1997

A case study on inquiry-based science education and students' feelings of success

Joan Catherine Brady Orcutt
San Jose State University

Follow this and additional works at: https://scholarworks.sjsu.edu/etd_theses

Recommended Citation

Brady Orcutt, Joan Catherine, "A case study on inquiry-based science education and students' feelings of success" (1997). *Master's Theses*. 1519.
DOI: <https://doi.org/10.31979/etd.y4zq-geaq>
https://scholarworks.sjsu.edu/etd_theses/1519

This Thesis is brought to you for free and open access by the Master's Theses and Graduate Research at SJSU ScholarWorks. It has been accepted for inclusion in Master's Theses by an authorized administrator of SJSU ScholarWorks. For more information, please contact scholarworks@sjsu.edu.

INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

UMI

A Bell & Howell Information Company
300 North Zeeb Road, Ann Arbor MI 48106-1346 USA
313/761-4700 800/521-0600

A CASE STUDY ON
INQUIRY-BASED SCIENCE EDUCATION AND STUDENTS'
FEELINGS OF SUCCESS

A Thesis
Presented to
The Faculty of the College of Education
San Jose State University

In Partial Fulfillment
of the Requirements for the Degree
Masters of Arts

By
Joan Catherine Brady Orcutt
August 1997

UMI Number: 1386220

UMI Microform 1386220
Copyright 1997, by UMI Company. All rights reserved.

**This microform edition is protected against unauthorized
copying under Title 17, United States Code.**

UMI
300 North Zeeb Road
Ann Arbor, MI 48103

© 1997

Joan Catherine Brady Orcutt

ALL RIGHTS RESERVED

Approved by the Division of Teacher Education

A handwritten signature in cursive script, reading "Karen E. Reynolds".

Dr. Karen Reynolds, Advisor

A handwritten signature in cursive script, reading "Robertta H. Barba".

Dr. Robertta H. Barba, Advisor

A handwritten signature in cursive script, reading "Carolyn Nelson".

Dr. Carolyn Nelson, Advisor

A handwritten signature in cursive script, reading "Serena H. Stanford".

APPROVED FOR THE UNIVERSITY

ABSTRACT

A CASE STUDY ON INQUIRY BASED SCIENCE EDUCATION AND STUDENTS' FEELINGS OF SUCCESS

by Joan Catherine Brady Orcutt

This thesis addresses the advantages of an inquiry-based science environment in an eighth grade science class. It examines students at varying aptitude levels and their demonstration of growth in understanding science concepts. In addition, the individual students' feelings of success towards learning in such an environment are examined.

Research on this subject reveals that students at all aptitude levels are able to demonstrate learning in an inquiry-based environment and feel successful in their learning. Information was gathered from student interviews, pre- and post-unit tests and through researcher observations. This information can be used to support the idea that educating students in a inquiry-based environment allows students at all aptitude levels to demonstrate growth in learning and to feel successful in regards to their learning.

ACKNOWLEDGEMENTS

For Cory Orcutt, without his patience and understanding I could not have finished this project. And to my parents, Kevin and Susan Brady, without their support and belief in my abilities this would not have happened. I love and thank you all.

TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS.....	v
LIST OF TABLES.....	vi
CHAPTER	
I INTRODUCTION.....	1
Statement of the problem.....	2
Purpose of the study.....	3
Methodology.....	4
Definition of Terms.....	5
Assumptions and Limitations.....	6
Summary.....	6
II LITERATURE REVIEW.....	8
History.....	9
Definition of Constructivism.....	10
Definition of Inquiry Based Education.....	13
Studies Supporting Inquiry Based Science Education.....	15
Studies Against Inquiry Based Science Education.....	19
Conclusion and Research Statement.....	22
III METHODOLOGY.....	24
Description of Units.....	24
Student Sample.....	26
Overview.....	27
Procedure.....	27
Analysis.....	30

IV RESULTS.....	33
Observations.....	33
Overview of Units.....	33
Records of Scores.....	35
Discussion of Matter Unit.....	37
Discussion of Acid / Base Unit.....	40
Discussion of Geologic Time Unit.....	42
Student Interview Responses.....	43
Demonstrating Learning.....	44
Positive Attitudes.....	54
Relationship Between Students' Attitude and Demonstrated Growth.....	55
Study Design Limitations.....	56
Inconsistencies in Questioning.....	56
Time of Sessions.....	56
Summary.....	57
V DISCUSSION AND CONCLUSION.....	58
Student Interactions and Opinions.....	58
Demonstrated Growth.....	60
Students' Feelings of Success.....	61
Relationship Between Students' Attitude and Demonstrated Growth.....	62
Implications.....	63
Factors in Student Learning.....	64
Summary of Results.....	66
Study Design Limitations.....	68
Inconsistencies.....	68
Time of Sessions.....	69
Class Make Up.....	69
Individual Student Responses.....	70
Research Interpretations.....	70
Small Study Size.....	71
Further Research.....	71
Summary and Conclusions.....	73
REFERENCES.....	75
APPENDICES.....	81
Class Scores.....	82
Student Interviews.....	98
Pre/Post Test Questions.....	103

TABLES

I.	Student Aptitude Levels.....	26
II.	Methodology Tools Used to Answer Research Questions.....	28
III.	Matter Unit (Average Scores by Activity).....	36
IV.	Acids and Bases (Average Scores by Activity).....	39
V.	Geologic Time (Average Scores by Activity).....	41
VI.	Student A Scores.....	46
VII.	Student B Scores.....	48
VIII.	Student C Scores.....	50
IX.	Student D Scores.....	52

Chapter One

Introduction

Education from the modernist perspective has been one of teacher-directed lessons in which students need to memorize and reiterate the concepts being taught. Learning is defined by psychometricians only in terms of test scores, leaving out particular “knowledge, skills, talents, educational acquisitions, memory, and wisdom” (Jensen, 1981, p. 41). This factory model idea leaves the goals of education lying outside the curriculum, and determined prior to the instructional process; once firmly set, they [students] are “driven through” the curriculum (Doll, 1993). This form of education effectively removes the student from direct interactions with the teacher and the curriculum.

Current reform encourages teachers to involve students in developing goals for their own learning (Doll, 1993). Bruner (1983) sees a need to develop curricular plans and instructional strategies that utilize student-student and student-teacher verbal interactions. Humans have the unique ability to learn from others, through conflicts that create dilemmas which will generate growth. Educators need to transform the learner from a copier of others’ patterns to a generator of one’s own ideas.

Traditional science curricula follows the modernist perspective with an industrial vision of society. This dominant force has shaped our society and our values, including the way we envision education and schooling. The goal of this vision is to eliminate waste in education rather than concerns about efficiency in the model itself. Schools adopted this assembly line model

as multipurpose, creating multileveled classrooms which gave way to discrete, but contiguous, grade levels. This model, with its emphasis on control through standardization and progress through efficiency, both answered America's need in a rapidly changing society and provided a methodology for the future. Teaching was defined as the transfer of knowledge from teacher to learner. The school day was designed into standardized increments of time to allow for this transference to occur (Doll, 1993).

Science education has increasingly supported the need to facilitate the transformation of the learner as an active participant in their learning. More and more curricula are stressing hands-on lessons and opportunities for students to interact with materials. Hands-on lessons, however, are not the complete idea. In order for students to construct meaning from their learning, they need to approach it in an inquiry-based manner. An inquiry-based method not only incorporates the use of hands-on lessons, but it enhances learning through activities. These activities allow students to discover and support ideas they uncover through testing their own ideas and developing understanding of science concepts. Science by inquiry offers students an opportunity to interact with and manipulate materials which will help them better understand concepts that on a non-inquiry level seem unfathomable (Hodson, 1990).

Statement of the Problem

In my current teaching position, I have struggled with the problem of educating students by involving them in their learning and by creating more personalized learning situations that have meaning and relevance to their

lives. I believe that all students can learn and should succeed in learning science. For years I have taught science lessons which involved students in their learning. When I needed to check their understanding on a written test, I was continually disappointed with the results. No matter how well I thought I prepared the students they could not demonstrate their understanding of the concepts in this means. It was frustrating for me, because I knew they understood. I rethought my teaching program and designed a program which allows me to offer students many avenues to demonstrate their understanding of the concepts being taught.

Instruction in my classroom is designed to allow all students to feel successful and to learn no matter what level of aptitude they possess. On a daily basis, students continually explore the unknown, grapple with everyday ideas/problems, and learn science through the process of inquiry. My program offers situations where meaning is constructed through lessons that are interesting and meaningful, allowing students to understand difficult science concepts and demonstrate their knowledge, rather than simply repeat what has been memorized from textbooks. Not only do students learn, but they begin to feel successful and active participants in their learning. This form of teaching is relatively new, and many educators today fail to incorporate the inquiry aspect into the hands-on lessons. Due to its newness, research on how an inquiry based science classroom achieves learning and assesses learning is needed. An investigation of students' feelings of success and its relation to their actual attainment of the objective goals of the lesson can add to the knowledge and research base that currently exists.

Purpose of the study

The purpose of this case study was to determine through observations and interviews, the nature of students' feelings of success in science classes at the junior high school level. It also considered the extent to which students gained understanding of the concepts of the lessons through demonstration. The following questions were addressed:

1. Do students at all aptitude levels demonstrate growth in their understanding of science concepts in a inquiry-based environment?
If so, how?
2. Does an inquiry-based environment generate positive attitudes toward learning, a sense of success and control over students' learning? If so, how?
3. Is there a relationship between students' attitudes and their demonstrated growth in science learning and understanding?
If so, what is the nature and relationship between those variables?

Methodology

This case study focused on the progress made by four eighth grade students as they carried out activities and experiments in three science units. The study involved observations and interviews with students while they carried out these activities and experiments. Subjects included two female students and two male students at a junior high school in the San Francisco Bay Area in California. There is a diverse socioeconomic background at the school, along with a diverse, but predominantly White and Asian-American population. The students represented various levels of demonstrated aptitude: high, average, low average, and resource students (classified by

district standards as having learning disabilities). Observations were facilitated through videotaping both student interviews and activities. Data was collected by (1) interviewing students regarding their understanding of the concepts being taught, (2) interviewing students as to their feelings of success in the current unit, (3) reviewing video and audio tapes of students' feelings and performance, (4) teacher observations of students and video tapes, and (5) pre and post-test questionnaires.

Analysis of the data included determining students understanding of the science concepts being taught and how successful the students felt in regards to their learning. Interviews were used to elicit student responses which allowed the researcher to examine factors that may have lead to student success. Limitations inherent to the study were identified.

Definition of Terms

For purposes of this study, I used the following terms. I have defined these terms as they relate to my study.

1. Inquiry-based environment - teaching is based on the general proposition that science curricula should reflect the nature of science. One aspect is having the learner acquire knowledge through investigations while employing procedures similar to what scientists themselves use; and making the learner aware that the knowledge being acquired from the investigation is tentative- that is, subject to question (Duschl, 1986).
2. Student Success - reflects individual students' demonstration of understanding of science concepts.

3. Constructivist Approach - a philosophy which offers various opportunities for students to construct understanding from their interactions with materials and with the science concepts being taught.
4. ITBS Test- The Iowa Test Of Basic Skills used by this district to determine aptitude levels of students.
5. High Aptitude Level- a student scoring above the seventieth percentile on the ITBS test.
6. Average Aptitude Level- a student scoring near the fiftieth percentile on the ITBS test.
7. Low Average Aptitude Level- a student scoring near the twenty-fifth percentile on the ITBS test.
8. Resource Student- a student scoring below the tenth percentile and having passed a district battery of tests which determined a learning disability.

Assumptions and Limitations

This research study assumed that all students have been involved in previous science lessons and classrooms which relied on written examinations to assess their mastery of science concepts taught. As preliminary research, this case study was restricted to four eighth graders at one junior high school in the San Francisco Bay Area. Students were chosen from my science classes which use an inquiry-based learning environment, where students constructed meaning from interacting with peers and

materials. Also, the students were chosen to fall into the following categories: high, average, low average and resource student placement according to standardized test scores (Iowa Test of Basic Skills).

Research subjects participated in three instructional units of varying lengths. The shortest unit was one and one-half weeks. The other two lasted approximately two and one half weeks. The students received science instruction Monday through Friday for an average of fifty minutes per day.

Summary

This study contributes to the knowledge base in the area of teaching science through inquiry. The study focuses on students' personal concepts of success when allowed to construct meaning by interacting with concepts and materials. Empirical studies of how students develop their conceptions about phenomena in physics (McCloskey, 1983; Smith, Carey, & Wiser, 1986; Viennot, 1979; Wiser & Carey, 1983), biology (Carey, 1985), and astronomy (Vosniadou & Brewer, 1987) all support the view that learning is a process of constructing and reconstructing personal theories and models. These processes facilitate construction of conceptual relations. Teaching science in an inquiry-based environment allows all students to demonstrate growth in their understanding of science concepts and generate positive attitudes towards learning.

Chapter Two

LITERATURE REVIEW

The educational system is currently undergoing a paradigm shift, from a Modernist philosophy to a post-Modernist philosophy. Science education reform is following a constructivist and inquiry-based approach. Reformers have not been satisfied with a science curriculum that merely emphasizes the simple recall of facts (Roth, 1989). Dissatisfaction with current science programs in the elementary/junior high classroom has led to numerous attempts to change the nature of science teaching. The goal of reform is to emphasize the development of conceptual understanding, allowing students to incorporate higher-level thinking skills into their lessons, and to make science more relevant to their life experiences. "Science is not just a collection of laws or a catalog of facts. It is a creation of the human mind with its freely invented ideas and concepts. Physical theories try to form a picture of reality and to establish its connections with the wide world of sense impressions" (Einstein, Infeld, 1938, p. 57). Most textbooks present science as a large body of knowledge which involves memorizing facts and being able to recall them. The National Committee on Science Education Standards and Assessments (1992) states that school science education must reflect science as it is practiced by the laboratory scientist. If students are expected to understand the modes of reasoning of scientific inquiry, they must be educated in a similar manner.

