Temple University
Doctoral Dissertation
Submitted to the Graduate Board

Title of Dissertation: (Please type) THE IMPACT OF COMPUTER-BASED VERSUS "TRADITIONAL" TEXTBOOK SCIENCE INSTRUCTION ON SELECTED STUDENT LEARNING OUTCOMES

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Date of Defense: (Please type) October 28, 1999

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Date Submitted to Graduate Board: 11/10/99

Accepted by the Graduate Board of Temple University in partial fulfillment of the requirements for the degree of Doctor of Education.

Date 4/4/00

(Dean of the Graduate School)

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DOCTOR OF EDUCATION

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by

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January, 2000

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ABSTRACT

THE IMPACT OF COMPUTER-BASED VERSUS "TRADITIONAL" TEXTBOOK SCIENCE INSTRUCTION ON SELECTED STUDENT LEARNING OUTCOMES

Alan H. Rothman

Doctor of Education

Temple University, 2000

Doctoral Advisory Committee Chair: Dr. Joseph Schmuckler

This study reports the results of research designed to examine the impact of computer-based science instruction on elementary school level students' science content achievement, their attitude about science learning, their level of critical thinking-inquiry skills, and their level of cognitive and English language development. The study compared these learning outcomes resulting from a computer-based approach compared to the learning outcomes from a traditional, textbook-based approach to science instruction. The computer-based approach was inherent in a curriculum titled The Voyage of the Mimi, published by The Bank Street College Project in Science and Mathematics (1984).

The study sample included 209 fifth-grade students enrolled in three schools in a suburban school district. This sample was divided into three groups, each receiving one of the following instructional treatments: (a) Mixed-instruction primarily based on the use of a hardcopy textbook in conjunction with computer-based instructional materials as one component of the science course; (b) Non-Traditional, Technology-Based-instruction fully utilizing computer-based material; and (c) Traditional, Textbook-Based-instruction utilizing only the textbook as the basis for instruction.

Pre-test, or pre-treatment, data related to each of the student learning outcomes was collected at the beginning of the school year and post-test data was collected at the end of the school year. Statistical analyses of pre-test data were used as a covariate to account for possible pre-existing differences with regard to the variables examined among the three student groups.

This study concluded that non-traditional, computer-based instruction in science significantly improved students' attitudes toward science learning and their level of English language development. Non-significant, positive trends were found for the following student learning outcomes: overall science achievement and development of critical thinking-inquiry skills. These conclusions support the value of a non-traditional, computer-based approach to instruction, such as exemplified by The Voyage of the Mimi curriculum, and a recommendation for reform in science teaching that has recommended the use of computer technology to enhance learning outcomes from science instruction to assist in reversing the trend toward what has been perceived to be relatively poor science performance by American students, as documented by the 1996 Third International Mathematics and Science Study (TIMSS).

ACKNOWLEDGMENTS

Of all the fine people who deserve my thanks for the support they have provided throughout this process, none rank above my wonderful wife, Helene. During the darkest moments, when bringing this research this fruition seemed beyond any measure of comprehension or reality, Helene provided the light that kept me on a positive path toward completion of this project. Who and where I am today are owed, in no small part, to her.

I wish to thank Dr. Joseph Schmuckler and Dr. Matthew Bruce for serving as my advisors during my studies at Temple University. I also thank Dr. Frank Sutman for the large amount of time he gave toward crafting this study into a strong, comprehensible written format. I would like to express my sincere gratitude to Dr. Roslyn Gorin, Dr. Marvin Hirshfeld, Dr. Donald Walters, and Dr. Christine Woyshner. All, in my opinion, are fine educators who unselfishly provided the tutelage and guidance that helped me grow both as a professional and a person.

Lastly, I wish to thank all of the teachers and administrators in the district in which I am employed, who continue to give everything they have each day to improve the future through the education of our children.

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CHAPTER 1

INTRODUCTION

Statement of the Problem

This dissertation reports the results of research that was designed to examine the impact of computer-based science instruction on elementary school level students' science content achievement, their attitude about science learning, their level of critical thinking or inquiry skills, their level of cognitive development, and the extent of their English language development. The study compared the learning results that occurred from a computer-based approach with the results of a traditional, textbook-based approach to science instruction. The computer-based approach, used with elementary school level fifth-grade students, was The Voyage of the Mimi, an instructional program published by The Bank Street College Project in Science and Mathematics (1984).

The study was motivated by a problem found in many school districts across the nation; namely that the effectiveness of science education in American schools continues to be a contentious issue because American students, at the fourth, eighth, and twelfth grade level, generally performed poorly in science and math achievement on international, high-stakes assessments, such as the 1996 Third International Mathematics and Science Study (TIMSS), when compared to students in other industrialized countries in the world. A trend toward decreasing science achievement was indicated in TIMSS, as American students progressed from the elementary school level to the secondary level, resulting in questioning of the effectiveness of current approaches to science instruction, including traditional, textbook approaches, similar to those currently used in many American elementary schools. The problem of decreasing student science achievement in the nation's schools has resulted in the creation of reform efforts to search for ways to increase the effectiveness of science teaching across the United States.

The standards contained in the National Science Education Standards (National Research Council, 1996) call for the development and use of non-traditional approaches to science instruction that are constructivist in nature, rather than traditional, behaviorist modes of instruction, to improve the results of science teaching and produce students better able to contribute to the advancement of the nation's technological emphasis. The results obtained through the study reported herein will help to develop a deeper understanding of the impact of non-traditional, computer-based approaches to science instruction, such as The Voyage of the Mimi, on learning. The results of this study also will contribute to the examination of whether use of a computer-based approach is enough, in and of itself, to produce significant improvement in students' science achievement and attitudes toward science learning.

