promote metacognitive activities within the science classroom in order to create an intellectual environment in which learners willingly engage in the type of critical reflection and discussions that are necessary to promote evaluation of their own conceptions. They concluded that conceptual change and metacognitive awareness are tied together in that both promote the importance of connecting new information to former knowledge. Also concluded was that a failure on the part of students to examine their conceptual understanding and the cognitive processes that produce understanding will result in a failure to learn

scientific knowledge at a conceptual level (Hennessey & Beeth, 1993). Based on Hennessey and Beeth's study metacognition and conceptual change instruction are necessarily tied together in order to provide students with optimum educational experiences.

A quantitative research study which addressed the association between metacognition and science achievement was performed by Holden and Yore (1996). In their case study, Holden and Yore utilized a pretest-posttest design to explore various learner characteristics and science achievement. Their sample included five classrooms where teachers utilized guided inquiry within the framework of comprehensive instruction. Science achievement was measured by a 19-item objective test while metacognition was measured by an extended Index of Science Reading Awareness (ISRA) test. Holden and Yore (1996) found that results supported the assumption that self-directed learners more effectively construct and retain knowledge. They also found that metacognitive learner characteristics are positive influences on science learning. Holden and Yore further explored this by comparing changes in conceptual knowledge for low and high levels of metacognitive awareness. In all comparisons, those students with high metacognitive awareness made greater gains in conceptual knowledge than those with low metacognitive awareness (Holden & Yore, 1996).

Theories regarding metacognition were discussed. In the following section the author presents a review of literature about the theories regarding conceptual change in science. Conceptual change can be defined as the cognitive process of adjustment of understanding from an incorrect conceptual understanding to one that is correct. The ideas of conceptual change and metacognition are related in that in order to promote conceptual change

learning, it is necessary for students to continually engage in metacognition (Hennessey & Beeth, 1993).

Theories of Conceptual Change in Science

Cognitive research in science education has focused on how students learn and make meaningful connections of new or misunderstood concepts to their existing knowledge base. The findings of these research studies have resulted in numerous reform movements related to increasing scientific understanding and literacy. One of the leading reform documents is Science for All Americans, which was prepared by the American Association for the Advancement of Science [AAAS] (1990). In this book the AAAS described that concepts are the essential units of human thought and that concepts which do not have multiple links with how a student thinks about the world are not likely to be remembered or useful. The AAAS (1990) iterated that concepts are most concretely understood when they are encountered in a variety of contexts and expressed in a variety of ways for that ensures that there are more opportunities for them to become embedded in a student's knowledge system. Any instructional program should include a component which determines students' prior thoughts and beliefs.

According to Grote (1997) activities have the potential to engage students' curiosity, causing them to question their prior and sometimes naive understanding of natural phenomenon. The mere description of a concept or generalization by a teacher is often colored by the child's prior understanding. The teacher says one thing, but the child comprehends another. Although "telling" is faster, it does not always produce true understanding (Grote, 1997). The teacher should not treat children as empty vessels

into which teachers pour their knowledge; more respect should be shown to the students as learners and as human beings. In following these recommendations, it is very important for the teacher to be aware of initial student misunderstandings in order to provide the kinds of experiences that will address erroneous concepts (Grote, 1997).

Ausubel (1968) emphasized the need for teachers to start instruction where the students' conceptual understanding is at the time. Ausubel contended that the most important factor influencing learning is what the learner already knows. Some considerable conceptual misunderstandings are represented in examples from the work of the Learning in Science Project in New Zealand (Osborne & Freyberg, 1985). One example from the Learning in Science Project was evidenced with the scientific and children's perspective of what a plant is. Scientific perspective simply explained that plants are producers. The children's view of a plant was that it grows in a garden. Children also believed that carrots and cabbage from the garden are not plants, they are vegetables. According to the children, trees are not plants. They were plants when they were little but when they grow up they are not plants. Also believed is that plants take their food from multiple sources in the environment. And finally according to the children, photosynthesis is not important to plants (Osborne & Freyberg, 1985). The children's perspective is far from the true scientific perspective. The educator must know what the students' understanding is and plan and present prescriptive pedagogy to correct the misunderstandings.

A significant amount of empirical research and writings relate reform movements and instruction which promotes conceptual

change to gaining an understanding of student's themselves. A well renowned educational theorist, Ausubel, (1968) explained that a respect for the activity of a learner's mind is a part of "cognitive" or conceptual change learning. Jovanovic and Dreves (1998) explained the importance of promoting an understanding of students after their study of students' attitudes about science as a subject before and after using performance based instruction. Jovanovic and Dreves concluded that, "If we are to ensure the effectiveness of the science education reform effort, we need to better understand what happens to students when they learn science over a long period of time in a context where active performance is a daily expectation" (p. 245).

In his article which addressed changing and measuring attitudes in science classrooms, Kobella (1989) concluded that even if students are given that best educational opportunities, their attitudes may prohibit them from achieving conceptual change. Kobella also discussed means of measuring attitude among students in science. Kobella recommended the use of Likert scales or semantic differential scales to measure attitudes of students about science. The conclusion drawn from the literature about theories related to conceptual change is if an educator's goal is to promote conceptual change within their student's cognitive processes, as recommended by reform promoters, the educator must strive for an understanding of the students and their cognitive processes.

Theories regarding conceptual change in science were discussed. In the following section the author presents a review of literature about science instructional techniques. The discussion of science instruction is limited to those techniques

which were utilized in this research including, inquiry, questioning, concept mapping, and cooperative learning.

Science Instructional Techniques

Science instructional techniques are chosen to communicate scientific concepts and promote long term learning of the concepts. Lowry (1998) explained a new view of learning which draws its strength from cognitive neuroscience, cognitive psychology, and artificial intelligence. The new view helps educators understand what fosters learning and gives ideas for improving teaching techniques that are ineffective or detrimental to learning. The new view comprises three beliefs. The first belief is that learners construct understanding for themselves. The second belief is that to understand is to know relationships. The third belief is that knowing relationships depend on having prior knowledge (Lowry, 1998). As an example, according to the Learning in Science Project, children believe that gravity is something that holds us to the ground, but the scientific perspective expands this rather naive interpretation in explaining that gravity is a force between any two masses and depends on the size of the masses and the distance between their centers (Osborne & Freyberg, 1985). It is imperative that the instructor has knowledge of students' prior beliefs before planning pedagogy to teach a concept.

When preparing lessons and planning which instructional techniques to use, Engel Clough and Wood-Robinson (1985) suggested several things teachers may try, although they admit that these ideas have not been tested. These suggestions are: (1) start with students' ideas and revise teaching strategies to take some account of them; (2) provide more structured opportunities for

students to talk though ideas at length, both in small group and whole class discussions; (3) begin with known and familiar examples; and (4) introduce some science into the curriculum at earlier grade levels drawing out-of-school knowledge (p. 129).