History

Society can no longer afford to produce a citizenry incapable of understanding and applying the concepts, principles, and processes of science to the environment (Cherif, 1993). Recent proposals and recommendations which address steps for improving science education continue to endorse the inquiry approach of teaching science (National Science Foundation, [NSF] 1980; Welch, Klopfer, Aikenhead, & Robinson, 1981). Research on students' preconceptions in science started at the end of the nineteenth century with investigations of children's ideas of natural phenomena such as heat, frost, and fire (Hall & Brown, 1903). The inquiry perspective contends that the curriculum should present discrepant events or problematic situations in order to allow students to develop better understanding of the nature of science. Inquiry allows students to be involved in the decision-making process of their learning. This will increase students interest in science simply by having the opportunity to do science. The constructivist view has become the leading theoretical position in education and has become a powerful driving force in science education, particularly during the past decade (Ernest, 1993; Malone & Taylor, 1993; Steffe & Gale, 1995; Tobin, 1993). The constructivist perspective asserts that individuals construct and restructure their schemas of the world, through their own mental activity, as a result of experiences with phenomena and social interactions. At the heart of constructivism is the idea that every process of interpretation is a construction based on the conceptions already held by the researcher (Treagust, Duit & Fraser, 1996).

As far back as 1882, the Education Department declared that the instruction of scholars in science shall be given mainly by experiments (Hodson, 1990). During the 1960's, the process of inquiry teaching emerged as a leading strategy to meet the needs of reformers. Roots of the inquiry approach to teaching science are typically attributed to Joseph Schwab (Duschl, 1986). In the middle of the 1970s, there began a boom of research on students' conceptions of science and mathematics that continues today. Reform continued into the 1970's with many criticisms of teaching styles. Some major criticisms of current science programs are the failure of programs to account for the different developmental levels of the students and the lack of emphasis on the social or technological context in which science develops (Cherif, 1993). The major thrust of science education reform for the 90's has been an emphasis in hands-on science that leads to scientific literacy for students (Lindberg, 1990). Reformers feel that acquiring science knowledge through hands-on investigations is beneficial to students and allows teachers to meet the goals of reform which are to emphasize the development of conceptual understanding. The constructivist philosophy along with the inquiry approach promote student engagement in higher level thinking activities. Learning science involves being introduced to the "ways of seeing" of the scientific community and thus involves a socialization process (Driver, 1989).

Definition of Constructivism

The appeal of the constructivist view is it provides a plausible, functional framework for understanding and interpreting experiences of learning and teaching; in this way, constructivism acts as powerful theoretical

referent "to build a classroom that maximizes student learning" (Tobin & Tippins, 1993, p. 13). Constructivism consists of two basic principles, one psychological and the second epistemological. Both emphasize the belief that knowledge cannot be separated from knowing. These two principles, which make up von Glasersfeld's (1990) radical constructivism, include many facets of Piaget's genetic epistemology, and often serve as a reference position for discussions of constructivism in education (Treagust, Duit & Fraser, 1996).

According to von Glaserfeld's view, the first principle states knowledge is not received passively but is built upon by the cognizing student. In short, students construct their own meanings from words or visual images they hear or see. When engaging in this construction of meaning, that which the learner already knows is of central importance. Von Glasersfeld's second principle states that the function of cognition is adaptive and enables the learner to construct viable explanations of experiences (Treagust, Duit & Fraser, 1996). According to Strike (1987) these two principles of constructivism are simply common sense; that is, they are shared by almost everyone who deals with science education.

The constructivist view allows a consistent explanation of major empirical findings concerning the significance of students' pre-instructional conceptions in the learning process, and also facilitates predictions regarding outcomes of instruction. It values a belief that students' pre-instructional conceptions are difficult to change through instruction because they guide and, at times, determine students' sense-making process when information is provided by the teacher or textbook (Treagust, Duit & Fraser, 1996). In such approaches, there is a phase in which students' ideas are elicited and discussed

in class before the science concept is presented. A key feature in the phase of contrasting students' ideas and the science conceptions is negotiation, in which the teacher is a facilitator rather than a transmitter of knowledge (Treagust, Duit & Fraser, 1996).

Researchers of constructivism believe knowledge not only is personally constructed but also socially mediated (Prawat, 1993; Taylor, 1993). Rather than being concerned with knowledge as the representation of the truth, constructivism focuses on the way in which learners construct viable and useful knowledge. Constructivist teaching and learning approaches explicitly aim to help students make the constructions that lead to understanding the scientific points of view (Treagust, Duit & Fraser, 1996). Constructivism acts as a powerful theoretical referent "to build a classroom that maximizes student learning" (Tobin & Tippins, 1993, p. 7). Constructivism is simply common sense.

Many empirical studies provide ample evidence that students hold pre-instructional conceptions in many fields and these are substantially different from the scientific and mathematical concepts taught in school. Most of these conceptions are held strongly and hence are very resistant to change. German educator, Diesterweg (1790 - 1866) pointed out that it is of utmost importance to start instruction from the student's point of view. It is necessary, therefore, for the teacher to investigate students' pre-instructional conceptions (Jung, 1993). The hallmark of Dewey's approach to education was an attempt to connect subject-matter knowledge with the child's experiences.

If constructivist approaches are to be implemented effectively, teachers' traditional beliefs about transmission approaches to learning need to be challenged (Prawat, 1992).

Definition of Inquiry-Based Education

Inquiry is a general process by which human beings seek information or understanding about what they are learning or experiencing. It is an approach to teaching and learning that searches for knowledge and understanding by questioning, observing, investigating, analyzing and evaluating a set of circumstances (Welch, Klopfer, Aikenhead & Robinson, 1981). An inquiry-based program should present discrepant events or problematic situations, encourage observation, ask for explanations, encourage the testing of those theories, and debrief the process (Cherif, 1993). The main goal of an inquiry-orientated curriculum is to increase the development of science process skills. Teachers play a crucial role in directing and providing the experiences students use to gain knowledge of a concept. Activities are structured in an open-ended format (where more than one possible solution, design, or answer is possible). These activities include an investigative situation that requires first-hand student participation and leads towards providing evidence that permits a question, posed at the onset, to be answered by the student (Lock, 1990).

The important aspect of an inquiry-based curriculum is that students are engaged in scientific, higher-level thinking activities and actions. The backbone of the curriculum is student investigations, not textbooks. Students are viewed as beginning scientists who explore phenomena through hands-on activities and who develop scientific thinking skills to increase

knowledge and conceptual understanding in the same ways that scientists use experimental work to construct new knowledge, concepts and theories (Roth, 1989).

To teach or not to teach science as an inquiry into inquiry--is the question posed by Duschl (1986), with regard to reforming science education. The rationale for teaching with an emphasis on inquiry is that an inquiry approach will allow students to develop a better understanding of the nature of science and therefore will be more interested in science due to the fact that they are actively involved in "doing" science (Blosser & Helgeson, 1989). According to Piaget, students must understand the concrete before they can perceive the abstract. There are many reasons for engaging in practical science activities. Derek Hodson (1990) discusses some of them.

1. To motivate by stimulation, interest and enjoyment.
2. To teach laboratory skills and apply them to everyday life situations.
3. To enhance the learning of scientific knowledge.
4. To give insight into the scientific method and develop expertise.
5. To develop certain "scientific attitudes" such as open-mindedness, objectivity and willingness to suspend judgment.

The concentration on factoids (terms, definitions, facts, and trivia that form the lowest level of the learning hierarchy) wastes students' time and erodes their motivation (Sachse, 1989). Open-ended laboratory work, however, allows student thinking to develop from concrete situations to abstract ideas and can be the vehicle for the arousal of curiosity and appreciation of the aesthetic aspects of the student (Hodson, 1990). Learners need to associate a personal connection or interest in the learning activity

they have been assigned. Personalizing the instruction can be accomplished by focusing on the conceptual aspects of the experiment, by identifying for oneself a problem that is interesting and worth investigating, related to the student's daily life experiences, or by designing the procedure to be adopted (Hodson, 1990). The individual facts or concepts students learn from those activities are not nearly as important as the lessons learned about the nature of scientific inquiry (Roth, 1989), for example, data gathering and interpretation of their findings to support or refute a hypothesis. Inquiry involves activities and skill development. The focus is on the active search for knowledge or understanding to satisfy a curiosity (Haury, 1993).

Studies Supporting Inquiry-Based Science Education

Studies conducted by Lunzer, Harrison and Davey (1972) found that students using familiar materials performed better on problem-solving tasks than those students using unfamiliar materials. If a student is unfamiliar with how equipment works, they cannot focus on solving the problem. Rather, they are trying to understand how to use the equipment and do not have the opportunity to solve the problem at hand. In these studies, control groups were used to determine how prior knowledge and familiarity with materials effected the problem solving abilities of students.

Evidence shows science-inquiry-related teaching fosters scientific literacy and understanding of science processes (Lindberg, 1961). Inquiry also increases vocabulary knowledge and conceptual understanding (Lloyd & Contreras, 1985, 1987) along with critical thinking (Narode, et al., 1987), a positive attitude toward science (Kyle, et al., 1985; Rakow, 1986), and higher achievement on tests of procedural knowledge (Glasson, 1989). Inquiry based

programs in the middle school levels have been found to generally enhance student performance, particularly as it relates to lab skills graphing and data interpretation (Matthers & Nayayama, 1988).

Glasson (1989) supports the idea of inquiry-based teaching. He discovered from his studies of 54 ninth-grade students (27 male, 27 female) at a university town in the Southeast, that students who participated in hands-on laboratory classes, which were student centered, performed significantly better on the procedural knowledge test than the students in the teacher-directed class. All students benefited from hands-on laboratory instruction. In the control group where students observed the teacher, rather than being actively engaged in the learning, it was found that they were more likely to become passive learners and were less motivated to solve problems independently. The students in the hands-on, experimental group were found to be at an advantage because they were actively exposed to the "operational" relationships among the variables. The importance of experience with the "actions of objects" in the development of procedural knowledge supports the Piagetian Theory.

Ted Bredderman's work (1982) is based on information gathered from over 60 studies he conducted between 1968 and 1983. These studies included 13,000 students in 1,000 classrooms. He compared three activity-based science curricula with the traditional read-and-recite approach. He concluded that the use of activity-based science programs substantially improved performance in science process skills and enhanced creativity. Modest increases were seen on performance tests of perception, logic, language development, science content, and math. Modest improvements were also

observed in attitudes toward science and science classes. Those students in non-traditional classes clearly outperformed those without the hands-on experiences. The strongest gains discovered by Bredderman's work with hands-on science activities was the increased knowledge in the area of process skills.

Regan Carpenter (1963) compared the text-book-recitation method with a problem-solving method, also referred to as activity-orientated approach. He concluded that the problem-solving method brought the most gains in content learning and that slower learners also benefited from this teaching method.

Researcher John Renner and colleagues (1993) found another advantage to science classes which relied upon hands-on activities. He conducted his study with two groups of thirty students. They were tested in observation, classification, measurement, experimentation, interpretation and prediction. Group 1 followed a hands-on program; Group 2 was exposed to only a read-and-recite approach. Renner concluded that a program based on hands-on activities led students to develop scientific literacy, meaning the ability to apply science learning to everyday life.

Renner's second study compared four experimental classes with four control classes. The experimental group had activity centered units, whereas the control group had been limited to nature walks, a science table and science related stories. Data concluded that the experimental group with the activity

centered curriculum out-scored the control group in every area of the comparison. From this study, it is clear to see that students who actively engaged in their learning benefited the most.

Research in the 1990's reveals the need for hands-on active science learning, yet we still have not structured the current curriculum to produce scientifically literate adults (Lindberg, 1990). The research on strategies and methodologies for teaching science has produced clear evidence that students in activity-based programs learn more than students in traditional text-book based programs (Walton & Butler, 1990). This conclusion is also supported by the research of Wang and Palincsar (1989). They discussed prevalent findings in the body of research from various theoretical and practical perspectives which points clearly to a relationship between academic success and an active student role in learning.

When students are involved with hands-on activities, it enables them to learn the process of science and become empowered to be scientifically literate (Lindberg, 1990), which translates to creating independent learners and thinkers. Research also shows that the kind of classroom experiences students have in science can dramatically affect their perceptions of science, scientists and their attitude toward science (Kyle, Bonnstetter, McCloskey & Fults, 1985). Kyle et al. conducted a five year study beginning in the 1983-84 school year. Of the 35 schools in the district, six were exposed to a program of science curriculum that emphasized inquiry and science process skills. During the first year, the activity-based program's effectiveness was assessed by comparing science attitudes of students exposed to the activity program and those not exposed. The results showed that 43% of the activity-based

science students chose science as a favorite student. In the control group, only 21% of the students chose science as their favorite subject. When compared to the least favorite student, the experimental group chose science 7% of the time, whereas those students in a non-activity science program chose science 18% of the time. This study also discovered that 75% of the students in the activity program found science fun and exciting. Science was boring to 50% of the non-activity group. Students in the activity program realized their inquiries gave them a feeling of success. These students were also able to see science as useful in their daily lives as well as in their future. A more positive view of science and scientists was reported from the experimental group as compared with the control group.

Activity science research shows the benefits of hands-on lessons which is most obvious in the area of science processing skills. In some cases, because of students prior ideas and knowledge, students bring their own questions and problems to a given teaching situation, which leads to learning (Driver & Bell, 1986). Science education driven by a textbook inhibits students ability to ask questions or to direct their learning.

Studies Against Inquiry-Based Science Education

Not all reformers or science teachers agree with the belief that science education should be hands-on and inquiry based. Latter day back-to-basics advocates contend that the new curricula does nothing that traditional approaches cannot do. According to these critics, if students are having fun discovering science they're probably not learning much anyway (Mechling & Oliver, 1983). Glasson (1989) did conclude that the physical manipulation of

the laboratory equipment was not a factor in improving declarative knowledge achievement. Declarative knowledge is a student's factual and conceptual mastery of a subject (Anderson, 1980).