The study also will help examine whether other substantive changes in science teaching, such as professional development in alternative teaching strategies and increased classroom access to technological resources, such as computers, videodiscs, and microcomputer-based laboratories, need to be made in conjunction with the use of these approaches to effect significant increases in student learning. The results of the reported study also will enable professionals to develop a better understanding of the inquiry process in science instruction through which critical thinking develops, another emphasis of the National ScienceEducation Standards.

Efforts toward the strengthening of the nation's educational practices (such as the federal government's Goals 2000 program) have led to drastically increased funding for expensive computer-based instructional resources at the elementary school level across the country. Typical, suburban school districts, like the one that served as the site for the research reported herein, have adopted a formalized technology plan outlining goals and strategies for using computer technologies as integrated, instructional tools designed to strengthen their educational practices and increase student learning outcomes. With accompanying annual technology budgets totaling millions of dollars, this school district, again, like many others, needs research results that indicate whether or not significant improvements in students' achievement and attitudes result from the use of this expensive equipment; thereby justifying, or not justifying, these large expenditures.

While there has been a rapid expansion in the purchase and use of science instructional programs that emphasize or depend upon computer technology, during this and the previous decade, the number of studies examining the impact of this approach to science instruction, specifically at the elementary school level, have been minimal. A report by the Panel on Educational Technology (1997), Report to the President on the Use of Educational Technology to Strengthen K-12 Education in the United States, stated that research conducted in this area should occur within authentic educational environments designed to provide educators and the public with sound empirical data to be used in examining the effectiveness of computer-based instructional approaches. In her 1994 publication, Jones focused specifically on non-traditional, computer-based instruction programs, such as The Voyage of the Mimi, noting the lack of investigation into potential effects on the development of student learning in various content areas. The study presented in this dissertation was designed to address this perceived need.

Research Questions and Hypotheses

The study reported in this dissertation responded to both local and national need to learn more about the impact of instruction that is computer-driven by proposing the following research questions and related hypotheses:

Question 1: Are there differences in the science achievement attained by elementary school level students whose science instruction emphasizes microcomputer-based experiences when compared to the levels of science achievement attained by elementary school level students whose instruction includes only textbook-oriented experiences?

Null Hypothesis 1: There will be no statistically significant difference in the science achievement attained between the elementary school level students taught with the methods indicated previously.

Question 2: Are there differences in the attitude toward science learning developed by elementary school level students whose science instruction emphasizes microcomputer-based experiences when compared to the attitude toward science learning developed by elementary school level students whose instruction includes only textbook-oriented experiences?

Null Hypothesis 2: There will be no statistically significant difference in the attitude toward science learning developed between the elementary school level students taught with the methods indicated previously.

Question 3: Are there differences in the levels of critical thinking or basic science inquiry skills developed by elementary school level students whose science instruction emphasizes microcomputer-based experiences when compared to the levels of critical thinking or basic science inquiry skills developed by elementary school level students whose instruction includes only textbook-oriented experiences?

Null Hypothesis 3: There will be no statistically significant difference in the levels of critical thinking or basic science inquiry skills developed between the elementary school level students taught with the methods indicated previously.

Question 4: Are there differences in the levels of cognitive development exhibited by elementary school level students whose science instruction emphasizes microcomputer-based experiences when compared to the levels of cognitive development exhibited by elementary school level students whose instruction includes only textbook-oriented experiences?

Null Hypothesis 4: There will be no statistically significant difference in the levels of cognitive development exhibited between the elementary school level students taught with the methods indicated previously.

Question 5: Are there differences in the levels of language development attained by elementary school level students whose science instruction emphasizes microcomputer-based experiences when compared to the levels of language development attained by elementary school level students whose instruction includes only textbook-oriented experiences?

Null Hypothesis 5: There will be no statistically significant difference in the levels of language development attained between the elementary school level students taught with the methods indicated previously.

Historical Background

The impact of the "microcomputer revolution" of the 1980's, featuring the use of personal, stand-alone desktop computers, has been well documented with regard to science education (Roblyer, 1988). Watson (1983) indicated the importance of computer-based science instruction, reporting that "by 1980 computers were the single most ubiquitous topic of National Science Foundation proposals and awards, reflecting educators' interest in utilizing their power for instruction" (p. 375).

Since the 1980's, use of computer-based instructional approaches has been expanding at an unprecedented rate, as indicated in the Office of Technology Assessment (1982) report Information Technology and Its Impact on American

Education, which predicted that American schools would have over four million microcomputers by 1994. According to the Software Publishers Association (1996), as of December, 1994, estimates of the number of computers in our nation's K-12 schools was 6.2 million, well above the four million estimate given by the United States Congress' Office of Technology Assessment report in 1982. A report from Quality Education Data, Incorporated (1995) indicated that 97 percent of all school districts across the nation owned at least some computers.

Johnson's 1997 publication, "Integrating Technology in the Classroom: The Time Has Come", presented the following developments as further evidence of the large investment being made in the potential of computer-based instruction for improving students' learning:

1. the formulation of a subgoal within the National Education Goals (Goals 2000) specifically addressing the need for educators to have ample opportunity to gain skills necessary to utilize emergent technologies (including computers) for instructional purposes;
2. the formulation of resolutions including references to technology planning, usage, and staff development, by the National Education Association;
3. the publication of a report by the Northwest Regional Laboratory for Research and Development indicating that one of the top six priorities in school planning was consideration of educational technology; and

4. the creation of the Office of Educational Technology by the United States Department of Education to coordinate planning of strategies for integrating technology into the nation's schools.