Driver (1983) explained that students alternative conceptions have been developed over an extended period of time; one or two classroom activities are not going to change their mistaken ideas. He emphasized the provision of time for students to discuss their observations which contrast with their previous understanding (1983). One instructional technique which was used in this study and fits these principles of learning was inquiry instruction. Inquiry instruction is a system which encourages students to form or reevaluate understanding of concepts, understand them, and apply them in contexts outside of the classroom (Hunt & Minstrell, 1990).

The inquiry instructional technique involves the teacher being aware of students' beliefs prior to the beginning of instruction. Instruction should be built to address misconceptions and allow students to realize inconsistencies between their beliefs and the correct conceptual understandings. According to Hunt and Minstrell (1990) the teacher should identify and choose activities to foster conceptual development and application. Inquiry learning yields a deeper understanding because it focuses on the question "How do we know?" (Dempster, 1993). The key to the inquiry system is questioning. Questioning includes prequizzes, discussions, and tests (Hunt & Minstrell, 1990). Teachers who use inquiry instruction should provide firsthand concrete experiences to challenge existing conceptions (Hunt & Minstrell, 1990).

During utilization of inquiry instruction, teachers should encourage students to communicate correct understanding and apply the understanding to new situations. According to Hunt and Minstrell (1990) students should be engaged in rationalizing discrepancies between initial conceptions and classroom experiences. Only after students have formed new concepts should new vocabulary and formulas be introduced or used. Students should finally be given ample opportunity to revisit their new ideas and give arguments or justification. Throughout the inquiry process the teacher should encourage qualitative and elaborative aspects of problem solving. As a closure for inquiry instruction for any given unit, teachers should attempt to test ideas and arguments in a way that allow no simple way out, like using a formula or repeating a memorized meaning (Hunt & Minstrell, 1990). Students must be able to analyze a problem situation, solve the problem, and explain their thought processes.

In their research to determine the effectiveness of inquiry instruction, Hunt and Minstrell (1990) tested the effectiveness of the instruction in two classes in two schools. One teacher utilized the prescribed inquiry system; the second teacher did not but iterated that the techniques that were used addressed the same ideas as the inquiry system. The research yielded results which supported the claim that the inquiry system clearly promoted better learning and performance. The improvement of student performance on the posttest was clearly greater in the group taught by inquiry than the improvement of student performance in the other group. In comparing scores of students from both groups on the mathematics portion of the Metropolitan Achievement Test, there was little difference in performance. In terms of physics

performance, the test group was clearly superior across the range of concepts covered. Thus it was concluded, students who are taught in an inquiry fashion, exhibit conceptual correction and formation (Hunt & Minstrell, 1990).

Concept mapping is an instructional technique which entails the visual representation of information (Plotnick, 1997). According to Plotnick (1997) there are several uses for concept mapping such as idea generation, design support, communication enhancement, learning enhancement, and assessment. Concept mapping provides a mechanism to assist students in making connections between numerous activities and concepts but does not provide the concrete experiences required to establish the anchoring concepts needed for meaningful learning (Odom & Kelly, 1998).

The use of concept mapping as an instructional technique is often considered to be based on the work of Ausubel (1968). Ausubel described meaningful learning as the non arbitrary, substantive relating of new ideas or verbal propositions to cognitive structure (Ausubel, 1968). After studying Ausubel's theories, Novak (1993) began to study the concept mapping technique. Novak (1993) concluded that meaningful learning involves the assimilation of new concepts into existing cognitive structures. In support of the concept mapping technique, Jonassen (1996) argued that students show some of their best thinking when they try to represent something graphically and is a necessary condition for learning.

According to Novak (1992) the process of meaningful learning can be improved by concept mapping in which the learner graphically represents concepts in a hierarchically arranged

structure and begins to progressively differentiate among concepts. In addition, the learner begins the process of integrative reconciliation, viewing the relationships between concepts rather than compartmentalization (Novak, 1992). Therefore concept mapping must be utilized as an instructional technique in conjunction with other pedagogy which provides students with concrete experiences.

When utilizing the concept mapping technique students prepare a visual map which demonstrates the relationship between concepts in a diagram. A concept map is a graphical representation where nodes represent concepts, and links represent the relationships between concepts. Representing knowledge in the visual format of a concept map allows one to gain an overview of a domain of knowledge (Jonassen & Grabowski, 1993). The importance of concept mapping as an instructional technique lies in the advantage of providing a visual representation which allows for a holistic understanding that words alone cannot convey (Plotnick, 1997). In addition, concept maps prepared by students not only express their conceptions but also their misconceptions (Ross & Munby, 1991). As a result, concept maps can help instructors diagnose the misconceptions that make instruction ineffective (Ross & Munby, 1991).

Another important instructional technique, which can be use alone or in conjunction with other techniques, is questioning. Questioning can stimulate thought, action, and communication. Questioning as a technique can include encouraging students to ask questions or asking students questions. When carrying out inquiry investigations, one of the first skills students need to learn is that of asking questions (Edwards, 1997). Young children seem to

have a never ending supply of questions. Older children rarely ask questions, preferring instead to let their teachers perform this duty. According to Edwards (1997) there are three basic strategies for helping students ask questions. One strategy is to provide students with an observable phenomenon. A second strategy is to have students read articles regarding interesting happenings in science. A third strategy is for teachers to suggest possible topics for investigation.

When questioning students one challenge facing teachers is the need to frequently check and respond to their students' level of understanding while at the same time keeping the students actively engaged in learning (Latham, 1997). An engaged student interacts with the topic and helps to construct his or her own learning, often through active dialogue, not rote responses (Bruner, 1996). Teachers must consider numerous factors such as the learning goals for the lesson, the context in which the questions were asked, and the strength of students' responses and adapt their questioning techniques accordingly (Barden, 1995). Questioning as a technique is essential to the structure and planning of pedagogy and therefore to student learning.

An instructional technique which is often used in conjunction with other science instructional techniques like those described earlier is cooperative learning. Cooperative learning in the science classroom entails a group of student working together to discuss scientific topics. Group members may need to summarize what others have said, ask for clarification, and take alternative perspectives (AAAS, 1990). The AAAS (1990) recommended that the collaborative nature of scientific work should be strongly reinforced by group activity in the classroom. The reasoning for

their recommendation comes from the fact that scientists and engineers, in the field, work mostly in groups and less often as isolated investigators (AAAS, 1990).

Regarding cooperative learning, Johnson and Johnson (1987) explained that having students work together, cooperatively, is more powerful than working alone, competitively, or individually. More students learn more material when they work together. Students have more positive attitudes when they work together cooperatively than when they compete or work individually. Students are more positive about the subject being studied, the teacher, themselves as learners in that class, and are more accepting of each other. There is increasing evidence that students who "talk through" material with peers learn it in a more effective way than students who just read or listen to material (Johnson & Johnson, 1987).

In summation, there are a vast number literature pieces concerned with conceptual change, instructional techniques used to accomplish conceptual change, the importance of understanding students, and students understanding themselves in accomplishing conceptual change. There are also many resources which describe metacognition and the understanding of the student as a learner. A few of the reviewed studies relate metacognition to conceptual change. Those that do investigate the relationship between metacognition and conceptual change emphasize the importance of understanding metacognition in order to thoroughly promote conceptual change learning. This descriptive research study analyzed secondary students' opinions about science instructional techniques which resulted in their own conceptual formation.