The substantial increase in the amount of practical work during the 1960's curriculum innovations did not lead to increased uptake of optional science or to more positive studies towards science (Hodson, 1990). Hodson further brings to light the fact that empirical evidence concerning the efficacy of practical work as a better technique to learn scientific knowledge is difficult to interpret and somewhat inconclusive. Practical work is not necessary to provide students with desired laboratory skills. However, he stresses that certain laboratory skills are necessary in order for children to successfully engage in practical science work. Theoretical considerations must precede experimental inquiry. Practical work, based on discovery learning, puts the cart before the horse (Hodson, 1990). Several researchers have provided striking evidence regarding ways in which students' alternative theoretical frameworks lead them to misinterpret the nature and purpose of the experiment they conducted. This compounds their misconceptions (Driver, 1983). Suggesting that students can readily acquire new concepts by engaging in open-ended discovery learning activities is absurd (Hodson, 1990). Hodson further states that students need a good foundation of scientific principles and information and then and only then are they able to perform activities and interpret the scientifically appropriate answers.

Several studies have also shown that students view practical work as a less boring method of teaching science, rather than allowing them to develop a sense of enjoyment from science itself. Even after several years of

practically-orientated science lessons, many students were unable to perform even simple laboratory procedures (Hodson, 1990).

In a study of practical lessons in a number of British secondary schools, Moreira (1980) found that students often perform experiments in class with only a rudimentary idea of what they are doing. They have virtually no understanding of the purpose of the experiment or the reasons for the choice of procedure. It was also discovered that students had little understanding of the underlying concepts being taught by the teacher. The students were simply following a recipe. There was no thought process, self discovery or inquiry involved.

An American study of three teaching styles (lecture/discussion; laboratory work/discussion; lecture/teacher demonstration/discussion) revealed that only in respect to the development of laboratory skills did practical work show any significant advantages over other methods (Yager, Englen & Snider, 1969). No significant differences were noticed with respect to conceptual gains, the understanding of scientific methodology or in student motivation.

Hofstein and Lunetta (1982) argue that most studies of the efficacy of practical work have been flawed by poor experimentation. More precisely, small research group size, inadequate control of the variables, and the use of inappropriate test instruments are the leading causes of the flaws. One of the major problems researchers have with current studies is the obvious differences between practical exercises, designed to develop manipulative skills, experiments, used to illustrate key concepts, and inquiries enabling students to conduct their own investigations. Researchers tend to lump all of

these experiences under the heading of “practical work.” A laboratory activity that is open-ended with one teacher may be highly directive when another teacher presents the same lesson.

Further complications arise due to the fact that experiments give unanticipated results that lead students to discover an “alternative science.” The usual response is to inform the student that they got the wrong results. This, however, instills a concern with what “ought to happen” and a preoccupation with “the right answer.” It also projects a view that scientists know well in advance the results of experiments they conduct (Hodson, 1990). Until the focus is more on what students are actually doing in laboratory experiments, the best method for instruction cannot be determined.

Conclusion and Research Statement

It is apparent that the method used to teach science has an important effect on the students’ attitudes toward science (Kyle et al., 1985). Science classes need hands-on activities if learning is to progress beyond mere fact-cramming (Mechling & Oliver, 1983). In order for students to do well in science, the teaching style must focus on ways to interest and actively engage students. Across grade levels, students overwhelmingly prefer science that emphasizes inquiry and process (Kyle, Bonnstetter, McCloskey & Fults, 1985). Research results also show that the kind of classroom experiences students have in science dramatically affects their perceptions of science, scientists and their attitude towards science (Kyle et al., 1985) By allowing students to engage in open-ended, hands-on experiments, and not providing a list of procedures, students must use their knowledge of concepts previously studied to develop their own procedures (Tinnesand & Chan, 1987).

Students are likely to begin to understand the natural world if they work directly with natural phenomena using their senses to observe and using instruments to extend the power of their senses (National Science Board, 1991). Many opportunities must be provided to students for collection, sorting and cataloging; observing, note taking and sketching; interviewing, polling and surveying (Rutherford^d Algeren, 1990). It must also be discussed that an emphasis on inquiry-orientated teaching does not necessarily preclude the use of textbooks or other instructional materials (Haury, 1993). By itself inquiry based teaching is a method to allow students a better opportunity to understand a difficult subject.

The purpose of this study was to investigate the students' feeling of success in science at the junior high school level and how their feelings regarding leaning contributed to meeting the objectives of the science lessons. Current trends in educational reform clearly support the idea of a curriculum which allows students to construct meaning through the interaction of materials and experiences. This study attempted to examine an inquiry-based science program and how students' feelings of success contributed to their ability to demonstrate learning.

Chapter Three

METHODOLOGY

The purpose of this case study was to discover if my students, at all aptitude levels, who are learning science in an inquiry-based environment can demonstrate growth in understanding science concepts and develop positive attitudes toward learning and if there was a relationship between these two variables. Conducted at a junior high school in the San Francisco Bay Area in California, this study involved four eighth grade science students. These students engaged in daily hands-on activities and lessons which covered three individual science units. The first unit was a two and one-half week instructional period on Matter. The second unit covered the chemistry of Acids and Bases over a two week period. A two and one half week unit on Geologic Time completed the study. The students received no special treatment, nor were they separated from the whole class. I was interested in discovering whether learning science in an inquiry-based environment would allow students at all aptitude levels to develop positive attitudes toward learning and allow students to demonstrate growth in their understanding of science concepts. Analysis of students' feelings was determined through a series of interviews I conducted. Demonstration of growth was determined through questionnaires I gave prior to lessons and after the lessons.

Description of the Units

The first unit dealt with the concepts of Matter. I designed this unit to engage students in a variety of situations which incorporates numerous

modalities. Textbooks and note taking were used to teach students a method for discovering information about the unknown. The students were also presented problems which dealt with the concepts of matter. Almost all activities included hands-on or manipulation of materials. These included the states of matter, the changes in states of matter, the physical and chemical properties and how to determine if the matter has undergone a physical or chemical change. Laboratory investigations involving visual observations and problem solving guided students in their interactions with the subject matter. The unit culminated with an activity allowing students to use knowledge gained to complete a task involving the separation of substances based on their characteristics.

The chemistry of Acids and Bases was presented as the next unit. In this unit, students were again exposed to numerous situations involving textbooks, note taking, and hands-on activities. The concept of acids and bases was discovered through interactions with unknown solutions and the students' ability to determine its category. The final activity was based on previous knowledge from the unit and required students to actually neutralize a toxic spill of a very strong acid.

Finally, a unit on Geologic Time was incorporated into this study. Students again used many modalities to help them understand the concepts of the unit. Hands-on activities allowed students to interact with the concept and develop methods for solving problems presented in the lessons. Unlike many science units which require memorization of information provided by the teacher, this unit stressed information gathering skills to complete the assignments and activities.

Student Sample

Students were recruited from eighth grade science classes at a junior high school, in the San Francisco Bay Area, California. Four students were chosen to represent a variety of aptitude levels, based on the Iowa Test of Basic Skills (ITBS) scores. This selection allowed me to observe the effects of inquiry-based instruction on various aptitude levels of students in my classrooms. I selected the students in my study to represent four of my five classes and to represent the various aptitude levels in my classes. The students were chosen for convenience and accessibility. I did not have any gender bias in mind when I chose them, it just worked out that the female students were labeled average or above and the male students were labeled below average.

Table I

Student Aptitude Level

Student	Gender	Aptitude Level
A	female	above average
B	female	average
C	male	low average
D	male	resource student

The students' parents or guardians were given a cover letter and consent form to be signed prior to participating in the study. To facilitate the students' anonymity, each student was assigned a letter A through D and referred to by this letter in all research data and discussions (see Table I).

Overview

This study incorporated the use of pre- and post-unit interviews. At times mid-unit interviews were conducted to help determine the student's attitudes and demonstration of growth regarding science concepts.

Videotapes and audiotapes were used to record the student responses.

Prior to each unit of instruction, students were given a pre-test questionnaire to determine previous knowledge. At the end of each unit the same questionnaire was given to the students in the form of a post-test. Teacher observation was also incorporated into this study to help determine if students at all aptitude levels could demonstrate growth in their understanding of science concepts and to discover if students had a positive attitude regarding their learning.

Procedure

The students were interviewed prior to the beginning of the first unit regarding their attitudes about science in the previous years and this year. The students were told that I was interested in discovering if an inquiry-based environment allowed students to demonstrate understanding of science concepts and if it allows for the development of positive student attitudes regarding learning. To help me determine if these questions could be answered, I used audiotapes of conversations with students and videotapes of interviews. Also collected were audiotapes and videotapes recording student interactions with peers during lessons. An interview was also conducted to record each student's feelings about their responses to pre-test and post-test questionnaires. Students participated in unit activities lasting from two to three weeks. During that time, students were periodically interviewed

regarding their attitudes and the growth they demonstrated in understanding the science concepts being taught.

While the students were being interviewed, a tape recorder was used to record their responses. Each audio tape was labeled with the student's letter, the date, the time and the unit being studied. The code that relates the students' names to their letter was kept in a locked file drawer at my residence.

Table II

Methodology Tools Used to Answer Research Questions

Research Question	Observation/Data
1. Do students at all aptitude levels demonstrate growth in their understanding of science concepts in an inquiry-based environment? If so, how?	interviews, videotape observations, pre- and post-test scores, grades
2. Does an inquiry-based environment generate positive attitudes toward learning, a sense of success and control over their learning If so, how?	interviews, videotape observations
3. Is there a relationship between students' attitudes and their demonstrated growth in science learning and understanding? If so, what is the nature and relationship between those variables?	interviews, videotape observations

Students were periodically videotaped while involved in activities. I placed the video recorder in the corner of the room and faced it toward the direction of the student being observed, so it was not a distraction. The students were also videotaped in the culminating activity of the unit to allow me to determine if students demonstrated growth in their understanding of the science concepts being taught. Each videotape was labeled with the student's letter, the date, the time and the unit being studied. The code that relates the students' names to their letter was kept in a locked file drawer at my residence.

In order to ascertain where the students were in the learning process, I conducted interviews during the unit and at the end of each unit. The following questions were asked by the researcher:

1. What are we studying/learning?
2. What do you know now that you previously didn't?
3. How successful do you feel that you have learned the concept being taught?

Additional questions were asked to gather further information if the above questions did not reveal pertinent information. Example extension questions that were asked included: (1) "What did you find difficult? Why?", (2) "What did you find easy? Why?"; and (3) "What should be changed or not changed in your opinion? Why?" The student responses were transcribed (see Appendix B) and used in the interpretation of the factors that may have led to student's feelings of success and their ability to meet the objective goals of the unit.

The interviews and videotapes were used to allow me to reflect and observe student interactions with materials and information along with student attitudes. This information was used to help determine if students demonstrated growth in learning science concepts.

Before and after each unit was completed, the students were given a pre-test questionnaire and post-test questionnaire which were exactly the same. The students were able to compare pre-test answers with post-test answers, along with information gathered from the unit. This allowed students to judge for themselves if they had learned. Through evaluation of their answers, they determined their growth in learning science concepts in an inquiry-based environment.

I was also able to use the questionnaires to help me determine if the students had positive attitudes. The individual student's responses are located in Appendix C.

Individual class scores were collected and recorded to compare the four students in the case study to the entire class to verify accurate representation of the information. This data is located in Appendix A. The individual student data is located in Chapter 4.

Analysis

Interviews

Analysis of the data included viewing videotapes of students' interactions with science materials used in unit lessons, and reviewing audio tapes of the student interviews conducted by the researcher. I questioned students on their understanding of science concepts being taught. Students were questioned regarding their attitudes toward learning in the inquiry-

based environment. Data was collected through the use of videotapes and audiotapes. These were used to record the students responses during the interviews and allowed me to review their responses as needed. The results of these interviews are located in Appendix B. Review of the videotapes allowed me to see if the students demonstrated growth in their understanding of the concepts being taught in the unit, and the individual student's attitude toward learning. The additional questions that arose from the student interviews allowed me to examine other factors that may have led to student success or feelings of success. In addition, any limitations inherent to the design of the study were noted.

Pre- and Post-test Questionnaires

Each student in the research study was given a pre-test and post-test questionnaire before and after the unit. Results of the pre-test and post-test questionnaires were compared for each unit and then assessed to determine if the students demonstrated growth in their understanding of the science concepts being taught.

To help evaluate the answers to these tests, I developed the following rubric which used a five point scale. The total possible points that could be earned per question was five. Points were awarded based on the following criteria:

- 1 point for a definition that met the researcher's expectation.
- 1 point for an expanded answer.
- 1 point for evidence of a learned concept.
- 1 point for providing an example.
- 1 point for stating a generalization (application other than given in class).

In each of the three units I used, various points could have been earned. In the first unit, Matter, there were a total of five questions asked. The maximum score possible in this unit, based on my rubric, was twenty-five points. The second unit, Acids and Bases, consisted of six questions for a total of thirty possible rubric points. The final unit, Geologic Time, contained five questions for a total of twenty-five points for each student.

Although many answers were non-technical, they were acceptable for introductory classes, at this level. The researcher reviewed the unit activities and discussions in order to evaluate if the students demonstrated growth in their learning. The results of this questionnaires is located in Appendix C.

Class Data

Data was also analyzed in regard to the entire population exposed to an inquiry-based learning environment. Class scores were collected for each unit and each activity. These scores were averaged. The average scores were then compared to the scores obtained by the four students in the case study. I used these results to determine if the four students in the study were representative of the entire class. This data is compiled in Appendix A by unit and class. The scores for the individual students in this study are located in Chapter 4. Through the comparison of these scores, I was able to determine if the students in this case study were representative of all my students. Also, I was able to compare students' demonstration of growth in their understanding of the science concepts and their attitudes toward learning in an inquiry-based environment to the student population in my classes.