The need for research helping to substantiate or disprove a link between the use of computer approaches and improved student learning is evident through a variety of government and educational initiatives. For example, Mervis (1999) reported that the National Science Foundation, the National Institutes of Health, and the Department of Education recently collaborated to form the Interagency Education Research Initiative (IERI). The goal of the IERI is to provide funding to support research initiatives designed to improve instruction in science, math, and reading through innovative approaches, such as those based on the use of technology. With a multi-million dollar budget, extending beyond the year 2001; research, such as that reported in this dissertation, providing insight into the contributions that can be made through non-traditional, computer-based approaches to instruction to the improvement of learning by students, has emerged as a priority of both governmental and other educational agencies and organizations.

Definition of Terms Used in the Study

Definitions for significant terms used in this study are as follows:

1. Computer-Based or Microcomputer-Based Instruction: Instruction that incorporates a significant amount of some type of digital computer technology, such as the personal or microcomputer, CD-ROM, videodisc, etc. (revised from Braun, 1991).
2. Computerized Simulation: Computer hardware and/or software that allow experiences or interactions with models representing real-life phenomena (revised from Lunetta & Hofstein, 1981).
3. Microcomputer-Based Laboratory or MBL: A series of electronic probes directly interfaced with a computer which allow, in real time, computerized data collection, graphic data display, and data analysis of variables, including temperature, distance, light intensity, pH, sound, etc. (revised from Tinker, 1985).
4. Interactive Computer/Videodisc Learning and Instructional System/Program: A digital video and audio delivery system combining computerized text, graphic, and sound capabilities into multimedia presentations that allow individual responses to be made dependent upon the choices of the user (revised from Smith & Lehman, 1988).

5. Computer-Assisted Instruction or CAI: An instructional approach in which the computer is utilized to deliver information in a tutorial, or step-by-step, manner to assist students in the attainment of specific learning objectives (revised from Simonson & Thompson, 1994).
6. Computerized Tutorial Program: Computer software designed to introduce specific educational knowledge and/or skills (revised from Baird, 1989).
7. Science Achievement: One's level of understanding of the natural world, the fundamental scientific principles guiding it, and the related process skills and reasoning abilities necessary to interpret it (revised from The Psychological Corporation, 1993).
8. Science Attitude: One's state of mind, feeling, or disposition towards the discipline of science and science learning (revised from Hogan, 1975).
9. Critical Thinking-Inquiry Skills: Higher order questioning and other reasoning strategies and processes based upon the research theory presented within Bloom's taxonomy. Such thinking involves more than a "passive" recall or knowledge of facts and ideas, instead requiring an "active" processing and integration of questioning and information gathering in order to analyze, apply, classify, synthesize, and evaluate data, ideas, concepts, conclusions, and solutions (revised from The Psychological Corporation, 1993).

10. Levels of Cognitive Development: The levels of thinking, as defined by Piaget's developmental research theory. Included are pre-operational, operational, concrete, and formal stages of reasoning based upon thinking tasks requiring conservation, classification, relations, perspective imaging, and other skills related to the processes of thought (revised from Patterson & Milakofsky, 1980).

11. Language Development: The ability to understand and communicate ideas and concepts in English language through the processes of reading and writing. Included are levels of reading vocabulary, reading comprehension, spelling skills, grammar skills, and written composition (revised from The Psychological Corporation, 1993).

Dissertation Format

This chapter introduced the study reported within this dissertation through a brief historical background and a statement of purpose. Also presented were the research questions that were addressed through analyses of collected data. These data support or fail to support null hypotheses related to each research question. The chapter concluded with a definition of terms used throughout the dissertation.

Chapter 2 is a review of literature presenting past studies that examined the results of other computer-based instructional tools. The methodology and procedure included in the design of the study are presented in Chapter 3. The data collected and accompanying statistical analyses of this data are presented in Chapter 4. Chapter 5 presents conclusions related to each research question along with discussion of implications related to these conclusions, as well as recommendations for further research.

CHAPTER 2

REVIEW OF THE LITERATURE

Introduction

This chapter presents examples of literature, published during the period 1980 to 1997, in support of the various components of the research undertaken and reported in this dissertation. The literature reports on studies that served as a model for this study and/or indicates why the study needed to be carried forward. While college level studies exist, only research reported for pre-college level student populations are included, serving as relevant models for this study with its elementary school level student population and associated, age-appropriate instructional approaches. The studies included were located through electronic searches of pertinent research databases, including ERIC, ProQuest Direct, ProQuest Digital Dissertations, SIRS, and others, using search descriptors, such as "technology" and "science"; "computer" and "science"; "videodisc" and "science"; "elementary" and "science"; and others, as well as manual searches of leading science education and educational technology publications.

The research questions addressed in this dissertation are pertinent especially as they relate to the use of microcomputers in support of inquiry/discovery process skill development through instruction in science at the elementary school level. In a review of research on the effects of microcomputer-based science instruction, Weller (1996) determined that an average of seven studies were published each year, between 1988 and 1995. He also indicated that "approximately one-quarter of the research reported on computer-based science learning from the past eight years involved CAI, one-fifth reported on simulations and microworlds, one-tenth on MBL's, one-tenth on interactive videodisc, and the remaining three-tenths focused on a wide variety of other approaches" (Weller, 1996, p. 462). Weller also noted a trend in which the number of published studies utilizing CAI declined during this eight-year period in favor of more published research on the other computerized science instructional methodologies (e.g. the use of simulations, MBL, and interactive videodisc).