CHAPTER III

METHOD

The Subjects

Participants in this study included 54 students who demonstrated conceptual change. Participants included 23 boys and 31 girls. Students were selected from three classes of a heterogeneously grouped Applied Physics course. Basic principles of physics were presented through, primarily but not exclusively, student-centered instructional techniques. Students were of mixed ability and mixed ages from grades ten through twelve. Students and parents were informed of the study through a letter which was explained in class and then sent home with students to share with their parents (See Appendix 1 for letter).

The School Setting

The school is a small rural school with approximately 350 students in the high school. The district has a total enrollment of approximately 1,400 students. According to the Ohio Department of Education (1998) approximately 2.1% of the enrollment is considered to be economically disadvantaged. Each teacher has an average of 18 students in each class. Approximately 60.4% of the district's revenue is provided by state sources (Ohio Department of Education [ODE], 1998). The school district covers an area of 46 square miles. Eighty percent of the students are transported from rural areas or surrounding small towns. The present school structure was erected in 1924, with additions built in 1961 and 1974. Availability of current technology for the students during the school day is limited at best. Everyday items are used as laboratory supplies in investigations designed to demonstrate basic scientific concepts. Approximately 30% of the high school

students have ambitions to further their education at an institute of higher education.

The Community Setting

The school is the center of a small community which relies on farming as its major industry. The school system is the largest employer in the town. Those families who do not own a large farm generally have at least one parent who works in a city, which is approximately forty-five miles away. As a result the district is considered to be a low-wealth district.

Data Collection

Construction of the Questionnaire

The questionnaire (See Appendix 2 for questionnaire) included a combination of forced-choice questions and open-ended questions which were organized under the five concepts which are presented in the "Description of the Program" section. Each concept was listed, and under each concept students were urged to answer questions using a Likert scale to represent which technique, of the three predominately used instructional techniques, they felt best promoted their correct understanding for each concept (Kobella Jr., 1989). The highest choice on the Likert scale was a five, meaning the identified technique helped the student to fully understand. The midpoint was a three, which indicated the technique had a part in the student's understanding. The lowest choice of the Likert scale was a one, indicating the technique did not help the student gain conceptual understanding.

Students were then asked to explain which of the three techniques best helped them to understand for each of the five concepts. The content validity of the questionnaire was established because of the reliance upon concepts which are

described in Benchmarks for Scientific Literacy, a national science educational reform document (AAAS, 1993).

Administration of the Questionnaire

The questionnaire was administered by the researcher. Administration of the questionnaire took place during class time. After the questionnaire was given to students, the researcher read the directions and each of the concepts and then invited students to express any misunderstandings they had. After students completed the questionnaires, they returned them to the researcher. The return rate for the questionnaire was 96%. Two of the 54 students did not complete a questionnaire because of extended absences from school.

Description of the Program

The program described incorporated the techniques of inquiry, questioning, and concept mapping. Cooperative learning was utilized in conjunction with all three of the techniques at various points in the program. At the beginning of this study, students completed an assessment which was designed to indicate their understanding of heat concepts. The concepts that were focused on in the unit of study were: (1) heat and temperature are terms which represent two different quantities; (2) heat is transferred between bodies which are at different temperatures and the masses of the objects are a factor in determining the final temperature of the bodies; (3) heat is transferred by the processes of conduction, convection, and radiation; (4) the ease with which a body releases or gains heat is dependent upon the body's specific heat capacity; and (5) heat is added to or taken away from a body as its phase changes without a change in temperature. As students participated in classroom activities,

the researcher participant conducted regular check points in order to assess students' conceptual understanding. Students were also reminded to view the posted heat concepts and record in their notebooks the moment they felt they gained a clear understanding of any of the concepts and what was happening in the classroom at the moment they formed a clear understanding.

On the first and second days of instruction inquiry, questioning, and cooperative learning were utilized. Students reviewed and reflected about their performance on the evaluated initial assessment. Students then worked, within cooperative groups, to determine the correct manner to measure temperature and the most efficient procedure to use when mixing substances which are initially at different temperatures. Students also prepared a graph to represent the relationship between the Celsius and Fahrenheit temperature scales.

The third day of instruction also involved inquiry, questioning, and cooperative learning. Students made observations of temperature changes which occurred when two samples of water, which were at different temperatures, were mixed. Students then advanced their experimentation to determine the effects of differing masses on temperature changes. As a result of the fourth day of instruction, students formulated a rule to explain the relationship between mass and temperature change.

As students participated in the fifth day of instruction, guided questioning was used to enable students to understand on a macroscopic level the manner in which heat is transferred between objects. Students used diagrams and graphs to represent their understandings in many circumstances and completed additional work, on an individual basis, outside of class. The sixth day of

instruction involved questioning to clarify student conceptions. On seventh day of instruction the questioning technique was utilized during a lesson which entailed students completing an evaluation designed to gain understanding of their conceptual understanding to this point in the instruction.

The eighth day of instruction utilized cooperative learning. The day began with students preparing definitions for heat transfer processes based on their observations formed while viewing drawings, pictures, and hands-on examples of heat transfer. The ninth day of instruction involved inquiry investigations of temperature changes during phase changes. Students prepared line graphs based on their data and answered questions using their graphical representations.

On the tenth day of instruction, students worked in cooperative groups to prepare a list of terms associated with the unit of study covering heat. Students worked within their groups to determine which term best represented the central theme of this unit of study. Students then worked to form a visual representation of their understanding of the relationship between the terms in the form of a concept map. On the eleventh day of instruction, students shared their maps with other students, and then the instructor prepared an all encompassing concept map on the chalk board for the students.

On the twelfth day of instruction, students completed another evaluation to gain clarity of the students' conceptual understanding. On the thirteenth day of instruction, prescriptive questioning was performed to further clarify the heat concepts. The final day of the data collection was completed as students answered the research questionnaire.

CHAPTER IV

RESULTS

Presentation of Results

Fifty-four students filled out the questionnaires about their opinion of the science instruction technique which resulted in their conceptual change. The return rate was 96% due to extended absences of two students from school.

Because the questionnaire was organized under the five concepts described in Chapter 3, the results include separate tables which illustrate the results for each of the five concepts. The concepts were as follows: (1) heat and temperature are terms which represent two different quantities; (2) heat is transferred between bodies which are at different temperatures and the masses of the objects are a factor in determining the final temperature of the bodies; (3) heat is transferred by the processes of conduction, convection, and radiation; (4) the ease with which a body releases or gains heat is dependent upon the body's specific heat capacity; and (5) heat is added to or taken away from a body as its phase changes without a change in temperature. Students were instructed to represent, by choosing a number on a Likert scale, the degree to which each of the three instructional techniques utilized in the presentation of each of the concept helped to gain understanding. The Likert type scale ranged from a high choice of five which indicated the student believed the technique helped them to fully understand the concept. The midpoint of three indicated the technique had a part in the student's understanding. And a low choice of one indicated the technique had no part in the student's understanding. The results are expressed as a mean score and are presented in tables

one through ten. Students were asked, in an open-ended manner, which technique best helped them to understand and why.