Chapter Four

RESULTS

The primary purpose of this research was to determine if students at all aptitude levels were able to demonstrate growth in their understanding of science concepts, generate positive attitudes in an inquiry-based environment, and if there is a relationship between students' attitudes and their demonstrated growth in science learning. It was my intention to investigate an inquiry-based environment which allows students to construct meaning from their experiences.

Observations

This study focused on the students' demonstration of growth in their understanding of science concepts and their attitudes toward learning in an inquiry-based environment. The research study was organized to include three different science units of the current 8th grade curriculum. Students were interviewed prior, during and after each of the units in this study. For each unit, pre-test questionnaires were developed and administered to the students prior to any discussion about the unit. At the end of each unit, the same questions were asked in the form of post-test questionnaires.

Overview of the units

Units comprising this research study reflect the current eighth grade science curriculum of a school district in the San Francisco Bay Area. All of the lessons and activities were taught by myself to five different eighth grade science classes. Each class received the same lesson on the same day. The four research students represented four of the five classes.

The first unit was on the concepts of Matter. This unit began with a pre-test administered to each research student on the day prior to beginning the unit. Students were instructed to answer it as accurately as possible, but not to worry if they did not know the answer. This unit consisted of a reading assignment with specific concepts the students needed to discover. It was followed by a mini-lecture and then a lab in which students completed a phase change experiment. In this lab, students took a solid to a liquid and then to a gas, while recording temperature and time information. Another lab allowed students to see a chemical change occurring when liver was mixed with hydrogen peroxide. Homework assignments were given to reinforce what was being taught in the classroom. Students were also exposed to five different mystery powders that needed to be identified by using their physical and chemical properties. This unit concluded with students learning how to use the periodic chart to find information about atoms. At the end of this unit the research students were given a post-test questionnaire.

The second unit was Acids and Bases. This unit also began with a pre-test questionnaire administered to the four research students, prior to the discussion of any information on the unit. The unit began with a reading assignment with specific instructions on what information to obtain. Following this assignment, the students received a mini-lecture and a demonstration of the various tests for determining acids and bases. The major assignment was to determine whether approximately twenty substances were either acids or bases. In this assignment, not all substances clearly tested one way or the other, so students were forced to problem solve

in order to determine whether the substance was an acid or base. The four research students completed the unit with a post-test questionnaire.

The final unit of this research study dealt with the concepts of Geologic time. Again, the four research students were given a pre-test questionnaire to determine what they knew before being exposed to any information in the unit. This unit's first assignment had students place various events on a time line. When the earth was created, the first humans, dinosaurs and other major historical events were some of the events. Following this activity, students received two homework assignments reinforcing class work. The major assignment for this unit consisted of the students creating a geologic time line of the Cenozoic, Mesozoic, and Paleozoic eras. These time lines needed to represent the geological surroundings which were present during each era. Finally, the four research students were each given a post-test questionnaire at the conclusion of the unit.

Records of Scores

Although only four students officially participated in this research study, all students in my classes participated in the activities. The total number of students involved in this study was approximately 170. The following is a summary of the scores by class and a listing of scores for the individual research students. Detailed results for all students can be found in Appendix A.

Table III

MATTER UNIT
(Average Scores by Activity)

MATTER	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5
Class 1	7	21	7	7	17
Class 2	7	21	7	7	16
Class 3	8	21	7	7	15
Class 4	7	22	8	7	17
Class 5	7	22	6	6	17
Student A	7	25	10	10	20
Student B	7	25	0	0	18
Student C	8	23	7	8	20
Student D	9	24	7	0	16

Discussion of Matter Unit

The results of the first unit on Matter are provided in Table III. Each class that participated in the lessons was included in the data. Also included were the individual scores for each of the students participating in the research study.

Assignment 1 had a possible point total of 10 points. The class averages were seven points, except one class in which the average was eight. All students received a score of at least seven, and two received higher scores. Overall the students' scores reflect those of the classes.

Assignment 2 contained a possible score of twenty-five. The class averages ranged from twenty-one to twenty-two. The students' scores ranged from twenty-three to twenty-five. The students' scores in this assignment were above the class averages by at least one point.

The third assignment had a possible score of ten. The class averages ranged from six to eight. The students' scores on this assignment ranged from zero to ten. In the case of the zero score, the student did not turn in the assignment, which led to the score being so low. Other students' scores are reflective of the class averages.

In the fourth assignment, the class was able to earn a possible score of ten. The class averages were from six to seven. The students' scores ranged from zero to ten. Again, the zero scores were due to two of the students not turning in their assignments. The two students that did complete the assignment scored above the class averages by at least one point.

The final assignment of this unit had a possible score of twenty. The class averages ranged from fifteen to seventeen. The students' scores ranged from sixteen to twenty. All the students did complete this assignment. The scores of three of the four students were higher than the class averages. Student D received a lower score, but still within the class averages range.

Table IV

ACID AND BASE UNIT
(Average Scores by Activity)

ACIDS & BASES	Activity 1
Class 1	16
Class 2	18
Class 3	18
Class 4	17
Class 5	17
Student A	25
Student B	0
Student C	15
Student D	0

Discussion of Acid and Base Unit

The second unit contained information on acids and bases. Students were involved in one major assignment in this unit. The assignment lasted about one and one-half weeks. There was a possible point score of twenty-five. Class averages and students' scores are listed in Table IV. The class averages ranged from sixteen to eighteen. Students' scores ranged from zero to twenty-five. The results of students' scores were lower due to two of the students not completing the assignment. Student A and Student C did complete the assignment. Student A scored twenty-five points, much higher than any of the class averages and Student C scored fifteen, lower than the class averages by one point.

Table V

GEOLOGIC TIME UNIT
(Average Scores by Activity)

GEOLOGICTIME	Activity 1	Activity 2	Activity 3	Activity 4
Class 1	7	21	8	12
Class 2	7	21	8	12
Class 3	6	21	7	13
Class 4	8	21	8	13
Class 5	7	20	9	11
Student A	8	25	10	15
Student B	0	24	0	14
Student C	10	24	7	12
Student D	0	19	9	13

Discussion Of Geologic Time Unit

The final unit in this research study covered concepts of Geologic Time. This unit consisted of four graded assignments. A class average ranging from six to eight was earned on the first assignment. Students' scores ranged from zero to ten. Again, two of the students failed to complete the assignment and therefore received a zero score. Student A and Student C did complete this assignment and received scores at or above the class averages.

The second assignment in this unit received class average scores ranging from twenty to twenty-one. The students' scores ranged from nineteen to twenty-five. All students scored above the class averages except for Student D. Student D, however, only scored one point below the class averages.

In assignment three, a possible of ten points could have been earned. The class averages on this assignment ranged from seven to nine. The students' scores ranged from zero to ten. Student B did not complete this assignment, thus earning a score of zero. Students A, C and D scored at or above the class averages.

The final assignment in this unit could have earned a total score of fifteen. The class averages on this assignment ranged from eleven to thirteen. The students' scores ranged from a low of twelve to a high of fifteen. All students completed this assignment and their scores are reflective of the class averages.

Student Interview Responses

Each of the four research students was interviewed to help determine their understanding of the content being taught and their feelings as to how they felt about their learning. A pre-research study interview was given to the four students. The research study was explained to each student prior to their completing the interview. Students were instructed to answer honestly, and not to be concerned with pleasing me.

After the final unit, a post-research interview was conducted with the four students. During this interview, I reviewed the information that had been taught during the study, and reviewed the assignments with the students and their individual scores. Finally, I asked each student to reflect on their learning and to explain how successful, or unsuccessful they felt during and at the conclusion of the study. The student responses were recorded and summarized in Appendix B.

The overall consensus of student responses were positive and supportive of the inquiry-based design of the classroom. Constructing knowledge from the activities and lessons they engaged in allowed the majority of students to learn in a comfortable setting.

The research students believed that learning by doing was the best method of learning for all students. Students also believed the activities encouraged them to learn and made difficult concepts easier to comprehend. These students also felt they were learning more science concepts than in previous years. Some students stated that previous years of book work and

lectures had left them feeling that mastering science was an unobtainable goal. According to their responses, these students now feel they can learn and succeed in science.

I also noticed that two of the four research students admitted to not working to their potential and hence, were receiving lower grades. One student did feel a lot of success based on their science grade, and also admitted that they were trying harder than in the past. The final student, who has been classified as a resource student by district standards, did feel that his grade was not as good as it could be. He cited the fact that the information was becoming more difficult and that he was not trying as hard as he could have tried.

The change in student interest and effort levels could have been due to outside demands on their time, the time of year and/or other unknown influences. It seems to be a yearly trend at my school that grades and student effort levels are higher in the beginning of the year and as the year progresses, grades and interest levels decrease.

Demonstrating learning

During this study, I administered a pre-test questionnaire to the research students prior to the individual units being taught to help determine if learning had occurred. At the end of each unit, the same questions were asked in a post-test questionnaire format. The individual student's responses are located in Appendix C.

To help evaluate the answers to these tests, I developed the following rubric which used a five point scale. The total possible points that could be earned per question was five. Points were awarded based on the following criteria:

- 1 point for a definition that met the researcher's expectation.
- 1 point for an expanded answer.
- 1 point for evidence of a learned concept.
- 1 point for providing an example.
- 1 point for stating a generalization (application other than given in class).

In each of the three units I used, various points could have been earned. In the first unit, Matter, there were a total of five questions asked. The maximum score possible in this unit, based on my rubric, was twenty-five points. The second unit, Acids and Bases, consisted of six questions for a total of thirty possible rubric points. The final unit, Geologic Time, contained five questions for a total of twenty-five points for each student.

Although many answers were non-technical, they were acceptable for introductory classes, at this level. I reviewed the unit activities and discussions in order to evaluate if the students demonstrated learning.

Student Scores**TABLE VI****Scores of Student A**

Matter Unit	pre-test	post-test
Question 1	2	3
Question 2	0	4
Question 3	0	2
Question 4	0	4
Question 5	2	5
Total	4	18
Acids & Bases	pre-test	post-test
Question 1	2	5
Question 2	2	5
Question 3	0	5
Question 4	3	5
Question 5	0	5
Question 6	3	5
Total	10	30
Geologic Time	pre-test	post-test
Question 1	1	3
Question 2	0	2
Question 3	4	4
Question 4	5	5
Question 5	3	5
Total	13	19

With regard to the unit on Matter, Student A scored a total of four on the pre-test and eighteen on the post-test. There was a possible score of twenty-five points on the pre-test and twenty-five points on the post-test. The answers appeared vague in the pre-test, along with two answers that stated they did not know the answer. Post-test results for Student A demonstrated knowledge gained during the unit which allowed for more correct and detailed answers to be recorded.

Student A scored ten out of a possible thirty points on the Acids and Bases pre-test questionnaire. Two of the questions in the pre-test were answered correctly, yet not very detailed. Four other questions were answered with wrong answers or a statement of not knowing. The post-test questionnaire presented an excellent example of knowledge gained during the unit. The score of thirty out of a possible thirty convinced me that through the various hands-on activities, demonstrations during the units, and discussions, this student had grasped the concepts of the unit.

The final unit of Geologic Time consisted of five questions on the pre-test and post-test. There was a possible score of twenty-five rubric points available for the student to earn. Her pre-test score was thirteen, whereas this student's post-test score was nineteen. There was only a slight increase in the student's scores. I interpreted this slight gain due to three of the pre-test questions being answered correctly. In these answers, I found that simple answers were given and not expanded upon, which could have lead to lower scores.

Table VII

Scores of Student B

Matter Unit	pre-test	post-test
Question 1	0	3
Question 2	0	3
Question 3	0	3
Question 4	0	3
Question 5	0	3
Total	0	15
Acids & Bases	pre-test	post-test
Question 1	0	0
Question 2	0	1
Question 3	0	3
Question 4	0	4
Question 5	0	4
Question 6	0	4
Total	0	16
Geologic Time	pre-test	post-test
Question 1	2	3
Question 2	0	4
Question 3	0	4
Question 4	2	4
Question 5	2	4
Total	6	19

Student B, who is categorized as an average student, showed an increase in knowledge in all of the units studied. In the first unit on Matter, the student received a pre-test score of zero and a post-test score of fifteen. These scores were reflective of five answers of "I don't know." After the post-test was administered, the student was able to obtain a score of fifteen. Three

of the answers were acceptable to me as demonstrating knowledge gained. The other two were considered leaning toward understanding, yet not mastering it. All of the answers by this student in this unit were vague and simple.

In the second unit on Acids and Bases, the student again scored zero out of thirty on the pre-test due to three answers of "I don't know" and three wrong answers. On the post-test, this student scored a total of sixteen points out of a possible thirty. All answers on the post-test, except one, were determined to be correct. Although the answers showed that concepts had been learned, they were vague and simple. In some cases, one word answers were given.

The Geologic Time unit was the only unit in which this student received a score other than zero on the pre-test. A score of twenty-five was possible. Student B scored a total of six on the pre-test. Of the five questions asked, only two were considered correct. All others were either wrong or "I don't know." The post-test results did show evidence that some of the concepts of the unit had been learned. All five of the post-test questions were answered with acceptable and correct answers. The answers were vague and simple, yet they convinced me that knowledge had been gained.

Table VIII**Scores of Student C**

Matter Unit	pre-test	post-test
Question 1	0	3
Question 2	0	3
Question 3	0	4
Question 4	0	0
Question 5	0	2
Total	0	12
Acids & Bases	pre-test	post-test
Question 1	0	2
Question 2	0	2
Question 3	0	3
Question 4	0	3
Question 5	0	3
Question 6	0	4
Total	0	17
Geologic Time	pre-test	pos-test
Question 1	2	4
Question 2	0	4
Question 3	2	4
Question 4	2	4
Question 5	2	3
Total	8	19

Prior to the research project, Student C was classified as a low-average student based on ITBS scores. This student also demonstrated learning in the three units. The Matter unit pre-test questionnaire received a score of zero out of a possible twenty-five. This student answered all five questions with the same response, "I don't know." A post-test questionnaire administered after the unit received a score of twelve, again out of a possible twenty-five.