Using Weller's classification scheme for computer-based science instruction, the impact of such instruction on the variables examined in this study are presented in the following sections: (a) Meta-Analyses from 1980 to Present; (b) Impact of Computer Simulations on Students' Science Achievement and Science Attitude; (c) Impact of Microcomputer-Based Laboratories on Students' Science Achievement and Science Attitude; (d) Impact of Interactive Videodisc Instructional Systems and Programs on Students' Science Achievement; and (e) Impact of Computer-Assisted Instruction and Computer Tutorial Programs on Students' Science Achievement and Science Attitude. While studies examining recent computer-based science instruction approaches, such as telecommunications and Internet-based programs and CD-ROM and hypermedia programs, also exist, these studies are not included because they are not relevant to the results from the approach to science instruction examined in the study reported herein.

A section Correlation Between Students' Attitude and Achievement highlights a study that established a positive correlation between attitude and academic achievement within the context of science classes at the middle and high school levels. This study is included because of its focus on the relationship between science attitude and achievement. Both of these variables are addressed in this dissertation.

A section Relationship Between Critical Thinking Skills and Science Inquiry Skills highlights literature establishing a relationship between students' critical thinking skills and science inquiry skills. Establishing of this relationship relates to the study reported in this dissertation, in that it examines the impact of a microcomputer-based instructional approach on the variable of critical thinking skills. Significant findings regarding this variable may extend to science inquiry skills, a topic of extreme interest to other recent research conducted through the Center for Science Laboratory Studies at Temple University.

The final section of this literature review: Summary of Findings from the Review of the Literature, summarizes conclusions based upon the research findings presented within the preceding sections.

Meta-Analyses from 1980 to Present

Since 1980, a number of meta-analyses have been conducted that summarize instructional computing research data collected over time. These also address the impact of instructional technologies in specific areas, such as science education, over a period of time. Utilizing a statistical analysis referred to as effect size, a common measurement scale for the comparison of the impact of technology-based instruction across a variety of studies has been determined. The most significant meta-analyses, related to the study reported herein, are summarized below.

Meta-Analyses of Studies on the Impact of Computer Instruction on Students' Science Achievement, Science Attitude, and Critical Thinking Skills

Several meta-analyses on the impact of computer instruction on students' science achievement, science attitude, and critical thinking skills have been conducted since 1980. These include one that studied the influence of computer instruction on science and mathematics achievement (Kulik & Bangert-Drowns, 1983).

This study performed a meta-analysis of the results of significant earlier meta-analyses related to science and math achievement conducted by researchers such as Hartley (1978); Burns and Bozeman (1981); Kulik, Bangert, and Williams (1983); and others. Kulik and Bangert-Drowns determined that for the impact of computer science and mathematics instruction on student achievement, there was a gain from the 50th to the 66th percentile for students instructed utilizing computer methodologies.

One of the most influential studies resulting from a meta-analysis that analyzed the results of the use of microcomputers in education during the period from 1980 to 1987 was conducted by Roblyer, Castine, and King (1988). Reports of over 200 complete studies related to the instructional effectiveness of microcomputers were received and, of these, 38 studies and 44 dissertations met established criteria to be included in the meta-analysis. From this review, Roblyer, Castine, and King noted a trend of increasing amounts of research being conducted on the impact of microcomputer-based instruction with "almost three-quarters of the studies in the time reported during the period from 1985-1987" (1988, p. 70). They also indicated that 21 studies and 23 dissertations included in their meta-analysis focused upon the elementary level.

The above referred to researchers completed a total of 17 meta-analyses, each based on various content areas and other features. From these they concluded that the impact of computer instruction varied greatly dependent upon the content area addressed, with science having the highest reported effect for any specific curricular discipline. In fact, the research indicated that the "use of computer applications in math, reading, and cognitive skills areas all reflected similar effects, while science effects were nearly twice as great" (Roblyer, Castine, & King, 1988, p. 78). Also, the use of computers were found to have a significant positive effect, both on the attitudes of students towards themselves and toward school learning of subject matter. The use of computers in instruction also were found to have a significant effect on the development of students' problem solving and thinking (inquiry) skills. Resulting from these and other findings, the conclusion was made "that computer applications have an undeniable value and an important role to play in classrooms of the future" (Roblyer, Castine, & King, 1988, p. 131).

In the report of the results of their meta-analysis, Roblyer, Castine, and King also presented a review of past meta-analyses that focused on studies of the effects of microcomputer-based instruction on learning time and attitude toward the learning of content. The report of this study indicated that using computers reduced the time required for learning and increased attitudes toward learning content or school learning.

Roblyer, Castine, and King cited a past meta-analysis that focused on the effects of microcomputer-based science instruction. The study, conducted by Willett, Yamashita, and Anderson in 1983, concluded that the greatest effect was attributed to computer simulation type of experiments. Note that this conclusion was based on the result of one study.

Niemac and Walberg's (1985) meta-analysis also considered the effects of microcomputer-based science instruction on content achievement (math, science, reading, etc.). The conclusion that science content learning was significantly improved through microcomputer-based instruction was reported.

A meta-analysis reported by the Software Publishers Association (1996) focused on the achievement effects of computers in elementary school level settings. The study (Ryan, 1991) that incorporated 40 earlier studies conducted between 1984 and 1989 indicated results in favor of the computer-oriented instructional approaches.