Table 1

Mean Scores of Instructional Techniques by All Students, Boys, and Girls for Concept 1: Heat and Temperature

Instructional Technique	All	Boys	Girls
Inquiry	3.08	3.32	2.90
Concept Mapping	3.29	3.09	3.43
Questioning	3.90	3.82	3.97

When asked which instructional technique best helped students to understand the concept, 49% of the students chose questioning, 28% chose concept mapping, and 25% chose inquiry.

Common reasons given by those students who chose questioning were: (1) questioning was helpful in understanding because the technique was useful in understanding when the student was absent during the inquiry exercises; (2) questioning by the teacher helped students clarify their ideas; and (3) anticipated teacher questions provided incentive to pay close attention to the material. Common reasons given by those students who chose concept mapping were: (1) concept mapping helped students to visualize relationships and (2) it was the best technique to show that heat and temperature are two different quantities. Reasons which were provided by students who chose inquiry included: (1)

four heads were better than one; (2) it helped to discuss material with group members; and (3) it involved hands-on work.

Table 2

Mean Scores of Instructional Techniques by All Students, Boys, and Girls for Concept 2: Heat Transfer According to Mass

Instructional Technique	All	Boys	Girls
Inquiry	3.56	3.86	3.33
Concept Mapping	2.87	2.86	2.87
Questioning	3.73	3.91	3.60

When asked which instructional technique best helped students to understand the concept, 43% chose inquiry, 41% of the students chose questioning, and 16% chose concept mapping.

Reasons which were provided by students who chose inquiry included: (1) it demonstrated the concept the best and (2) it gave a chance to actually calculate the final temperature. Common reasons given by those students who chose questioning were: (1) it clarified blurry ideas; (2) it helped put all of the information together; (3) the teacher worded things in an easier way to understand; and (4) it helped understanding for the days students missed due to absence. Common reasons given by those students who chose concept mapping were: (1) concept mapping helped students to visualize relationships and (2) it helped to

tie everything together.

Table 3

Mean Scores of Instructional Techniques by All Students, Boys, and Girls for Concept 3: Heat is Transferred by Process of Conduction, Convection, and Radiation

Instructional Technique	All	Boys	Girls
Inquiry	3.33	3.23	3.40
Concept Mapping	3.17	2.91	3.37
Questioning	3.77	3.64	3.87

When asked which instructional technique best helped students to understand the concept, 40% of the students chose questioning, 30% chose concept mapping, and 30% chose inquiry.

Common reasons given by those students who chose questioning were: (1) it helped go over things missed due to absence; (2) questioning by the teacher helped students clarify their ideas; and (3) answers were put in words to remember. Common reasons given by those students who chose concept mapping were: (1) concept mapping helped students to visualize relationships; (2) students can remember the picture in their mind; and (3) it helped give clear ideas. The main reason given for the choice of inquiry was that it made the students analyze pictures and forced them to think about similarities.

Table 4

Mean Scores of Instructional Techniques by All Students, Boys, and Girls for Concept 4: Specific Heat Capacity

Instructional Technique	All	Boys	Girls
Inquiry	3.02	3.23	2.87
Concept Mapping	2.88	2.82	2.93
Questioning	3.65	3.95	3.43

When asked which instructional technique best helped students to understand the concept, 56% of the students chose questioning, 22% chose concept mapping, and 22% chose inquiry.

Common reasons given by those students who chose questioning were: (1) it helped go over things that were missed due to absence; (2) questioning by the teacher helped students clarify their ideas; and (3) teachers questions helped the student to answer questions. The common reason given by those students who chose concept mapping was that it helped the students visualize relationships. The main reason given for the choice of inquiry was that it provided hands-on examples.

Table 5

Mean Scores of Instructional Techniques by All Students, Boys, and Girls for Concept 5: Heat Transfer During Phase Changes Does Not Result in a Temperature Change

Instructional Technique	All	Boys	Girls
Inquiry	3.27	3.36	3.20
Concept Mapping	2.65	1.90	2.70
Questioning	3.58	3.55	3.60

When asked which instructional technique best helped students to understand the concept, 53% of the students chose questioning, 35% chose inquiry, and 13% chose concept mapping.

The common reasons given by those students who chose questioning were: (1) it gave practice in expressing ideas and (2) questioning by the teacher helped students clarify their ideas. The reasons which was provided by students who chose inquiry was concept was actually seen in the activity. Common reasons given by those students who chose concept mapping were: (1) it gave a good idea of how everything tied together and (2) it helped to present the relationships which were not understood before.

Upon review of the data from this study, a difference was found among the average scores, by grade, for each instructional technique used in each concept. Therefore, the following five

tables include the average scores for each technique and each concept, according to grade of the subjects.

Table 6

Mean Scores of Instructional Techniques by Grade for Concept 1: Heat and Temperature

Instructional Technique	10	11	12
Inquiry	3.23	2.94	3.00
Concept Mapping	3.54	3.22	2.57
Questioning	4.23	3.62	4.00

Table 7

Mean Scores of Instructional Techniques by Grade for Concept 2: Heat Transfer According to Mass

Instructional Technique	10	11	12
Inquiry	3.77	3.69	2.14
Concept Mapping	3.23	2.75	2.43
Questioning	3.92	3.41	4.29

Table 8

Mean Scores of Instructional Techniques by Grade for Concept 3: Heat is Transferred by Process of Conduction, Convection, and Radiation

Instructional Technique	10	11	12
Inquiry	3.46	3.12	3.57
Concept Mapping	3.38	3.03	2.86
Questioning	4.31	3.59	3.14

Table 9

Mean Scores of Instructional Techniques by Grade for Concept 4: Specific Heat Capacity

Instructional Technique	10	11	12
Inquiry	3.75	2.94	2.14
Concept Mapping	3.23	2.78	2.14
Questioning	3.92	3.47	3.57

Table 10

Mean Scores of Instructional Techniques by Grade for Concept 5: Heat Transfer During Phase Changes Does Not Result in a Temperature Change

Instructional Technique	10	11	12
Inquiry	3.54	3.25	2.57
Concept Mapping	3.46	2.38	2.14
Questioning	4.23	3.44	2.86

Discussion of the Results

This section includes a discussion of the results obtained by averaging the Likert scores for each instructional technique as it was used in each concept. Also included is a summary of the answers to the question following each concept which inquired what method was preferred overall and why.

Concept 1- Heat and Temperature

The first concept presented for student understanding was the idea that heat and temperature are two different terms which represent two distinctly different albeit related quantities. Experience shows that students often use the terms interchangeably and incorrectly even though instruction for this concept included physically measuring each property. The researcher expected concept mapping to be ranked first by all students because the

class concept map, heat and temperature were clearly demonstrated as different quantities with different associated properties.