Three of the post-test questions were answered to an acceptable degree by the student. There was evidence of learning, but mastery of the concepts was not evident. I did, however, accept the student's responses as proof of learning.

The second unit on Acids and Bases received a pre-test score of zero out of a possible thirty. All six questions were answered wrong or with the phrase, "I don't know." This student appeared to have little knowledge of the unit prior to it being taught. The post-test score of Student C was seventeen out of a possible thirty. Many of the answers had expanded information, but they were vague and not evident of true learning. This student did master some of the concepts and have a better understanding of the subject matter by the end of the unit, but true learning was not evident to me.

The final unit was the only unit in which this student showed pre-unit knowledge. Out of a possible score of twenty-five, this student scored eight on the pre-test questionnaire. Two of the answers showed some understanding of the concepts to be taught, yet the others were wrong or very vague. After the unit, this student scored a post-test questionnaire score of nineteen out of a possible twenty-five. All five of the post-test answers were correct. Although these answers were somewhat vague, I was satisfied that learning had occurred.

Table IX

Scores of Student D

Matter Unit	pre-test	post-test
Question 1	1	0
Question 2	0	0
Question 3	0	0
Question 4	0	0
Question 5	2	4
Total	3	4
Acids & Bases	pre-test	post-test
Question 1	0	0
Question 2	0	0
Question 3	0	3
Question 4	0	4
Question 5	0	3
Question 6	0	0
Total	0	10
Geologic Time	pre-test	post-test
Question 1	0	2
Question 2	0	3
Question 3	0	4
Question 4	1	4
Question 5	0	4
Total	1	17

The final student in the research study was considered below average in abilities and had been classified as a resource student by the school district. In the Matter unit pre-test questionnaire, this student scored a three out of a possible twenty-five. One of the pre-test answers supported the idea of understanding. On this unit's post-test, the student only received a score of four out of a possible twenty-five. This student seemed to have had difficulty with their understanding of the concepts and the unit information. I determined that these low scores could have been attributed to variations in the student's interest level or personal problems at the time of the study.

In the second unit on Acids and Bases, this student again received a pre-test questionnaire score of zero. All responses were the same, "I don't know." A post-test score of ten was earned. The answers the student gave allowed me to determine that the student was still confused and did not completely understand all that was taught during the lesson. The student was able, in some instances, to express his understanding of the unit. I interpreted the answers to be acceptable based on classroom situations and the student's aptitude level.

The Geologic Time unit was the only unit in which this student was able to demonstrate learning. Of the five questions asked in the pre-test questionnaire, for a possible twenty-five points, the student received a score of one. All of the answers on the pre-test questionnaire were vague and not acceptable to me. The post-test questionnaire score by Student D was increased to seventeen. Many of the answers were acceptable and accurate in regards to the unit lessons. Some of these answers were still vague, but based on the pre-test responses, evidence was presented that demonstrated learning.

Positive attitudes

Student interviews were conducted before, during and after the research study. I was interested in determining if an inquiry-based environment would generate positive student attitudes toward learning. The individual student responses are recorded in Appendix B.

Each of the research students expressed concerns about participating in the study because they felt they would not meet the requirements. I took extra steps to ensure they were aware that all that was required of them was for their answers to be honest. After some initial nervousness, the students began to relax.

All of the students felt that science was a difficult class at the junior high school level. In previous years, these students admitted to being confused and unsure of what was expected and of what they were learning. When questioned about their experiences this year in an inquiry-based environment, all students responded positively. These students felt that learning by doing was responsible for their increase in learning. The concepts of the science lessons became more clear to these students as they interacted with the material of the lessons and discussed information with their peers.

With regard to attitudes, these students felt as if they were successful in their science learning. Although some mentioned they could be doing better, all agreed that this inquiry-based environment allowed them to feel successful. It appeared that learning through interacting with materials, peers and previous knowledge, enhanced positive student attitudes toward learning.

Relationship between students' attitudes and demonstration of growth in learning

My final question in this research study as stated in Table II was to determine if a relationship existed between students' attitudes and their demonstration of learning. Data collected and recorded in Appendices B and C reflects the relationship between students' attitudes and demonstration of growth.

Based on interview responses, all students held a positive attitude toward learning science in an inquiry-based environment. Individual student scores on unit activities reflected that all students could demonstrate growth in learning science concepts. Two of the research students clearly demonstrated growth in science learning consistently. The other two students demonstrated limited growth in science learning. However, all students demonstrated some learning, and all had a positive attitude toward learning.

The technique used to determine both demonstrated growth and student attitudes was by teacher/researcher created tests or questionnaires. This information was private information and pertains only to myself and my students. It was not norm-referenced. It does appear, based on my results, that there is a positive relationship between students' attitudes and demonstrated growth in science. Based on the students who participated in an inquiry-based science environment, all had a positive attitude and were able to demonstrate learning. Not all students could demonstrate similar growth in understanding science concepts.

The students who demonstrated limited growth in science understanding seemed to adapt to an inquiry-based environment. It appears that students feel successful in this type of program, but it is difficult to determine if it is due solely to the program or other extenuating factors. There is a need to investigate this idea further to help clarify the relationship between students' feelings of success and their demonstrated growth in science understanding.

Study Design Limitations

Design limitations considered were the inconsistencies in my questioning technique, the differences in the time of day of the sessions and the individual class makeup. Also taken into consideration was the individual student's level of interest and daily feelings, which could influence the testing/learning results.

Inconsistencies in Questioning

Some of the information gathered from the students was in the form of interviews or questionnaires. Although they were predetermined questions I designed, I also asked questions to encourage elaboration by the students. Some of these took the form of "How do you know?" or "What does that mean?" which allowed me to gather more information to understand the student response. The interviews are summarized in Appendix B.

Time of Sessions

The time limit imposed on the students was the regular class periods of approximately fifty minutes. Each of the students received the same lesson, yet due to the make-up of each of the classes, discrepancies probably occurred.

Also it must be noted, that at different times of the school day, students respond with varying levels of excitement and interest.

Summary

This research study investigating inquiry-based science environment and students' feelings of success was conducted in an average eighth grade classroom in the San Francisco Bay Area in California. The students were randomly selected to represent the makeup of the entire eighth grade population. The lessons that students were exposed to reflected the lessons of the eighth grade science curriculum for the school district. Design limitations included the differences in class makeup and the time of day each session was conducted.

Chapter Five

DISCUSSION AND CONCLUSION

The purpose of the case study was to determine whether students could demonstrate growth in learning science concepts in an inquiry-based environment. In addition, this study addressed students' feelings of success and its relationship to their ability to master concepts. Results from four students came from pre-test and post-test questionnaires, interviews and observations I made addressed the following questions:

1. Do students at all aptitude levels demonstrate growth in their understanding of science concepts in a inquiry-based environment?
If so, how?
2. Does an inquiry-based environment generate positive attitudes toward learning, a sense of success and control over students' learning? If so, how?
3. Is there a relationship between students' attitudes and their demonstrated growth in science learning and understanding?
If so, what is the nature and relationship between these variables?

This chapter discusses the results and conclusions that can be drawn, and implications for encouraging inquiry-based classroom environments at the junior high school level. Design limitations of the study were considered and further research questions are proposed.

Student Interactions and Opinions

During the research study, I discussed with the students their feelings about learning and their feelings of success in learning. The student responses are summarized in Appendix B. All students responded positively regarding their science experiences this year. It was mentioned that compared to other years, the students did feel they were learning and understanding more in an inquiry-based environment.

I also determined that students felt the activities and experiments they did during the research study and during the entire school year, helped them to understand the difficult concepts being taught. The students felt an inquiry-based environment helped them visualize and see the relevance of the information being taught in the class. In previous years, science classes were difficult and relied upon book work and lectures with little relevance to the students' lives according to information gathered in student interviews. The students felt that in a class where they could interact with materials and peers to discover solutions, allowed them to demonstrate their learning and increase their feelings of success.

I reviewed the assortment of classroom assignments and activities the students were exposed to during the study. The assignments involved all modalities of learning styles. Based on the results of the individual classes and student scores, it was determined that an inquiry-based science environment benefits many students. Students in this research study represented varying aptitude levels. The students represented high, average, low average, and resource student, based on student test scores on the Iowa Test of Basic Skills (ITBS).

Implications of this study lead me to believe an inquiry-based science environment meets the needs of a variety of student aptitude levels. All levels of students in the research study felt successful in their ability to learn and earn a grade reflective of their knowledge and effort. Even special education students can benefit from a program that offers hands-on activities and offers relevance to students daily lives. The student responses support my belief that students learn more when they are involved in their learning and have a positive attitude. This success can be contributed to the active participation of the students and the control they felt regarding their learning. These responses were reflected in all three units of the research study.

Demonstrated Growth

During this research study, pre-test and post-test questionnaires were given to the research students. These questionnaires were administered to help me determine if students could demonstrate mastery of the concepts being taught. They were also used to allow the individual students to determine if they had comprehended the concepts being taught in each unit.

In all of the units, according to the rubric scoring presented earlier, all students improved their understanding of the science concepts being taught. The analysis of activity scores (located in Tables III, IV, and V) and pre- and post-test questionnaire scores provided data supporting students' abilities to demonstrate learning. Pre- and post-test questionnaire scores are located in Tables VI-IX. Through exposure to various materials and science concepts the majority of students in this study were able to demonstrate growth in their understanding of science concepts.

The questionnaires required reading; in some cases, I clarified questions or read the questions for the students. This removed the fear of failure in the students opinion because the students had a better understanding of how to answer the questions asked. Although the students' answers were in some cases very limited or sketchy, I took the liberty of interpreting their meanings. Considering the classroom in which the research study occurred was an entry level science class, the answers the students gave were acceptable. For most of the students, if not all of the students, this was their first exposure to laboratory science and the difficult concepts of Physical and Earth Science. It was acceptable that limited answers were given, or that the answers were not very detailed. I felt that any increase in the pre-test/post-test questionnaire scores was a demonstration of student mastery. Learning cannot be based on complete mastery of a subject, rather it should be based on increases gained due to exposure to various bits of information that students interact with during their educational experiences.

Student Feelings of Success

Prior to the research study, most of the students felt that they were not qualified to participate in this study. After completing the pre-test questionnaires, the students felt very unsuccessful. However, by the end of the unit, students felt very successful as they completed the post-test questionnaire. This success led the students to feel empowered and more interested in learning. In order for students to learn in a classroom situation, they need to be interested in what is being taught. Years of wrong and right answers determined by the educator have left students feeling unsure of what is required of them. Only in a situation where students can actively

is required of them. Only in a situation where students can actively participate in the planning and implementing of their lessons will they accomplish true learning. An inquiry-based environment allows this to occur.

Correlation between Demonstrated Growth and Students' Feelings of Success

My final question in this research study was to determine if a relationship existed between students' attitudes and their demonstration of learning. Data collected and recorded in Appendices B and C reflects the relationship between students' demonstrated attitudes and demonstration of growth.

Based on interview responses, all students held a positive attitude toward learning science in an inquiry-based environment. Individual student scores on unit activities reflected that all students could demonstrate growth in learning science concepts. Two of the research students clearly demonstrated growth in science learning consistently. The other two students demonstrated limited growth in science learning. However, all students demonstrated some level of learning, and all had a positive attitude toward learning.

The technique used to determine both demonstrated growth and student attitudes was by teacher/researcher created tests or questionnaires and interviews. This information was private information and pertains only to myself and my students. It was not norm-referenced. It does appear, based on my results, that there is a positive relationship between students' attitudes and demonstrated growth in science. Based on the students who participated

in an inquiry-based science environment, all had a positive attitude and were able to demonstrate learning. There were varying degrees of demonstrated growth based on student aptitude levels.

The students who demonstrated limited growth in science understanding seemed to adapt to an inquiry-based environment. It appears that students felt successful in this type of program, but it is difficult to determine if it is due solely to the program or other extenuating factors. There is a need to investigate this idea further to help clarify the relationship between students' feelings of success and their demonstrated growth in science understanding.

Implications

Educators should consider the results of this research study in implementation of their curriculum. In order to increase the current level of student understanding, educators need to actively engage students in their learning. If students can feel successful in their learning, they will have a desire to learn and understand more. This learning can only be achieved through a program that allows students to inquire about information and grapple with the unknown. Students need the experience of trying to make sense of their surroundings and information presented by educators. For too many years, students have been required to decipher what was the correct answer based on the educator's pre-set objectives. If students have a fear of failure, they cannot freely explore and come to terms with the unknown. Failure can lead students to turn away from learning and develop negative attitudes toward learning.

Factors in Student Learning

Each of the students who participated in this research study represented varying levels of ability. These students ranged from an above average ability level to a below average ability level. The below average level student was classified as a resource student and determined to have a learning disability.

Student A

This student had an extremely positive attitude regarding her learning. She did admit that she needed to apply herself more than she was, yet during the entire study she never had her grade, in science, drop below an A. According to her, doing activities helped reinforce science concepts and helped her to have a better understanding of the lessons. Overall, this student felt very successful in her abilities to learn science.

In my opinion, this student does well in any learning situation. She continually receives high grades and scores above average in all areas of school. I felt that learning in an inquiry-manner did improve the student's ability to apply her learning to other situations due to complete understanding of the concepts.

Student B

Student B entered this research study with some questions due to her fears of science. Her past experiences and grades in science were not her highest. She expressed her confusion with understanding what had been read or discussed in other science classes. After completion of the research study, this student had an extremely successful feelings regarding science. She felt using an inquiry-based program allowed her to do activities, which in turn, clarified the science concepts being taught.

I felt that this student did increase her knowledge of science during the lessons taught in the study. However, this student did fail to complete all the assignments in the study. This was due, in part, to missed classes in which the work was never made up. I included this student because at a typical junior high school, educators face this type of student on a daily basis. Not all students complete all of their assignments, so it was determined that this student brought more accuracy to the study.