Khalili and Shashaani (1994) conducted a meta-analysis studying the effect of computer applications on the academic achievement of students ranging from elementary to college. Their analysis included 36 studies published between 1988 and 1992. The results indicated that "the performance of the experimental group, those who benefited from the computer instruction, was 0.38 standard deviation higher than the performance of the control group" (Khalili & Shashaani, 1994, p. 53). The mode of the computer-based instruction was identified as a feature of importance, with "simulation" and "problem solving" producing the greatest achievement results.

In 1997, Christmann, Badgett, and Many conducted a meta-analysis of studies from 1984 to 1995 attempting to measure the achievement results of CAI with secondary students in sixth through twelfth grade. After a thorough search of over 1,000 publications, 26 studies were determined to have met the established criteria for inclusion. The researchers concluded that "students exposed to CAI showed higher academic achievement than 57.2 percent of the students exposed to traditional instruction" (Christmann, Badgett, & Many, 1997, p. 328).

Summary

In summary, the meta-analyses reported in this section indicate a substantial positive impact of technology-based instruction on students' achievement and attitude, specifically related to science content understanding as well as inquiry skills, including critical thinking skills.

Impact of Computer Simulations on Students' Science Achievement and Science Attitude

Since the 1980's, the potential of instruction using computer simulations has become an important area of educational computing research. A survey by Weiss (1987) reported that approximately 17 percent of high school classes using computers for science instruction utilized computer simulations for the following reasons:

1. to reduce instructional time (Clariana, 1988);

2. to allow students to experience situations and techniques that otherwise would be too costly, dangerous, or frustrating to furnish (Disinger & Fortner, 1984);
3. to integrate and analyze data and concepts over time (Hinze, 1984); and
4. to provide for role-playing opportunities (Bowker & Bowker, 1986).

Impact of Computer Simulations on Students' Science Achievement in Environmental Science

A trend noted in research in the area of computer simulations was the analysis of its effect on the development of environmental education skills. In one such study (Rivers & Vockell, 1987), the science achievement of high school students instructed with microcomputer simulations of environmental issues was compared to that of students instructed without simulations. The simulations treatment students were divided into two groups, "unguided simulation instruction" and "guided simulation instruction". The unguided students were provided with only "a short introduction" for each simulation while the guided pupils received "two to ten paragraphs of strategies to use" with the simulations (Rivers & Vockell, 1987, p. 407). Achievement, measured using the Biological Sciences Curriculum Study Process of Science Test, the Test of Integrated Process Skills (TIPS), and the Watson-Glaser Critical Thinking Appraisal, indicated that the guided students displayed significant gains over both the unguided and non-simulations students on the Watson-Glaser Critical Thinking Appraisal, with no additional significant differences found. Despite some reported inconsistencies across tests, instruction in environmental problem solving skills using guided computer simulations resulted in equal or improved achievement across groups of varying high school students.

A study by Sherwood and Hasselbring (1986) researched the impact of computer simulations on the science achievement of elementary students studying ecological concepts. In this research, groups of students instructed utilizing the computer science simulations Odell Lake and Odell Woods were compared with a group of students instructed without computer simulations. These two simulations present ecological situations where students are placed in the role of a particular animal and have to react to a variety of circumstances. Science achievement in ecology was measured using a researcher-created instrument containing a multiple-choice section and a second part requiring the completion of a food chain. The Coefficient Alpha reliabilities were reported as 0.56 and 0.77 for the first and second parts of the test, respectively. The results reported showed the students receiving the simulation treatment significantly ($p = 0.07$) outperformed the students instructed without computer simulations on the first part of the test. No significant differences were found among the subjects on the second portion of the test. The researchers concluded that, overall, the computer simulation instruction was equally effective to other instructional modes in terms achievement outcomes.

Impact of Computer Simulations on Secondary School Level Students' Science Achievement and Science Attitude

Research investigating the effects of computer simulations instruction on science achievement, outside the realm of environmental problem solving, studied populations of secondary students. A study by Choi and Gennaro (1987) compared science achievement in volume displacement of junior high school students instructed using computer simulations and a hands-on laboratory. Scores on the California Achievement Test (CAT) were used to determine initial achievement differences between the students in the two treatment groups. A multiple-choice test on volume displacement was designed and validated for this study. Results of the initial administration of the conceptual test yielded no significant differences in science achievement between the student groups.

The study (Hounshell & Stanford, 1989) compared the biological science achievement of traditionally- and computer-instructed high school students, with the students in the computer treatment group utilizing computer simulations for 60 percent of the time in place of lecture and 70 to 80 percent of the time in place of more traditional laboratory experiences. The traditional lecture and laboratory group were involved in the normal lecture and laboratory biology course taught at the high school level. Achievement in biological science content was measured through the Comprehensive Test of Basic Skills. The students in the computer simulation group significantly outscored their traditionally-instructed counterparts.

Lazarowitz and Huppert (1993) studied use of a computer simulation to instruct high school students in microbiology. The computer-based treatment presented topics related to the biology of microorganisms, microbial metabolism, fungi as allies, bacteria as allies, using a combination of a computer simulation, entitled The Growth Curve of Microorganisms, along with traditional laboratory work. The traditional treatment used "a traditional classroom-laboratory setting" (Lazarowitz & Huppert, 1993, p. 368). Pre-test scores indicated that no initial significant differences existed among the students in the groups. However, a two-way Analysis of Variance (ANOVA) of the post-test scores yielded a significant difference in the science achievement favoring the students in the computer simulation treatment group. An Analysis of Covariance (ANCOVA), with the pre-test serving as a covariate, of the science process skills scores indicated that the students in the computer simulation treatment group achieved significantly higher on three of the nine Biology Test of Science Processes subscales, including graph communication, data interpretation, and variable control. With the support of these results, the researchers concluded that the use of the computer simulation "helped students in the experimental group achieve higher academic performance" and served as "a vehicle students can use to acquire and master science process skills" (Lazarowitz & Huppert, 1993, p. 379).