When comparing the boys' scores for each instructional technique to the girls' for the same technique, boys and girls preferred the questioning technique with averages scores of 3.82 and 3.97 respectively. (See Table 1) Questioning by students and the teacher can facilitate understanding by clarifying student ideas (Edwards, 1997). During the instruction for this concept all students were not confident with their understanding until it was confirmed by teacher and student questions.

The girls' second preference was concept mapping with an average scores of 3.43 and inquiry was third with an average score of 2.90. The boys' second preference was inquiry with a score of 3.32, and the third preference was for concept mapping with an average score of 2.90. This difference may be due to the behavior of the boys becoming engaged in inquiry exercises more quickly. In a research study regarding gender and age with students' science achievement and attitude, Greenfield (1996) found that males generally had experienced more and were more positive about physical activities in the science classroom. When the concept map was made, the girls of the cooperative groups tended to take on a more authoritative role than the boys which may explain the girls' higher ranking of concept mapping.

When considering the preference of all students combined, questioning was the chosen instructional technique with a score of 3.90. The average score for concept mapping was 3.29. And the average score for inquiry of 3.08. The process of paying close attention to the various learning activities and then presenting the degree to which each helped has engaged all students in

metacognition. As defined by Blakey and Spence (1990) metacognition is the process of the learner thinking about their learning process. With regards to Concept 1, learners believed questioning helped the most in their conceptual understanding. Concept mapping and inquiry were second and third choices.

After determining the average score for instructional techniques as used for concept 1 by grade, grade ten students ranked every instructional technique higher than grade eleven and grade twelve students. (See Table 6) The higher scores of the tenth grade students indicate a higher opinion of the instruction. The class in which this research was performed, was geared for grade ten students. The may scores indicate the subject matter is thought of in a more positive manner by the grade ten students. This occurrence agreed with gender research which stated younger students are generally more positive about instruction than older students (Greenfield, 1996).

All three grades indicated a preference for questioning with average scores of 4.25, 3.62, and 4.00 for grades ten through twelve, respectively. The grade ten and eleven students chose concept mapping as their second more preferred technique with scores of 3.54 and 3.22. Twelfth graders chose inquiry second while tenth and eleventh graders chose it third with scores of 3.00, 2.94, and 3.23, respectively. Twelfth grade students clearly understood heat and temperature with the initial inquiry instruction and considered the questioning instruction to have clarified their understanding. This would be expected as most twelfth grade students have had opportunity for more instructional exposure to physical science concepts.

Concept 2- Heat Transfer According to Mass

The second concept presented for student understanding was the idea that heat is transferred between bodies which are at different temperatures and the masses of the bodies are a factor in determining the final temperature of the mixture. This concept was presented with primarily questioning and inquiry. As students participated in instruction for this concept they seemed overwhelmed. This observation may have resulted from the newness of Concept 2. The inquiry instruction required complex reasoning skills and gave students a concrete hands-on base which will be remembered. According to Hunt and Minstrell (1990) during inquiry instruction students are engaged in rationalizing discrepancies between initial conceptions and classroom experience with the use of complex reasoning skills.

With Concept 2 it appears the final student decision making and conclusions relied highly on questioning by the students and teacher. Questioning as a technique is essential to the planning of pedagogy and therefore to student learning (Barden, 1995). The researcher expected concept mapping to be the least preferred for this concept because it was the least demonstrative of mass affecting heat transfer. Concept mapping was most useful in providing a visual representation which allowed for a holistic overview of a domain of knowledge (Jonassen & Grabowski, 1993). Concept 2 was more applicable to a small part of the overall heat and temperature domain and therefore concept mapping was not the best technique to represent the association between mass and heat transfer.

When comparing boys' scores for each instructional technique to the girls' for the same technique, boys clearly preferred

inquiry with an average score of 3.86 compared to the average girls score of 3.33. (See Table 2) As with Concept 1, boys preferred inquiry instruction more than the girls. This may indicate that the boys were more receptive to the active learning involved in inquiry instruction. According to Greenfield (1996) boys traditionally have more experience with physical activities and are therefore more receptive to such activities. Girls again preferred concept mapping with an average score of 2.87 but did not have a higher average score than the boys score of 2.86. Again, questioning as a technique was preferred by boys with an average score of 3.91 compared to an average girls' score of 3.60. Questioning as a technique can stimulate thought, action, and communication (Edwards, 1997). The preference of questioning by students may have been because questioning was the technique which engaged students' thought process more than the other two techniques.

When considering all students, questioning was again the instructional technique of choice with an average score of 3.73. The next preferred technique was inquiry with an average score of 3.56. The lowest rated instructional technique for Concept 2 was the concept mapping technique with an average score of 2.87. The preference of questioning as the instructional technique of choice for all students indicated the majority of the students considered the point of understanding to be when the concept was clearly stated by themselves or the instructor. Though the hands-on or minds-on activities which utilized inquiry were the students' initial and most concrete exposure, the students needed the relationship described by questioning the instructor. According to Barden (1995) questioning by students can help to clarify

misunderstandings. In the future, students who have gained some distance from the subject matter may remember best the concrete inquiry experiences. Inquiry based learning yields a deeper understanding because it focuses on the question "How do we know?" (Dempster, 1993).

After determining the average score for instructional techniques as used for Concept 2 by grade, grade ten students ranked inquiry and concept mapping higher than grade eleven and grade twelve students. (See Table 7) Grade twelve students ranked the questioning technique higher than the other two grades. Grade ten students did choose inquiry as a close second with an average score of 3.77. Eleventh grade students preferred inquiry with an average score of 3.69 and questioning was ranked second with an average score of 3.41. Concept mapping was the second preferred instructional technique of the grade twelve students and the third preferred instructional technique of the grade ten and grade eleven students. The student choices for this concept agreed with related research. Related research stated that the key to the inquiry system is questioning (Hunt & Minstrell, 1990). Also during inquiry instruction, teachers should provide firsthand concrete experiences to challenge existing conceptions (Hunt & Minstrell, 1990). Thus the students valued the inquiry instruction but found the questioning pedagogy most helpful.

Concept 3 - Heat is Transferred by Processes of Conduction, Convection, and Radiation

The third concept presented for student understanding was that heat is transferred by the processes of conduction, convection, and radiation. This concept was taught primarily with the use of the questioning technique. Therefore, the researcher

would have expected the first choice of students to be questioning. Concept mapping would have been expected to be a second choice because the class map visually showed that differences between each method of heat transfer.

Girls gave the highest rating for each technique. (See Table 3) Both boys and girls preferred questioning with average scores of 3.64 and 3.77, respectively. Also both boys and girls ranked inquiry second and concept mapping third. The boys' average score for inquiry was 3.23 and for concept mapping was 2.91. The girls' average score for inquiry was 3.40 and for concept mapping was 3.37. Of all of the concepts, the instructor would have expected inquiry to have been the third choice of all students. The inquiry exercise designed to stimulate student understanding for this concept was presented over a brief time, one class period, and involved abstract visualization to determine relationships from pictures. The results indicated students considered the brief inquiry exercise more beneficial than the instructor expected. The inquiry activity for Concept 3 encouraged students to form new conceptual understanding before vocabulary was introduced as was recommended by Hunt and Minstrell (1990).