Student C

Of all the students in the study, Student C was the student who felt the highest level of success in his science understanding. He continually experienced low grades in his classes, year after year. This was the first year that he actually had a grade in a class that was above a D. He attributed this to class activities; it was easier for him to remember and understand what was being taught. He also found he was putting out more effort in his learning because he felt successful and it was reflective in his scores. For the first time, he actually admitted to enjoying science and learning.

I noticed the increased level of interest this student displayed in his learning. This student ranked in the low average range based on test scores. He never experienced success in his learning, until now. I believe that visual techniques used in an inquiry-based program helped this student to comprehend the difficult science concepts being taught.

Student D

In this student's opinion, he was learning and feeling successful by experiencing science through inquiry. Many of his scores and responses were below average and vague. He felt he was learning, but not really putting any effort into his science lessons.

This student underwent the most dramatic changes during the study, in my opinion. He is classified as a resource student. He has experienced low grades for most of his school years. During the research study, he was frequently absent. He admitted to being confused and uncertain in his understandings of the concepts. I believe that some changes occurred during the study that were uncontrollable. This student appeared to undergo a personality change during this study. I consulted with other educators familiar with the student and all admitted to noticing some changes. These changes were not identified even when I discussed my feelings with this student. This student was included in this study because he also reflects the type of student many educators have in their classroom. I felt even though this student did not make giant gains in science knowledge, he did admit to feeling more successful in his learning. A student who feels successful is learning according to studies conducted by Kyle et al. (1985).

Summary of Results

Questionnaires, interviews, student observations and student scores were used during this research study to determine if students exposed to an inquiry-based science environment could learn the science concepts presented and feel successful in their learning. Analysis of the data and observations

gathered from this research study indicates that the students did learn the science concepts taught and did feel successful.

With regard to the students mastering the concepts of the science lessons, it was determined that learning had occurred. Based on the individual learning abilities of the students, each student achieved different levels of learning. Levels achieved were determined to be reflective of similar students at this location. The students responses in the pre-test and post-test questionnaires supported the idea of student learning. Comparing individual research student scores with class average scores, the hypothesis that students can master science concepts and demonstrate growth in understanding in an inquiry-based environment were supported. This research study is supported by the findings of Lindberg (1990), Lloyd and Contreras (1985, 1987), Glasson (1989), Bredderman (1982), and others. Inquiry-based teaching increases knowledge and understanding of science concepts. Students also performed better and learned more as stated in these studies.

Student learning can be attributed to activities which allowed students to be in an environment which was conducive to learning. Inquiry-based programs lead to students developing interest in learning. Developing interest in science can lead to positive attitudes. The development of student motivation was a direct response to inquiry-based learning. This study supports the findings of Hodson (1989), Blosser and Helgeson (1989), Haury (1993), Kyle et al. (1985), and others. These studies stress the idea that positive attitudes in science enhances learning and allows students to have a better understanding of concepts being taught.

Students' feelings of success can be attributed to active participation in their learning. The more students felt the lessons had relevance to their lives the more importance they placed on learning the concepts. This supports the ideas presented in studies by Hodson (1990), Haury (1993), Kyle et al.(1985), and others. In these studies, students saw relevance to lessons and realized that their inquiries satisfied students' curiosity.

Overall, it was determined from the study results, a program which supports inquiry-based science education does support my hypothesis that and inquiry-based program allows students to learn science concepts and feel successful in their learning. This study contributes to expanding data supporting active learning in an inquiry-based environment.

Study Design Limitations

Design limitations that were explored included inconsistencies in questioning students, time of sessions, class make-up, individual student responses, researcher's interpretations and small study size.

Inconsistencies in Questioning

Student interviews were slightly different for each research student. Although the same basic core of questions was asked every time, depending upon the student responses or confusion to the question, I may have asked more questions, or reworded the questions. In some cases, the student responses clearly demonstrated learning or mastery of the science concept. In other cases, learning was not clearly demonstrated. I based interpretation of student responses on previous knowledge of the students and prior experience with student aptitude levels at the school.

Time of Sessions

The imposed time limit for this study was fifty minute class sessions, five days a week. In some instances, due to school assemblies and fire drills, not all students received this time limit. Overall, all the students received the same lessons, but in a few cases some lessons were longer than others.

Another inconsistency was in the time of day of the science class. I noticed a change in attention levels between morning, mid-morning and afternoon classes. It appeared that morning classes were more likely to concentrate on the lessons and demonstrate mastery of the science concepts sooner than other classes. The afternoon classes had difficulty in demonstrating mastery due to noted tiredness and difficulty in concentrating on the lesson.

Class Make-up

In each class the students represented a heterogeneous mixture. Yet, in actuality, due to outside influences, not all the classes were equal. At this school, students are tracked in the following categories:

High Language and Social Studies

Average Language and Social Studies

Special Education Language and Social Studies

Algebra

pre-Algebra

Grade level math

High school math placement (Geometry)

Special Education math

Foreign Language, levels 2-3 (High School Level)

This fact leads to inconsistencies in student placement. The high level classes are scheduled at certain times and tend to place larger homogeneous groups in some classes, especially science. I was aware of differences between classes in regards to student grouping.

Individual Student Responses

I was aware that some of the students may have answered the questions to please me. The questions were designed to be generic so all student responses' could be evaluated equally. It was noted that once the study began, the students appeared to be very concerned with my opinions and reactions.

Once the four research students were chosen, they began to demonstrate the Pygmalion Effect. The students seemed to concentrate more on what they thought I wanted to hear, rather than always answering honestly. Also noted was the Hawthorne Effect, where the research students felt they were part of an elitist group which needed to do well in their science lessons in order to support my efforts. I believe that these items did effect my study in that the students did not respond without a bias.

Researcher's Interpretations

During this study I was working with eighth grade students. At times it was necessary for me to help illicit a response from a student. In some instances it required my questions to take a different pathway from the other students. In some cases, it was necessary for me to interpret the language of the eighth graders. (Junior high school students sometimes develop their own language.)

In many cases the answers the students responded with were typical of what an educator who sees approximately 170 students on a daily basis receives. A classroom teacher has a limited time to interview students, and in turn, short answers are typical responses teachers receive. These answers are acceptable to judge student knowledge. In future studies, it would be advisable to obtain more teacher-student interaction/study time. This would allow more observations to be recorded by the researcher. It would also allow the teacher/researcher more time to conduct interviews and obtain more detailed responses to questions.

Small Study Size

This study consisted of the responses of four students. The student responses reflected the entire population of the junior high school at which the study was conducted according to average student scores (located in Appendix A). In future studies, it would be advisable to expand the research group to be sure accurate results are being recorded. Also it will provide the researcher with more accurate student responses.

Further Research Questions

Since this case study was a preliminary research on student's demonstrated growth and feelings of success in an inquiry-based science program, additional research is indicated. These areas include:

1. **Researcher's Rapport**

Could the personality of the researcher affect the responses and the learning of the students? If so, how? I discovered that the students seemed to enjoy just talking with me about science or

non-science events. I feel that this could have had an effect on how well they did in my class.

2. Curriculum Design

Is it the specific design of a curriculum that increases student success and knowledge, or can any inquiry-based program offer student success? I am concerned that the time I spent arranging lessons in an orderly fashion has allowed my students to build on previous knowledge. If another educator simply incorporated inquiry-based lessons in any order, will the students still be able to achieve learning and feel successful?

3. Group Size

Does the size of the research group affect the outcome of the study? Would a larger group change the results? It would be interesting to determine if a classroom of fewer students would lead to more student success and learning. I feel that if smaller classes were possible, I would have had more time to interact with the students.

4. Time of Sessions

a. If the students of the research group received more time to process new information, would their responses be different? If so, how?

b. If the researcher had more time to interview, observe and question research students would the results be different? If so, how? In my opinion, it is very difficult to condense lessons into

a set time period. Some lessons require less time and others more. I think a schedule that allows for this would benefit all students.

5. Researcher's Bias

- a. If procedures were incorporated into the study, could the researcher's bias be removed from the study? How would this effect the results?
- b. Is there a way to remove the Pygmalion and Hawthorne Effects to obtain accurate student responses? If so, what could be changed?

6. Study Design

- a. Did the order in which the units were presented affect the outcomes? If so, how?
- b. If different activities had been used, would different results be obtained? For example, if I had chosen other activities, or presented them differently, could the results be different? I believe that the results would have been different if this had occurred. It is my opinion that my students need to have concepts build upon others to help reinforce previous knowledge. It is also necessary for new knowledge to fit into the previously set format.

Summary and Conclusions

If an inquiry-based science program is implemented at the junior high school level, an additional instructional strategy will be available to educators. Not only will an inquiry-based program enable educators to teach

more science, students will be able to understand more science concepts and feel more successful in their learning.

In order for science education to make vast advancements in the next few years, it must be presented in a way that builds on students' prior knowledge, incorporate students into planning the curriculum, and allow for hands-on experiences to be a daily occurrence in classrooms.

The classroom educator is challenged by a vastly diverse classroom today. Not only do educators face the usual differences in student abilities, they are now faced with many learning disabilities and behavior problems. An inquiry-based environment will allow educators to involve all students in learning and reduce the level of distractions in the classroom. All students can benefit from a program which begins with students' levels of understanding, involves them in relevant experiences, and enables them to gain knowledge and understand foreign concepts. Not only will student knowledge be increased, student interest levels will also be increased as well as students' feelings of success in their learning if an inquiry-based environment is implemented.

While the results of this case study reflects only four students in an eighth grade science classroom, the results support the notion that student learning in an inquiry-based program benefits many students. There is little doubt that a program which involves students in their learning will increase student knowledge and feelings of success. In turn, this will lead to an students having a positive attitude in science and at school.

REFERENCES

- Anderson, J. R. (1980). *Cognitive psychology and its implications*. San Francisco: Freeman.
- Blosser, P. E., & Helgeson, S. L. (1989). Selected procedures for improving the science curriculum. *Clearinghouse for Science, Mathematics, and Environmental Education*. Columbus, Ohio.
- Bredderman, T. (1982). Activity science the evidence shows it matters. *Science and Children*, 20, 39-41.
- Bruner, J. S. (1983). *In search of mind: Essays in autobiography*. New York: Harper and Row.
- Carey, S. (1985). *Conceptual change in childhood*. Cambridge, MA: MIT Press.
- Carpenter, R. (1963). A reading method and an activity method in elementary science instruction. *Science Education*. April.
- Cherif, A. (1993). Relevant inquiry. *Science Teacher*, 60, 26-28.
- Doll, W. E. (1993). *A post-modern perspective on curriculum*. New York, New York: Teachers College, Columbia University.
- Driver, R. (1983). *The pupil as scientist*. Open University Press.
- Driver, R., & Bell, B. (1986). Students' thinking and the learning of science: A constructivist view. *School Science Review*, 67, 443-456.
- Driver, R. (1989). The construction of scientific knowledge in school classrooms. In R. Millar (Ed.), *Doing science: Images of science in science education* (pp. 83-106). London, England: Falmer Press.
- Duschl, R. A. (1986). Textbooks and the teaching of fluid inquiry. *School Science and Mathematics*, 86, 27-32.
- Einstein, A., & Infeld, L. *The evolution of physics*. Cambridge University Press.
- Ernest, P. (1993). Constructivism, the psychology of learning, and the nature of mathematics: Some critical issues. *Science & Education*, 2, 87-93.

- Glasson, G. E. (1989). The effects of hands-on and teacher demonstration laboratory methods on science achievement in relation to reasoning ability and prior knowledge. *Journal of Research in Science Teaching*, 26, 121-132.
- Hall, G. S., & Brown, C. E. (1903). Children's ideas of fire, heat, frost and cold. *Pedagogical Seminar*, 10, 27-85.
- Haury, D. L. (1993). Teaching science through inquiry. *Clearinghouse for Science, Mathematics, and Environmental Education*, Columbus, Ohio. ED359048.
- Hodson, D. (1990). A critical look at practical work in school science. *School Science Review*, 70, 33-40.
- Hofstein, A., & Lunetta, V. N. (1982). The role of laboratory in science teaching: neglected aspects of research. *Revised Educational Research*, 52, 201-217.
- Jensen, A. (1981). *Straight talks about mental tests*. New York: Free Press.
- Jung, W. (1993). Uses of cognitive science to science education. *Science & Education*, 2, 31-56.
- Kyle, W. C. Jr., Bonnstetter, R. J., McClosky, S., & Fults, B. A. (1985). Science through discovery: Students love it. *Science and Children*, 23, 39-41.
- Lindberg, D. H. (1990) What goes around comes 'round doing science. *Childhood Education*, 67, 79-81.
- Lindberg, L. (1961). Learning through searching. *Childhood Education*, 38, 58-60.
- Lloyd, C. V., & Contreras, N. J. (1985, December) *The role of experiences in learning science vocabulary*. Paper presented at the Annual Meeting of the National Reading Conference, San Diego, CA Ed 281 189.
- Lloyd, C. V., & Contreras, N. J. (1987, October) What research says: Science inside-out. *Science and Children*, 25 (2), 30-31.

- Lock, R. (1990). Open-ended, problem-solving investigations, What do we mean and how can we use them? *School Science Review*, 71, 63-72.
- Lunzer, E.A., Harrison, C., & Davey, M. (1972). The four-card problem and the development of formal reasoning. *Quarterly Journal of Experimental Psychology*, 24, 326-339.
- Malone, J. A., & Taylor, P. C. S. (Eds.). (1993). *Proceedings of topic group 10 at the seventh international congress on mathematical education: Constructivist interpretations of teaching and learning mathematics*. Perth, Australia: Curtin University of Technology.
- Mattheis, F. E., & Nayayama, G. (1988, September) *Effects of a laboratory-centered inquiry program on laboratory skills, science process skills, and understanding of science knowledge in middle grade students*. ED 307 148.
- Mc Closkey, M. (1983). Intuitive physics. *Scientific American*, 248, 123-130.
- Mechling, K. R., & Oliver, D. L. (1983). Activities, not textbooks: what research says about science programs. *Principal*, 62, 41-43.
- Moreira, M. A. (1980). A non-traditional approach to the evaluation of laboratory instruction in general physics course. *European Journal of Science Education*, 2, 441-448.
- Narode, R., Heriman, M., Lochhead, J., & Slomianko, J. (1986) Teaching thinking skills: Science. Washington DC: *National Education Association* ED 320 755.
- National Committee on Science Education Standards and Assessment (1992) *National science education standards: A sampler*. Washington, DC; National Research council.
- National Science Board (1991). *Science and engineering indicators- 1991*. Washington, DC: U S Government Printing Office. (NSB91-1).
- Prawat, R. S. (1992). Teacher's beliefs about teaching and learning: A constructivist perspective. *American Journal of Education*, 100, 354-395.