Friedler, Merin, and Tamir (1992) conducted a study investigating the effect of computer simulation instruction on the science achievement and attitude of high-school biology students. The computer-based treatment group received instruction in enzymatic processes using a computer simulation, allowing for investigation of the reaction rates of various enzymes through the control of factors, such as pH and temperature. The traditional treatment group was instructed in the same enzymatic processes through traditional laboratory activities. A course test containing essay and multiple-choice questions on enzymatic reactions was utilized as a pre- and post-test to measure science achievement. A "perceptions scale" was used by the researchers to measure "satisfaction and motivation of the students" (Friedler, Merin, & Tamir, 1992, p. 351). Analysis of the data indicated a significant difference ($p < 0.02$) in science achievement favoring the students in the computer simulation treatment group. The attitudinal data collected demonstrated "positive perceptions regarding enjoyment and motivation during the learning period" on the part of the students in the computer simulation treatment group (Friedler, Merin, & Tamir, 1992, p. 353). The researchers concluded that "it is possible to teach new biological topics using computer simulations" and that "integrating computers into the classroom will help broaden and deepen the students' knowledge as well as to expose students' difficulties in conceptualization" (Friedler, Merin, & Tamir, 1992, p. 356).

Summary

In summary, the studies reported in this section indicate a substantial positive impact of computer simulation-oriented science instruction on students' science achievement and attitudes about science.

Impact of Microcomputer-Based Laboratories on Students' Science Achievement and Science Attitude

Microcomputer-based laboratories (MBL's) were developed during the 1980's (Technical Education Research Centers, 1984; Tinker, 1985). These laboratory experiences utilize a variety of electronic probes directly interfaced with the computer, allowing computerized data collection and analysis as experiments were being conducted. Examples include graphic displays of temperature and monitoring of distances, light intensities, pH, and other variables. Weiss (1987) reported that laboratory-computer interfaces were in 14 percent of secondary science classes with microcomputers by 1987.

Proponents of MBL's have indicated the following reasons for its use in science instruction. It supports the:

1. potential of the graphic presentations of data obtained, making experiments more meaningful (Graef, 1983);
2. preference of scientists, mathematicians, and engineers to collect and represent their own data via similar computerized media (Mokros & Tinker, 1987);
3. ability to help students form a bridge between concrete and formal operations through the connection of the concrete experiment with its abstract graphic representation (Mokros, 1986); and

4. ability to provide higher quality measurements, easier interpretation of large amounts of data, and increased motivation through prompt feedback (Rogers, 1987).

Impact of Microcomputer-Based Laboratory Experiences on Elementary School Level Students' Science Achievement

McFarlane, Friedler, Warwick, and Chaplain (1995) conducted a study investigating the effects of MBL instruction on the achievement of graphic interpretation skills by elementary school level students. Students in computer-based instruction treatment groups used an MBL system with temperature probes and computer graphing while students in traditional laboratory instruction groups used conventional thermometers and paper-and-pencil graphs. The statistical analysis of the pre- and post-test scores of the students in the traditional laboratory instruction groups indicated improvement in achievement, but not enough to be classified as statistically significant. The students in the MBL instruction treatment groups showed a significant increase ($p \leq 0.01$) in their level of achievement. The conclusion to the study was that the "ability to read and interpret temperature/time graphs was greatly enhanced" along with the "ability to sketch temperature time curves to predict the behavior of a novel system" due to the MBL treatment (McFarlane, Friedler, Warwick, & Chaplain, 1995, p. 476).

Impact of Microcomputer-Based Laboratory Experiences on Secondary School Level Students' Science Achievement and Science Attitude

A three-month longitudinal study conducted by Mokros and Tinker (1987) examined the impact of MBL instruction on the science achievement of middle-school students. The instrumentation included a multiple-choice test on graphing skills, used as a pre- and post-test, and a "think-aloud interview", allowing the subjects to discuss the graphs in the context of the experiments (Mokros & Tinker, 1987, p. 374). Analysis of the data indicated a significant increase in the students' achievement in interpreting and using graphs as a result of the MBL instruction.

Nachmias and Linn (1987) conducted a study examining the impact of MBL instruction on the physical science achievement of middle-school students. The MBL curriculum, called The Computer as Lab Partner, focused on a series of topics in physics and chemistry. The instrument, called the Critical Evaluation of Graphs (CEG), measured student evaluation of graphic validity. Using a Paired t-Test for analysis of the data, significant gains ($p < 0.001$) in the ability of the students to ascertain the validity of graphic representations were noted as a result of the MBL instruction. Significant increases ($p < 0.001$) also were noted in the students' ability to evaluate the source of graphic invalidity.

Adams and Shrum (1990) conducted a study comparing the scientific graphing skills achievement of high school biology students instructed using computer-based and traditional approaches. The students in the computer-based instruction treatment group were instructed using a microcomputer-based laboratory "interfaced with probes for collecting, displaying, and graphing data" (Adams & Shrum, 1990, p. 779). The students in the traditional instruction group were instructed "using stopwatches, thermometers, pencils, paper, and data tables to collect, record, and graph data" (Adams & Shrum, 1990, p. 779). The Test of Graphing in Science (TOGS) was utilized to measure scientific graphing skills. The results indicated that "based on an effect size of 0.48, it seems that microcomputer-based laboratory exercises ... result in educationally significant achievement on graph-interpretation tasks" (Adams & Shrum, 1990, p. 785).