The average scores for all students combined indicated questioning was the technique of choice. Inquiry was the second most preferred instructional technique, and concept mapping was the least preferred instructional technique. Students' opinions supported research by Odom and Kelly (1998) in which it is stated that concept mapping provides a mechanism to assist students in making connections between numerous activities and concepts but does not provide the concrete experiences required to establish the anchoring concepts needed for meaningful learning.

After determining the average score for instructional techniques used for Concept 3 by grade, it was found all three grades indicated the same order of preference for each technique. (See Table 8) Grades ten and eleven preferred questioning with averages scores of 4.31 and 3.59, respectively. Grade twelve preferred inquiry with an average score of 3.57. The second most preferred technique for all grades ten and eleven was inquiry with average scores of 3.46 and 3.12. The second most preferred technique for grade twelve was questioning with an average score of 3.14. The least preferred technique for all three grades was concept mapping with average scores of 3.38 for grade 10, 3.03 for grade eleven, and 2.86 for grade twelve. The grade ten students rated two of the three techniques, questioning and inquiry, higher than the other two grades. Twelfth grade students ranked inquiry higher than the other two grades. This indicates that though the grade ten students ranked the majority of the techniques higher than the other grades and can therefore be considered as having a more positive attitude about their instruction (Greenfield, 1996), the grade twelve students found inquiry more beneficial than did the other grades. This may have had some relationship to the instructor's consideration that inquiry was the most difficult technique to gain understanding of Concept 3. Twelfth grade students generally have more maturity and experience and may have been more receptive to the inquiry technique for this concept.

<u>Concept 4 - Specific Heat Capacity</u>

The fourth concept presented for student understanding was that the ease with which a body transfers heat is dependent upon the body's specific heat capacity. This concept was concretely demonstrated earlier in the instruction with the inquiry

technique. The actual terminology of "specific heat capacity" was only applied to the experience, of the effects of specific heat capacity, later in the unit with utilization of the questioning technique. Again, research of related literature about inquiry as a technique stipulated the presentation of the vocabulary follow conceptual understanding (Hunt & Minstrell, 1990). Therefore, the researcher would have expected students to prefer questioning with inquiry being a second choice. Even though the concrete experience was introduced during inquiry exercises, the terminology was introduced with questioning.

As expected both boys and girls preferred questioning with average scores of 3.95 and 3.43, respectively.(See Table 4) The boys rated the techniques as the instructor expected by ranking inquiry second, 3.23, and concept mapping third, 2.82. The girls chose concept mapping second with an average score of 2.93 but rated inquiry with a close third of 2.87. The higher ranking of inquiry by boys may be due to the occurrence of boys being more familiar and having more experience with physical activities (Greenfield, 1996). As stated before the girls were quicker to become engaged and take a leadership role in the concept mapping activity.

When considering the average scores for all students combined the techniques were rated in the manner the researcher expected, questioning first, 3.65; inquiry second, 3.02; and concept mapping third, 2.88. Therefore, when the students are considered as a whole, the instructional methods were chosen as the researcher expected. Questioning provided clarification (Barden, 1985). Inquiry provided concrete experiences and thus concrete understanding (Hunt & Minstrell, 1990). Concept mapping provided

a holistic overview with visible links between related concepts (Jonassen & Grabowski, 1993).

When examining the results for Concept 4 by grade, grade ten students ranked every instructional technique higher than grade eleven and grade twelve students which indicated a more positive attitude toward all of the instructional techniques for the concept. (See Table 9) All grades, ten, eleven, and twelve, preferred questioning with averages scores of 3.92, 3.47, and 3.57 respectively. Grades ten and eleven clearly chose inquiry as a second technique with average scores of 3.75 and 2.94 and concept mapping third with average scores of 3.23 and 2.78. The average scores by grade twelve students of inquiry and concept mapping were the same. The conclusion reached is that grade ten and eleven students rated the techniques in the order the researcher would have expected based on the actual instruction. Grade twelve students preferred questioning but did not consider either concept mapping or inquiry to have helped one more than the other. As students from grades ten and eleven are younger than the grade twelve students, a more positive opinion of the instruction may have been held by the grade 10 students (Greenfield, 1996). Therefore the younger students may have been more engaged with the techniques as the instructor expected.

Concept 5 - Heat Transfer During Phase Changes Does Not Result in a Temperature Change

The fifth concept presented for student understanding was that heat transferred during a change of phase does not result in a temperature change. If students had performed each procedure of the inquiry instruction as intended, the researcher would have expected inquiry to have been the preferred technique for Concept

5. However, the students exhibited inexperience with the more technical lab procedures used during the inquiry instruction and therefore relied upon teacher questioning to correct student misunderstandings. Therefore, the researcher would have expected questioning to be chosen as the most preferred technique. Concept mapping would have been expected to be the least preferred because Concept 5 was difficult to visualize in concept map.

Both boys and girls preferred questioning with average scores of 3.55 and 3.60, respectively. Also both chose inquiry as the second most preferred technique with scores of 3.36 and 3.20. Finally, both boys and girls rated concept mapping as the least preferred technique with average scores of 1.90 and 2.70. (See Table 5) Students rated instructional techniques in the same order the instructor would have expected as described earlier. Questioning, the most preferred technique, was essentially tied to inquiry the second most preferred technique because questioning plays an integral part to understanding inquiry instruction (Hunt & Minstrell, 1990).

After determining the average score for instructional techniques as used for Concept 5 by grade, each grade also rated the instructional techniques in the order the instructor anticipated. (See Table 10) Grade ten students gave the highest rating to all of the instructional techniques indicating a more positive opinion for the learning of this concept. The more positive opinion agreed with Greenfield's (1996) research which stated younger students are generally more positive about instruction.

Explanation of Chosen Instructional Techniques

Student explanations of a preference for the various

instructional techniques closely agreed with research. Research stated that questioning as a technique is essential to the structure and planning of pedagogy and therefore to student learning (Barden, 1995). As students explained a preference for the questioning technique with reasons including: questioning is useful in understanding material covered during an absence from school; anticipated teacher questions provided incentive to pay close attention to material; answers to student questions help to clarify unclear ideas; the teacher worded things in a way which was easier to understand and remember; and teacher questions helped the student to answer questions. Questioning is key to inquiry instruction and therefore to student understanding (Hunt & Minstrell, 1990).

Students who preferred concept mapping stated they did so because concept mapping: helped students to visualize relationships; helped tie everything together; helped students remember better because they could picture the map in their mind; and demonstrated relationships between terms which were not realized previously. Research about concept mapping states that concept mapping encourages students to view relationships between concepts rather than compartmentalizing them (Novak, 1992). Concept mapping provides a visual representation which allows for a holistic representation of subject matter (Plotnick, 1997).