- Prawat, R. S. (1993). The value of ideas: Problems versus possibilities in learning. *Educational Researcher*, 22(6), 5-12.
- Rakow, S. J. (1986). Teaching science as inquiry. Fastback 246. Bloomington, IN: *Phi Delta Kappa Educational Foundation*. ED 275 506.
- Renner, J. W., Stafford, D., Coffia, W., Kellogg, D., & Weber, M. (1993). An evaluation of the science curriculum improvement study. *School Science and Mathematics*, 73, 291-318.
- Rutherford, F. J., & Ahlgren, A. (1990). *Science for all Americans*. New York: Oxford University Press.
- Roth, M. W., & Roychoudhury, A. (1993). The development of science process skills in authentic contexts. *Journal of Research in Science Teaching*, 30, 127-152.
- Sachse, T. P. (1989). Making Science Happen. *Educational Leadership*, 47, 18-21.
- Smith, C., Carey, S., & Wiser, M. (1986). On differentiation: A case study of the development of the concepts of size, weight, and density. *Cognition*, 21, 177-237.
- Steffe, L., & Gale, J. (Eds.). (1995). *Constructivism in education*. Hillsdale, NJ: Erlbaum.
- Strike, K. (1987). Towards a coherent constructivism. In J. Novak (Ed.), *Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics Education* (pp. 67-78). Ithaca, NY: Cornell University.
- Taylor, P. C. S. (1993). Collaborating to reconstruct teaching: The influence of researcher beliefs. In K. Tobin (Ed.), *The practice of constructivism in science education* (pp. 267-298). Washington, DC: American Association for the Advancement of Science.
- Tinnesand, M., & Chan, A. (1987). Step 1: Throw out the instructions. *The Science Teacher*, 54, 43-45

- Tobin, K. (Ed.). (1993). *The practice of constructivism in science education*. Washington, DC: American Association for the Advancement of Science.
- Tobin, K., & Tippins, D. (1993). Constructivism as a referent for teaching and learning. In K. Tobin (Ed.), *The practice of constructivism in science education* (pp. 3-21). Washington, DC: American Association for the Advancement of Science.
- Treagust, D., Duit, R., & Fraser, B. (1996). *Improving teaching and learning in science and mathematics*. New York, NY: Teachers College, Columbia University.
- Viennot, L. (1979). Spontaneous reasoning in elementary dynamics. *European Journal of Science Education*, 1, 205- 221.
- von Glasersfeld, E. (1990). An exposition on constructivism: Why some like it radical. In R. Davis, C. Maher, & N. Noddings (Eds.), *Constructivist views on the teaching and learning of mathematics* (Journal of Research in Mathematics Education Monograph Number 4, pp. 19-29). Weston, VA: National Council of Teachers of Mathematics.
- Vosniadou, S., & Brewer, W. F. (1987). Theories of knowledge restructuring in development. *Review of Educational Research*, 57, 51-67.
- Yager, R. E., Englen, H. B., & Snider, B. C. F. (1969). Effects of laboratory and demonstration methods upon the outcomes of instruction in secondary biology. *Journal of Research in Science Teaching*, 6, 76-86.
- Walton, E., & Bulter, J. (1990). Teacher training for hands-on science. *Phi Delta Kappan*, 71, 738- 739.
- Wang, M. C., & Palincsar. A. S. (1989). Teaching students to assume an active role in their learning. In M. C. Reynolds (Ed.), *Knowledge base for the beginning teacher* (pp. 71-84). New York: Pergamo Press for the American Association of Colleges for Teacher Education.
- Welch, W., Klopfer, L., Aikenhead, G., & Robinson, J. (1981). The role of inquiry in science education: Analysis and recommendations. *Science Education*, 65, 33-50.

Wiser, M., & Carey, S. (1983). When heat and temperature were one. In D. Gentner and A. Stevens (Eds.) *Mental models*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Appendix A
Scores for all classes
by activity and
unit

MATTER UNIT
CLASS 1 PERIOD 1

Student	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5
1	0	0	8	19	10
2	10	22	10	14	10
3	8	23	7	0	0
4	6	24	7	20	10
5	9	20	5	16	8
6	7	25	10	20	10
7	8	22	9	20	7
8	8	21	8	18	0
9	9	19	7	13	0
10	7	23	6	18	6
11	0	19	7	16	9
12	9	23	10	20	10
13	7	20	8	17	7
14	8	25	10	20	10
15	9	24	7	16	0
16	8	24	0	17	10
17	6	23	7	20	0
18	8	23	6	17	9
19	9	23	6	10	9
20	5	25	5	20	5
21	8	24	10	20	10
22	7	24	6	17	10
23	7	24	10	20	9
24	8	0	8	20	9
25	5	21	7	16	9
26	8	23	10	20	10
27	8	20	7	16	7
28	0	21	0	0	0
29	8	21	9	16	0
30	8	24	7	17	10
31	9	25	6	18	10
32	10	24	10	20	10
33	7	17	5	16	0
34	8	21	10	20	10
35	10	24	10	20	0
36	6	20	8	16	7
Totals	258	761	266	603	241
Class Average	7	21	7	17	7
Standard Deviation	2.5	5.6	2.5	4.8	4.1

MATTER UNIT
CLASS 2 PERIOD 2

Student	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5
1	9	23	10	10	20
2	10	25	10	10	20
3	8	23	10	7	16
4	9	24	7	10	16
5	7	23	10	10	18
6	0	21	6	0	0
7	9	23	10	10	20
8	8	25	0	8	15
9	6	25	0	6	17
10	9	19	7	10	18
11	8	23	7	0	16
12	7	24	7	8	18
13	7	25	10	10	20
14	10	25	10	10	20
15	0	25	10	8	16
16	0	25	7	8	16
17	9	22	8	8	20
18	0	5	0	0	10
19	0	19	6	0	20
20	8	17	6	0	12
21	7	22	0	10	20
22	9	13	10	10	18
23	7	23	8	8	20
24	6	23	8	6	0
25	8	20	7	8	20
26	9	25	10	10	20
27	9	23	9	10	17
28	8	0	0	0	14
29	7	24	8	10	20
30	9	23	8	10	17
31	9	25	8	10	20
32	8	24	10	10	20
33	0	0	0	0	0
34	9	23	10	8	20
Totals	229	709	237	243	554
Class Average	7	21	7	7	16
Standard Deviation	3.3	6.6	3.5	3.9	5.7

MATTER UNIT
CLASS 3 PERIOD 4

Student	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5
1	10	24	10	10	18
2	9	25	10	8	19
3	9	19	0	7	0
4	5	20	5	0	15
5	9	0	9	6	0
6	8	23	7	10	20
7	8	23	8	10	18
8	0	20	8	0	16
9	9	24	9	10	19
10	7	25	9	10	18
11	10	25	10	10	20
12	8	25	8	8	18
13	8	24	9	10	19
14	0	25	0	0	0
15	9	20	0	10	17
16	8	21	0	6	15
17	8	28	10	8	20
18	8	21	8	8	16
19	9	0	5	10	18
20	8	25	10	10	20
21	8	21	7	0	16
22	8	23	7	8	20
23	9	20	7	0	12
24	8	21	7	8	12
25	9	20	7	8	16
26	7	25	0	0	18
27	10	25	10	10	20
28	6	20	8	10	10
29	7	21	0	6	10
30	10	25	10	10	20
31	7	20	8	8	18
Total	239	658	206	219	478
Class Average	8	21	7	7	15
Standard Deviation	2.4	6.1	3.6	3.7	5.9

MATTER UNIT
CLASS 4 PERIOD 5

Student	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5
1	9	23	7	5	16
2	7	24	8	10	18
3	7	19	9	5	14
4	9	20	6	10	18
5	7	22	8	8	12
6	0	0	6	0	16
7	10	23	10	10	18
8	6	24	10	0	17
9	8	23	9	8	20
10	7	19	10	8	14
11	7	24	10	10	20
12	7	19	7	5	17
13	6	19	8	0	18
14	6	24	8	0	18
15	6	24	10	8	18
16	8	25	7	10	10
17	9	25	9	10	20
18	8	23	10	8	20
19	8	23	9	6	15
20	9	23	8	10	16
21	9	15	6	8	11
22	8	25	10	10	20
23	9	24	7	8	20
24	8	25	10	8	18
25	6	20	6	8	12
26	8	25	10	10	20
27	9	23	0	8	15
28	10	22	8	8	20
29	7	25	7	10	20
30	6	21	0	9	16
31	0	20	7	7	17
Total	224	671	240	225	524
Class Average	7	22	8	7	17
Standard Deviation	2.3	4.7	2.5	3.2	2.9

MATTER UNIT
CLASS 5 PERIOD 7

Student	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5
1	8	23	7	10	20
2	8	21	5	6	13
3	9	25	10	8	16
4	5	22	6	6	20
5	8	20	7	6	15
6	0	25	9	10	20
7	9	22	0	0	17
8	7	21	0	0	18
9	7	21	9	0	0
10	9	23	7	8	18
11	9	25	10	9	17
12	0	0	0	0	0
13	8	22	10	10	20
14	7	23	9	10	20
15	8	23	10	9	20
16	7	21	9	8	20
17	10	23	9	9	18
18	7	25	10	10	20
19	9	25	0	0	18
20	7	25	7	10	20
21	8	20	6	10	20
22	8	21	7	10	16
23	10	25	10	10	20
24	9	23	7	0	20
25	0	21	7	10	17
26	8	25	7	9	20
27	10	23	0	4	18
28	10	25	7	0	20
29	9	22	0	0	0
30	9	24	10	4	20
31	8	23	7	0	20
32	8	25	0	8	16
33	8	25	10	10	20
Total	247	737	212	204	557
Class Average	7	22	6	6	17
Standard Deviation	2.6	4.3	3.7	4.2	5.7

ACIDS AND BASES
CLASS 1 PERIOD 1

Student	Activity 1
1	10
2	15
3	18
4	20
5	10
6	15
7	23
8	0
9	20
10	19
11	10
12	23
13	15
14	20
15	0
16	19
17	23
18	18
19	23
20	23
21	10
22	20
23	19
24	25
25	23
26	17
27	25
28	23
29	0
Total	486
Class Average	16
Standard Deviation	7.3

ACIDS AND BASES
CLASS 2 PERIOD 2

Student	Activity 1
1	20
2	21
3	19
4	23
5	24
6	0
7	23
8	0
9	18
10	14
11	21
12	15
13	19
14	23
15	15
16	15
17	23
18	0
19	19
20	13
21	17
22	25
23	16
24	0
25	20
26	23
27	25
28	13
29	23
30	25
31	19
32	23
33	25
34	19
Total	598
Class Average	18
Standard Deviation	7.4

ACIDS AND BASES
CLASS 3 PERIOD 4

Student	Activity 1
1	20
2	21
3	19
4	23
5	24
6	0
7	23
8	25
9	18
10	14
11	21
12	15
13	19
14	23
15	15
16	15
17	23
18	0
19	19
20	13
21	17
22	25
23	16
24	0
25	20
26	23
27	25
28	13
29	25
30	19
31	23
Total	556
Class Average	18
Standard Deviation	7.0

ACIDS AND BASES
CLASS 4 PERIOD 5

Student	Activity 1
1	23
2	23
3	15
4	13
5	20
6	0
7	22
8	20
9	25
10	21
11	24
12	13
13	0
14	0
15	15
16	23
17	25
18	23
19	24
20	15
21	10
22	24
23	24
24	25
25	20
26	23
27	0
28	20
29	25
30	0
31	0
Total	515
Class Average	17
Standard Deviation	9.2

ACIDS AND BASES
CLASS 5 PERIOD 7

Student	Activity 1
1	25
2	0
3	23
4	22
5	0
6	25
7	25
8	0
9	19
10	23
11	25
12	0
13	23
14	19
15	20
16	22
17	22
18	15
19	17
20	25
21	23
22	18
23	25
24	17
25	10
26	25
27	23
28	18
29	0
30	25
31	15
32	0
33	25
Total	574
Class Average	17
Standard Deviation	9.1

GEOLOGIC TIME UNIT
CLASS 1 PERIOD 1

Student	Activity 1	Activity 2	Activity 3	Activity 4
1	8	25	9	15
2	10	25	10	15
3	10	25	9	16
4	10	24	10	15
5	5	18	9	0
6	9	22	9	0
7	6	17	10	12
8	6	18	10	10
9	9	23	7	14
10	8	19	4	11
11	8	19	10	14
12	10	25	10	14
13	6	25	5	12
14	10	22	9	15
15	9	17	8	15
16	5	18	6	12
17	10	25	10	15
18	10	25	10	15
19	0	19	9	13
20	10	23	7	12
21	0	25	10	0
22	9	19	10	10
23	0	18	10	13
24	6	17	0	15
25	0	19	10	15
26	12	23	0	12
27	10	19	10	15
28	10	25	9	15
29	10	22	9	15
30	0	19	8	8
31	10	24	10	15
32	0	18	8	15
33	8	18	8	13
34	8	25	10	15
Total	242	725	283	421
Class Average	7	21	8	12
Standard Deviation	3.7	3.1	2.6	4.3