A study conducted by Brasell (1987) investigated the impact of MBL instruction on the graphing skills achievement of high school physics students. Students in computer-based instruction treatment groups were instructed in kinematics content using an MBL unit with motion probes. Students in a traditional instruction treatment group were instructed using paper-and-pencil activities. Students in a control group received no motion graphing instruction treatment. The conclusions indicated that MBL instruction led to improved graphing skills achievement.

Podell, Kaminsky, and Cusimano (1993) studied how the science achievement and attitude of high-school students were affected by MBL-oriented instruction. The physical science course students in this study were assigned randomly to either an MBL instruction group or to a traditional instruction group. The computer-based instruction treatment used MBL to instruct the students in "the structure of matter and energy transformations" (Podell, Kaminsky, & Cusimano, 1993, p. 68). The students in the traditional instruction treatment group were introduced to "the same content, although the method of instruction was more traditional and teacher-centered" (Podell, Kaminsky, & Cusimano, 1993, p. 68). Data related to student science achievement indicated that "a significantly greater proportion of students" in the MBL instruction group passed The New York State Regents Competency Test, measuring science achievement in life science, earth science, physical science, and technology and society content (Podell, Kaminsky, & Cusimano, 1993, p. 70). When the scores of "chronic truants (students with 18 or more absences per year)" were removed from the data pool, a statistically significant difference in the test scores themselves ($p < 0.05$) also was produced in favor of the students in the MBL computer-based treatment group. Science attitudes of the students were measured in terms of attendance and enrollment in future science classes. Students in the MBL instruction group were absent significantly less ($p < 0.001$) than students in the traditional instruction treatment group and also enrolled in a statistically significant higher ($p < 0.001$) proportion of "science courses for college-bound students" (Podell, Kaminsky, & Cusimano, 1993, p. 70). The overall conclusion was that "a microcomputer-based approach to science instruction in ninth-grade physical sciences had a positive impact on students' attitudes and behavior" and that "science achievement was higher for the computer group" (Podell, Kaminsky, & Cusimano, 1993, p. 71).

A study by Trumper (1997) examined the impact of MBL instruction on the science achievement of eleventh-grade physics students. Two classrooms were assigned randomly to two comparison groups. One comparison group was divided into two subgroups. The instructional treatment for both subgroups consisted of ten 90-minute lessons on physics concepts related to kinematics. Five of these lessons used "the conventional way (learning theory and formulae of accelerated movements, including concepts of instantaneous and average speed and free-fall, and applying them in problem solving)"; the other five used MBL instructional methodologies (Trumper, 1997, p. 95). The difference in the treatment of these two subgroups was the order in which the groups participated in the two modes of instruction, with one subgroup receiving the MBL instruction first and the conventional instruction second and the other subgroup receiving their instruction in the reverse order. The second comparison group received conventional kinematics instruction. Statistical analysis of the pre-test data yielded no significant difference among the comparison groups. The results of the post-test data indicated that "there is a significant improvement between the pre- and post-tests" in all the groups and that "a statistically significant difference, at an 0.01 level" in science achievement existed in favor of the students in the MBL instruction treatment subgroups (Trumper, 1997, p. 103). The overall conclusion was that the utilization of the MBL instructional methodologies is "pedagogically promising for the learning of kinematics concepts" (Trumper, 1997, p. 107).

Summary

In summary, the studies reported in this section indicate a substantial positive impact of MBL-oriented science instruction on students' science achievement and attitude toward science.

Impact of Interactive Videodisc Instructional Systems and Programs on Students' Science Achievement

The advent of interactive videodiscs can be traced back to around 1980. Interactive video utilizes video delivery in a manner that allows individual responses in the presentation to be made dependent upon the choices of the user (Smith & Lehman, 1988).

A surge in the number of videodisc players in American schools has been documented, growing from approximately 43,000 in 1987 to around 200,000 by 1994 (Manuel & Liu, 1996). Proponents of interactive videodisc technology have pointed out the following reasons for its use in science instruction:

1. provision of immediacy of feedback through the ability to allow rapid random access to video;
2. potential for multiple modalities of learning through the integration of video and computer text, graphics, and sound into multimedia instructional packages; and
3. potential for increased interest and efficiency of instruction through interactivity addressing individual learner needs (Smith & Lehman, 1988).

Impact of Interactive Videodisc Instruction on Secondary School Level Students' Science Achievement

A study by Lehman and Brickner (1996) incorporated teacher-conducted "action research" in examining the impact of interactive videodisc science instruction on student science achievement. The data from the study indicated significant increases in science achievement for all the classes except one. The study concluded that "these results tend to agree with the reviews of interactive video studies that have shown the technology to have a positive impact on achievement" (Lehman & Brickner, 1996, p. 98).

A study investigating the science achievement effects of interactive videodisc instruction with secondary students conducted by Sherwood, Kinzer, Bransford, and Franks (1987) compared the science achievement of junior high school students instructed with interactive videodisc and traditional science instructional strategies. The results indicated significant differences in favor of the students receiving interactive videodisc instruction.

Summary

The studies, reported herein, that examined the impact of interactive videodisc-driven instruction on students' science achievement indicated at least equal or, in most cases, improved science content achievement as compared to the results from traditional textbook-driven science instruction.