And finally, students who preferred inquiry gave reasons of: four heads are better than one; it helped to discuss material with group members; it involved hands-on work; and it demonstrated the concept. According to research, inquiry instruction provides firsthand concrete experiences to challenge existing conceptions (Hunt & Minstrell, 1990). Inquiry instruction is a system which

encourages students to form or reevaluate understanding of concepts, understand the, and apply them in contexts outside of the classroom (Hunt & Minstrell, 1990).

Cooperative Learning

When students were asked if cooperative learning was useful in their gaining understanding of the various concepts, 67% of students answered yes, 25% of students were undecided, and 8% of students answered no. Common reasons given by the students who were positive about cooperative learning as a part of instruction were: students learned more by working together; group discussion helped put ideas in words which are easier to understand; and four people working together were better than one.

Related research is in agreement with the majority of subjects opinions. Johnson and Johnson (1987) explained that having students work together, cooperatively, is more powerful than working alone, competitively, or individually. More students learn more material when they work together. There is increasing evidence that students who "talk through" material with peers learn it in a more effective way than students who just read or listen to material (Johnson & Johnson, 1987).

The common reason given by students who were undecided about the usefulness of cooperative learning stated that it had a part in understanding but was not the reason the students understood. Common reasons for students' feelings that cooperative learning did not have a part in their understanding were: if the group has easily distracted members in it, it is difficult to stay on track and it is not good to be in a group with people that are absent all of the time.

Summary

Results of both quantitative and qualitative data were discussed. In general, boys indicated more of a preference for inquiry instruction with a higher average score than girls for four out of the five concepts. Traditionally, boys have had more experience with the physical activities and equipment that goes along with inquiry instruction and are therefore more positive about such instruction (Jovanovic & Dreves, 1998). Girls preferred concept mapping with a higher average score for concept mapping on all five concepts. Girls were more receptive and attentive to gaining a holistic understanding which comes with concept mapping (Plotnick, 1997). Both boys and girls were favorable of questioning with girls having a higher average score than the boys for three of the five concepts. Both boys and girls ranked questioning highest for each of the five concepts. As stated before, with all of the concepts, inquiry was the initial technique used and the one which provided concrete experience but the results indicated that students relied on questioning to clarify their ideas and understanding (Barden, 1985). Students' qualitative responses confirmed that all of the instructional techniques were instrumental in students' conceptual understanding but questioning, by the student and by the teacher, provided a clarification of student thoughts and produced statements which were easy to understand and remember.

When results were presented by grade, grade ten students ranked the individually instructional techniques higher than the other two grades thirteen times out of the fifteen choices which agreed with Greenfield (1996) who explained that younger students are more positive about instruction. Grade twelve students ranked

individual instructional techniques higher than grade ten and grade eleven students two times out of the possible choices. With some of the concepts. Grade twelve students had more experience than the younger students and, therefore, had a more positive attitude about the instruction used to facilitate their learning. Grade eleven students did not rank any of the instructional techniques higher than the other two grades. Students' explanations of chosen instructional techniques closely agreed with the related literature for each technique.

When students were asked if cooperative learning was useful in their gaining understanding of the various concepts, a majority of the subjects answered in a positive manner. Students generally enjoy and excel with cooperative learning if they are in a group with students who value work time (Johnson & Johnson, 1987). Those students who did not value cooperative learning were generally those who were in a group with a student they did not like or did not feel was contributing to the group in a positive manner.

The process of the students representing various techniques as being preferred over others has engaged the students in metacognition and has therefore increased the likelihood that students will experience conceptual adjustment or change (Hennessey & Beeth, 1993). The implementation of this study has helped the learners choose powerful and meaningful learning approaches which enabled the learner to form lifetime knowledge and habits of mind (Novak, 1985). The metacognitive strategies in which students were engaged has encouraged students to examine their conceptual understanding and the cognitive processes which produced understanding in order to learn on a conceptual level

(Hennessey & Beeth, 1993).

Results were presented and discussed. In the following chapter the research study is summarized, conclusions are presented, and recommendations are made.

CHAPTER V

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Summary

Learning is a natural process of pursuing personally meaningful goals. It is active, volitional, and internally mediated; it is a process of discovering and constructing meaning from information and experience and is filtered through the learner's unique perceptions, thoughts, and feelings (McCombs, 1997). The actual construction of meaning appears to be a generative process that occurs in short-term memory which serves as a working interface between sensory input and long-term memory and where unprocessed information is rapidly lost (Holden & Yore, 1996). Holden and Yore (1996) stated that the constructed meanings are then stored in long-term memory by integrating these new ideas into existing knowledge structures or by reorganizing knowledge structures to accommodate new ideas. The entire process is orchestrated by the learners' metacognition, habits of mind, or epistemic disposition (Holden & Yore, 1996). While there is still much to be discovered about learning, it is known that knowledge must be acquired by the individual and that previous knowledge influences the acquisition of new knowledge (Novak, 1985).

According to Novak (1985) the learner chooses to learn superficially or meaningfully thereby enhancing existing cognitive structure. Part of the task of teacher is to help the learner choose powerful meaningful learning approaches (Novak, 1985). The process of the learner becoming aware of his/her preferences for learning strategies is metacognition. Metacognitive strategies are strategies that empower the learner to take charge of his/her own learning (Novak, 1985). Holden and Yore (1996) found a

significant association between prior conceptual knowledge and metacognitive self-management which supported their finding that self-directed learners more effectively construct and retain knowledge.

Conceptual change and metacognitive awareness are tied together in that both promote the importance of connecting new information to former knowledge (Hennessey & Beeth, 1993). According to Hennessey and Beeth, in order to promote conceptual change learning it is necessary for the students to continually engage in metacognition. A long term understanding of concepts cannot be expected to be produced if students fail to examine their conceptual understanding and cognitive processes. Holden and Yore (1996) concluded after their study of learning style characteristics and science achievement, that metacognitive learner characteristics are positive influences on science learning. In their research, Holden and Yore (1996) found that students with high metacognitive awareness and metacognitive self-management consistently made greater gains in conceptual knowledge than did those students with low metacognitive awareness and metacognitive self-management.

Based on research on metacognition, it appears that it is important for students to recognize what they believe contributes to their conceptual change. The purpose of this study was to analyze the opinions of secondary students about the type of science instruction which resulted in their conceptual adjustment or change.

The procedure which was performed in this research began with students completing an assessment before the instruction unit began. The objective of the assessment was to determined the

students' conceptual understanding and to plan a program of study to address student misconceptions. As students participated in classroom activities, students were reminded to view the posted heat concepts and record in their notebooks the moment they felt they gained a clear understanding of any of the concepts and what was happening in the classroom at the moment they formed a clear understanding. After the program of study was completed, students completed the research questionnaire which asked them to indicate by using a Likert scale how much of a part each of three science instructional techniques had in their conceptual adjustment and change. The questionnaire also asked students which instructional technique helped the most in gaining conceptual understanding. The students concluded the questionnaire by explaining whether or not cooperative learning had a part in their acquisition of conceptual understanding.