GEOLOGIC TIME UNIT
CLASS 2 PERIOD 2

Student	Activity 1	Activity 2	Activity 3	Activity 4
1	75	18	9	7
2	0	19	15	9
3	10	23	11	10
4	0	20	11	9
5	6	20	15	10
6	6	18	15	9
7	0	21	15	0
8	0	21	9	7
9	8	25	12	10
10	9	25	10	10
11	0	21	13	9
12	0	18	15	0
13	0	23	12	10
14	0	21	11	10
15	0	24	15	10
16	0	21	15	9
17	0	21	12	7
18	6	22	10	7
19	0	21	9	0
20	6	20	9	9
21	9	20	13	9
22	7	22	14	10
23	0	19	9	10
24	0	20	15	10
25	0	21	10	6
26	10	20	11	8
27	10	21	14	8
28	10	21	13	9
29	10	25	12	10
30	10	22	12	9
31	10	21	11	8
32	10	21	15	10
33	10	23	13	10
34	5	19	9	7
35	10	21	14	9
Total	237	738	428	285
Class Average	7	21	12	8
Standard Deviation	12.7	1.9	2.2	2.8

GEOLOGIC TIME UNIT
CLASS 3 PERIOD 4

Student	Activity 1	Activity 2	Activity 3	Activity 4
1	7	0	19	12
2	10	0	19	13
3	7	7	21	11
4	6	9	20	11
5	6	0	16	9
6	10	8	19	13
7	10	10	19	14
8	7	10	21	15
9	0	8	22	9
10	10	10	15	15
11	0	0	20	12
12	0	10	19	9
13	10	10	25	15
14	0	0	20	12
15	10	8	22	15
16	10	10	25	13
17	8	10	25	12
18	10	7	19	10
19	5	0	15	13
20	10	9	19	14
21	10	7	24	12
22	0	9	16	15
23	6	0	19	11
24	0	0	24	14
25	10	10	25	14
26	10	10	25	15
27	6	8	22	10
28	6	6	20	15
29	0	10	20	12
30	10	10	21	15
31	0	10	25	8
32	0	9	23	14
33	10	10	24	15
Total	204	225	688	417
Class Average	6	7	21	13
Standard Deviation	4.2	4.1	3.0	2.1

GEOLOGIC TIME UNIT
CLASS 4 PERIOD 5

Student	Activity 1	Activity 2	Activity 3	Activity 4
1	10	10	21	15
2	10	10	23	14
3	9	10	20	14
4	8	0	20	15
5	10	10	25	15
6	10	8	21	13
7	9	9	21	15
8	8	8	20	9
9	9	10	20	15
10	10	10	23	14
11	6	8	20	13
12	10	6	25	12
13	7	9	20	9
14	10	8	23	11
15	8	10	20	15
16	8	10	21	13
17	10	10	25	15
18	0	6	20	15
19	0	0	21	13
20	7	10	21	9
21	10	9	21	13
22	8	10	21	13
23	0	0	20	15
24	10	8	23	14
25	10	10	21	13
26	8	5	20	13
27	8	10	20	9
28	5	9	20	15
29	0	0	20	12
30	10	9	21	14
31	9	10	21	15
32	10	10	21	11
33	10	10	21	11
34	6	10	23	14
Total	263	272	723	446
Class Average	8	8	21	13
Standard Deviation	3.2	3.2	1.5	2.0

GEOLOGIC TIME UNIT
CLASS 5 PERIOD 7

Student	Activity 1	Activity 2	Activity 3	Activity 4
1	5	14	7	9
2	0	17	9	12
3	7	17	10	9
4	10	24	10	15
5	8	24	9	11
6	0	14	7	5
7	9	21	8	12
8	0	20	10	8
9	0	25	10	0
10	8	21	8	14
11	10	20	8	14
12	10	18	10	12
13	0	20	9	0
14	5	14	8	0
15	10	25	10	15
16	6	18	7	9
17	12	24	9	14
18	0	22	7	15
19	8	20	9	14
20	7	21	10	12
21	7	25	9	14
22	10	25	10	15
23	10	20	10	15
24	7	20	8	15
25	10	20	10	15
26	9	18	10	0
27	6	25	8	8
28	9	20	9	11
29	0	14	8	12
30	10	22	9	13
31	10	17	0	10
32	9	20	10	14
Total	212	645	276	342
Class Average	7	20	9	11
Standard Deviation	3.9	3.4	1.9	4.8

Matter Unit Scores

Research Students

	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5
Student A	7	25	10	10	20
Student B	7	25	0	0	18
Student C	8	23	7	8	20
Student D	9	24	7	0	16

Acids and Bases Unit Scores

Research Students

	Activity 1
Student A	25
Student B	0
Student C	15
Student D	0

Geologic Time Unit Scores

Research Students

	Activity 1	Activity 2	Activity 3	Activity 4
Student A	8	25	10	15
Student B	0	24	0	14
Student C	10	24	7	12
Student D	0	19	9	13

Appendix B
Research Student Interviews
Summarized
(using actual student language)

Pre-Research Study Questions

Question 1: Our class is based on learning by doing or experiencing science.
Is it more difficult for you to learn this way? Why or why not?

Student A: It's easier to learn by experiencing because you find out for yourself rather than having someone tell you something you might not understand.

Student B: No. I think it is more fun and you learn more than if you sat down. I mean that doing is more fun than reading about it.

Student C: No, I understand by touching and feeling, not by reading or seeing.

Student D: I don't know.

Question 2: Do you feel that you need less activities and more factual information to help you learn? Why or why not?

Student A: No. Life isn't made of facts. In order to learn you have to find the answer for yourself. If someone tells you something, and you are not interested in it goes out the other ear.

Student B: No. The activities are the funnest part and you learn more.

Student C: No. I like hands-on activities.

Student D: No, because the way you teach it is half activities and half information.

Question 3: How successful do you feel in science this year? Is this different from other years? How?

Student A: I feel very successful from the repeated learning habits. It's somewhat different because we're on our own most of the time (during activities).

Student B: I feel a lot more successful this year compared to other years.

Student C: I feel very successful. Yes, I've got a teacher who explains it more clearly than last year.

Student D: This year is different because I'm really trying. The other years are different because I didn't care, last year.

Question 4: Do the activities help you learn, or do they cause a distraction in your learning?

Student A: They really help me learn.

Student B: The activities help me learn more and faster.

Student C: They help me learn more.

Student D: No it is not distracting to me, it is also helping me learn.

Post Research Questions

Question 5: Do you feel you know more science now than you did before entering this science class? "Explain your feelings.

Student A: Very much (times 100). I never knew I could learn so much just in a few months. The activities just forced me to understand. They're really cool.

Student B: Yes I feel I do know more.

Student C: Yes. I learn something new everyday.

Student D: I think I know more this year because I'm really paying attention now.

Question 6: Do you feel that if you read a book you would know the same information, or do the activities help you understand the matter concepts? How?

Student A: I don't think I would have understood it if I just got information out of the book because seeing is believing. By experimenting, we can look and observe from beginning to end. If one of us gets stuck, the others can help them learn.

Student B: I don't understand as much if I read so I think I learned a lot more by doing experiments. I am a visual learner.

Student C: The activities make me know about matter and physical and chemical change because I learn more by doing, not reading.

Student D: I don't know

Question 7: Do you feel that your current grade is acceptable to you? Are you proud of it, or do you think it is not high enough, based on previous science grades? Explain.

Student A: I do not accept my current grade because I know I can do better. I have been to careless about homework, so I will try to raise my grade by the end of the quarter.

Student B: My current grade is OK, but I know I can do a lot better, but I need to try more.

Student C: Yes it is fine. You grade fairly. Well I am trying harder too.

Student D No. The work is getting harder and I am not trying as hard.

Question 8: Would you like to continue learning in my teaching style or change to a more teacher directed/book directed science class and have limited or fewer activities? Why or why not?

Student A: I like the way we are learning now rather than changing it. Everyone probably agrees because the activities come up in our conversations sometimes.

Student B: I would like to continue learning in this style because I am really learning about science.

Student C: No, don't change the style. I am having fun and learning at the same time. I never thought it was possible.

Student D: Don't change your teaching style. I do not feel I could be successful at all. My grades will go down if you change.

Appendix C
Pre and Post
Test Questions
and Responses
(using actual student language)

UNIT: MATTER

Question I: What is Matter?		
Student Response	Pre-Test	Post Test
A	Everything	Matter is everything
B	I don't know	Matter is everything
C	I don't know	Matter is everything
D	I don't know	Matter is what the universe is made of

Question II: What are the states of matter?		
Student Response	Pre-Test	Post Test
A	I don't know	Gas, liquid, solid, and that thing that doesn't exist on earth but some other place in the universe
B	I don't know	Solid, Liquid, Gas
C	I don't know	Solid, Liquid, Gas
D	I don't know	I don't know

UNIT: MATTER

Question III: What is viscosity?		
Student Response	Pre-Test	Post Test
A	I don't know	Resistance to flow
B	I don't know	Liquid flow
C	I don't know	How runny a liquid is
D	I don't know	I don't know

Question IV: What is an atom?		
Student Response	Pre-Test	Post Test
A	A molecule	Atoms are made of protons, neutrons, and electrons (And a nucleus in the center)
B	I don't know	protons and electrons
C	I don't know	molecules
D	I don't know	I don't know

UNIT: MATTER

Question V: What is the difference between a physical and chemical change?		
Student Response	Pre-Test	Post Test
A	Physical change is how the shape of an object changes	Physical change: something that changed its color shape size, but didn't turn into a different substance. Chemical change: when two different substances mix to create a new substance.
B	I don't know	A physical change is temporary. A chemical change is permanent
C	I don't know	A physical change is what you see. A chemical change is what you observe.
D	A chemical happens by itself. A physical somebody has to do it get a change.	A physical change is like a block of melted ice. A chemical change is if something chemical is added to another chemical

UNIT: ACIDS AND BASES

Question I: What is an acid?		
Student Response	Pre-Test	Post Test
A	A substance (liquid) usually bitter, shampoo, or soap!	A type of substance contained in fruit juices, usually sour and have positive ions
B	The bottom or main substance of a thing	Sour-tasting
C	A liquid substance	Acids have physical and, chemical properties when dissolved
D	I don't know	I don't know

Question II: What is a base?		
Student Response	Pre-Test	Post Test
A	A substance usually bitter, shampoo or soap	A type of substance contained in bitter, slippery liquid such as cleansing liquids. Have negative ions
B	The bottom or main substance of a thing	Bitter
C	A liquid substance	Bases share all physical and chemical changes when dissolved in water
D	I don't know	I don't know

UNIT: ACIDS AND BASES

Question III: Which is stronger an acid or a base?		
Student Response	Pre-Test	Post Test
A	Acid	They are both equally strong and equally dangerous
B	Acid	Both acids and bases are both the same in strongness
C	Base	They are the same in strength
D	I don't know	They are the same

Question IV: How do you determine if a substance is an acid or a base?		
Student Response	Pre-Test	Post Test
A	Use the litmus paper. Blue to red = acid Red to blue = base	You can use indictors (pH paper, litmus paper, cabbage juice, universal indicator) and observe changes in color
B	I don't know	You can determine if a substance is a acid or base because of the color it changes when you put some kind of an indicator
C	I don't know	Using indicators
D	I don't know	You can use that paper stuff and if it turns one color it's base and if it turns another color it's an acid. Also litmus paper.

UNIT: ACIDS AND BASES

Question V: What are indicators?		
Student Response	Pre-Test	Post Test
A	I don't know	Indicators-things (materials) used to determine if a substance is an acid or base pH paper, litmus paper, cabbage juice, and universal indicator.
B	I don't know	An indicator is a substance that determines if another substance is an acid or base - some are cabbage juice or universal indicator
C	I don't know	Indicators are used to determine if a substance is an acid or a base
D	I don't know	Paper stuff, cabbage juice - universal

Question VI: What is neutralization?		
Student Response	Pre-Test	Post Test
A	When you add either acid or base to make it neutral	When you take the other (base or acid) and mix it with the liquid to make it neutral
B	I don't know	A neutralization is where it is in the middle of an acid or a base
C	I don't know	Acid plus base solution creates a neutral and salt
D	I don't know	I don't know

UNIT: GEOLOGIC TIME

Question I: How old is the earth?		
Student Response	Pre-Test	Post Test
A	5 billion years	460,000,000
B	A lot of years old - 6.2 billion	4.6 billion
C	6 billion years old	4.6 billions of years
D	I don't know	Billions of years

Question II: What are the four divisions of geologic time?		
Student Response	Pre-Test	Post Test
A	I don't know	Pre Cambrian, archean, proterozoic
B	I don't know	Pre Cambrian, Paleozoic, Mesozoic, Cenozoic
C	I don't know	Precambrian, Paleozoic, Mesozoic, Cenozoic
D	I don't know	Paleozoic, Cenozoic, Mesozoic

UNIT: GEOLOGIC TIME

Question III: List the following in the order they occurred: The Big Bang, people, ice age, dinosaurs.		
Student Response	Pre-Test	Post Test
A	The big bang, dinosaurs, ice age, people	The big bang, dinosaurs, ice age, people
B	I don't know	The big bang, dinosaurs, ice age, people
C	dinosaurs, people, ice age, big bang	The big bang, dinosaurs, ice age, people
D	I don't know	The big bang, dinosaurs, ice age, people

Question IV: What is a time line used for?		
Student Response	Pre-Test	Post Test
A	For organizing and knowing when a certain time took place	A time line is used to see when different events occurred
B	To show the different stages of something	A time line shows the different eras or periods through time. It's used to help know the different stages of something
C	To graph the history of the earth	To tell what order and when events happened
D	To see how much things improve from way back	To tell how old the earth was and the different eras the earth went through

UNIT: GEOLOGIC TIME

Question V: What is the difference between an era and a period?		
Student Response	Pre-Test	Post Test
A	Period - a certain time when things occurred. Era - a time when things occur	Era is a larger period of time that divides the earth's history into four parts. Period is a smaller time period which divides the era into smaller sections
B	An era is longer than a period. And periods make up an era	Eras are longer
C	An era is longer than a period	Eras are longer
D	I don't know	An era is a division of time and a period happens within the era