Results of both quantitative and qualitative data were discussed. In general, boys indicated more of a preference for inquiry instruction with a higher average score than the girls for four out of the five concepts. Girls preferred concept mapping with a high average score for concept mapping on all five concepts. Both boys and girls were favorable of questioning with girls having a higher average score than the boys for three of the five concepts. Both boys and girls ranked questioning highest for each of the five concepts. Students' qualitative responses indicated that all of the instructional techniques were instrumental in their conceptual understanding but questioning, by the student and by the teacher, provided a clarification for student thoughts and produced statements which were easy to understand and remember.

When results were presented by grade, grade ten students ranked the individually instructional techniques higher than the other two grades thirteen times out of the fifteen choices, three for each concept. Grade twelve students ranked individual instructional techniques higher than grade ten and grade eleven students two times out of the possible choices. Grade eleven students did not rank any of the instructional techniques higher than the other two grades. All of the grades preferred questioning for each concept more than the other instructional techniques.

Students' explanations of why a particular technique was preferred agreed closely with related literature. When students were asked if cooperative learning was useful in their gaining understanding of the various concepts, a majority of the subjects answered in a positive manner.

Conclusions

Though there was a difference between the average scores for each technique, the close averages indicated that in most cases students realized that learning occurred as a result of a variety of instructional techniques. The questioning technique was preferred most often. Perhaps the choice stems from the need of high school students to have their understanding confirmed by the instructor.

The new metacognitive awareness students gained through participation in this study will aide in correct conceptual understanding for this unit and future instruction(Holden & Yore, 1996). The conclusions which can be drawn indicate this study's subjects believe, as do most science instructors, that while students may prefer one instructional technique to another, all

techniques have a place and provide experience in producing conceptual adjustment or formation.

Recommendations

This researcher recommends that teachers of all subjects include in their instruction encouragement for students to achieve a metacognitive awareness. The metacognitive awareness should aide in conceptual change and lifetime learning. Also teachers themselves should make an effort to understand which kind of instruction students value as it may be a different choice than their own. The process of doing so will affirm teachers' beliefs about instruction and aide teachers in becoming more effective facilitators of knowledge.

Appendix 1

January 22, 1999

Dear Parents or Guardians,

As an educator who is interested in continuously improving my teaching, I am planning to conduct some classroom research over the next several weeks. As you may know, the science department is well into teaching within a revised curriculum. We revised the curriculum, what we teach, several years ago to better meet the needs of all of our students. At the same time I have revised my teaching methods, how I teach, to better communicate new material to the students. The Applied Physics class is a result of the new curriculum and new teaching methods.

Research studies in science education, as well as national reform documents show that students learn best when the teacher knows what the students believe about various science topics. It also shows that the teacher should plan appropriate teaching methods to address any student misunderstandings. I know what the research says and I believe it is right. The reason for the research I want to perform with my students, is that I now want to know what the students think helps them to understand various concepts. What I plan to do is teach the same way I have all year thus far but I will ask the students to pay attention to the point they feel they gained a clear understanding of various concepts related to heat and temperature. After our heat and temperature unit concludes, I will ask them to fill out a questionnaire which will ask them to indicate which activity helped them to gain understanding of the various concepts.

My goal is to become more conscious of my students' feelings about their learning. That understanding will help me to improve my teaching practice. If you have any questions please feel free to call me at 692-5175 between 7:45 am and 8:50 am. Or you may call that number any time during the school day to leave a message.

Sincerely,

Mrs. Lora Brandon

Appendix 2

Research Questionnaire

Throughout the unit covering heat and temperature, I have asked you to analyze what activity you feel best helped you to understand the various concepts. Please answer the following questions to indicate what activity you feel helped you understand the best and then explain your choice. When answering the questions about the various types of activities, circle the number on the scale to represent the degree to which a type of activity helped you understand. The inquiry activities would include any work you did with your groups other than the concept map. Concept mapping would include the actual planning, preparation, and presentation on your group's maps. Questioning activities included checkpoints, review sessions, and tests.

Personal Data:

Circle one: Male Female

Grade: 10 11 12

Concept #1. Heat and temperature are terms which represent two different quantities.

Circle a number on the scale following each activity which best represents the degree to which the activity helped you have a thorough understanding of this concept.

INQUIRY ACTIVITIES

helped me to fully understand		had a part in my understanding		did not help me to understand
5	4	3	2	1

CONCEPT MAPPING

helped me to fully understand		had a part in my understanding		did not help me to understand
5	4	3	2	1

QUESTIONING

helped me to fully understand		had a part in my understanding		did not help me to understand
5	4	3	2	1

Which of the techniques listed above best helped you to understand this concept? Why?

Concept #2. Heat is transferred between bodies which are at different temperatures and the masses of the objects are a factor in determining the final temperature of the bodies.

Circle a number on the scale following each activity which best represents the degree to which the activity helped you have a thorough understanding of this concept.

INQUIRY ACTIVITIES

helped me to fully understand		had a part in my understanding		did not help me to understand
5	4	3	2	1

CONCEPT MAPPING

helped me to fully understand		had a part in my understanding		did not help me to understand
5	4	3	2	1

QUESTIONING

helped me to fully understand		had a part in my understanding		did not help me to understand
5	4	3	2	1

Which of the techniques listed above best helped you to understand this concept? Why?

Concept #3. Heat is transferred by the processes of conduction, convection, and radiation.

Circle a number on the scale following each activity which best represents the degree to which the activity helped you have a thorough understanding of this concept.

INQUIRY ACTIVITIES

helped me to fully understand		had a part in my understanding		did not help me to understand
5	4	3	2	1

CONCEPT MAPPING

helped me to fully understand		had a part in my understanding		did not help me to understand
5	4	3	2	1

QUESTIONING

helped me to fully understand		had a part in my understanding		did not help me to understand
5	4	3	2	1

Which of the techniques listed above best helped you to understand this concept? Why?

Concept #4. The ease with which a body releases or gains heat is dependent upon the body's specific heat capacity.

Circle a number on the scale following each activity which best represents the degree to which the activity helped you have a thorough understanding of this concept.

INQUIRY ACTIVITIES

helped me to fully understand		had a part in my understanding		did not help me to understand
5	4	3	2	1

CONCEPT MAPPING

helped me to fully understand		had a part in my understanding		did not help me to understand
5	4	3	2	1

QUESTIONING

helped me to fully understand		had a part in my understanding		did not help me to understand
5	4	3	2	1

Which of the techniques listed above best helped you to understand this concept? Why?

Concept #5. Heat is added to or taken away from a body as its phase changes without a change in temperature.

Circle a number on the scale following each activity which best represents the degree to which the activity helped you have a thorough understanding of this concept.

INQUIRY ACTIVITIES

helped me to fully understand		had a part in my understanding		did not help me to understand
5	4	3	2	1

CONCEPT MAPPING

helped me to fully understand		had a part in my understanding		did not help me to understand
5	4	3	2	1

QUESTIONING

helped me to fully understand		had a part in my understanding		did not help me to understand
5	4	3	2	1

Which of the techniques listed above best helped you to understand this concept? Why?

In your opinion, was cooperative learning (working in groups) useful in forming conceptual understanding? Why?

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R002583797