Impact of Computer-Assisted Instruction and Computer Tutorial Programs on Students' Science Achievement and Science Attitude

Various types of computer-assisted instruction (CAI) and computer tutorial programs have been available in science (and other) instruction since the 1980's. According to the 1985 survey conducted through Johns Hopkins University (Becker, 1987), over one-quarter of all computer usage in secondary school level science classes involved CAI or tutorials. Approximately 56 percent of elementary teachers using computers identified CAI or tutorials as a component of their computerized instruction (Dickey & Kherlopian, 1987). As reported by the Panel on Educational Technology (1997) in its Report to the President on the Use of Educational Technology to Strengthen K-12 Education in the United States, Glennan, Jr. and Melmed estimated that CAI systems were in approximately 30 percent of the schools in the United States in 1990.

Impact of Computer-Assisted Instruction and Computer Tutorial Programs on Secondary School Level Students' Science Achievement and Science Attitude

In a study by Yalcinalp, Geban, and Ozkan (1995), the impact of CAI on the science achievement and science attitude of eighth-grade students in two general science classes was examined. The students in the CAI treatment group were instructed using CAI "as a supplement to classroom instruction for the purpose of improving secondary-school students' understanding of chemical formulas and mole-related problems" while the students in the traditional instruction treatment group received the same "classroom instruction", supplemented by "attending the traditional recitation hours" (Yalcinalp, Geban, & Ozkan, 1995, pp. 1085, 1086). Science achievement related to chemistry was measured and attitude of students about the subject of chemistry was determined. ANOVA's used to examine the collected data indicated a significant difference in science achievement in favor of the students in the CAI treatment group. They also displayed a significantly higher positive attitude toward chemistry than the students in the traditional instruction treatment group. The study conclusions indicated that "the students who used the CAI accompanied with lectures scored significantly higher than those who attended recitation hours, in terms of school subject achievement in chemistry and attitudes toward chemistry subjects" (Yalcinalp, Geban, & Ozkan, 1995, p. 1083).

Wyman's (1988) study compared the science achievement of high-school physics students receiving a computer tutorial instruction treatment with that of students receiving "traditional, self-paced classroom instruction" (pp. 41, 43). Analysis of the pre-test to post-test data indicated no significant difference in the science achievement of the student groups. Therefore, the conclusion was made that both a computer tutorial and traditional instructional approach are "equally effective in terms of teaching the requisite skills" (Wyman, 1988, p. 45).

A study by Wainwright (1989) examined the impact of computer tutorial instruction on the science achievement of high school students compared to the use of paper-and-pencil worksheets as instructional reinforcers in chemistry. An ANOVA of the science achievement test data showed the students in traditional instruction group scoring significantly higher than those in the computer tutorial instruction group. Thus, the conclusion was drawn researcher reported "that the traditional worksheet approach is more effective than CAI" (Wainwright, 1989, p. 283).

A study by Jegede, Okebukola, and Ajewole (1991) examined the impact of computer tutorial instruction on the science achievement of high-school biology students. Students in two treatment groups were instructed using the same computer biological tutorials while students in another group received a traditional lecture instruction treatment. An ANCOVA, with the pre-test scores serving as a covariate, indicated no significant differences in science achievement among the student groups. The conclusion was made that the computer tutorial instruction resulted in science achievement equal to that of traditional lecture instruction.

Summary

The studies that examined the impact of CAI and computer tutorial instruction on science achievement yielded mixed results, indicating both increased, decreased, as well as equal science achievement outcomes as a result of this approach to science instruction. The study examining the impact of CAI on students' attitude about science did indicate changes in students' attitudes that were positive.

Correlation Between Students' Attitude and Achievement

This section highlights a study that established a positive correlation between attitude and academic achievement within the context of science classes at the middle and high school levels. This positive correlation relates to the study reported in this dissertation and its examination of the impact of a microcomputer-based instructional approach on students' attitudes toward science and science achievement. Potential significant findings regarding one of these variables could be extended to the other as a result of this study. The study is detailed below.

Research on the Correlation Between Students' Attitude and Achievement

Oliver and Simpson (1988) conducted a longitudinal study to examine if "student achievement is influenced by the constructs of attitude toward science, science self concept, and achievement motivation in science" (p. 144).

Initial data was gathered using a population of 5000 students in sixth through tenth grade. Science achievement data was based upon school grades from science classes. Reliability of these grades using Cronbach's Alpha was reported as 0.81.

Science attitudinal information was measured using a 58-item instrument with subscales related to attitude toward science, achievement motivation, and science self-concept. This instrument was validated for content by "a five member expert panel of sociologists and science educators" (Oliver & Simpson, 1988, p. 144). The reliability, using Cronbach's Alpha, was reported as 0.90 for the science attitude subscale, 0.85 for the achievement motivation subscale, and 0.55 for the science self-concept subscale.

Follow-up data was gathered subsequently on 850 students of the original 5000: 300 who were eighth graders, 500 were tenth graders at the time of the initial data collection. Analyses were performed to establish existent relationships between science attitudinal and science achievement variables.

Analysis of the collected data indicated "the relationship between each of the affective subscales and achievement in science was highly significant" (Oliver & Simpson, 1988, p. 149). The levels of significance were reported as $p = 0.0004$ for attitude toward science, $p = 0.01$ for achievement motivation, and $p = 0.0001$ for science self-concept. Therefore, the conclusion was made concluded "that affective behaviors in the science classroom are strongly related to achievement" (Oliver & Simpson, 1988, p. 153).

Summary

The positive correlation between students' attitude about science and achievement in science content, noted in the study reported above, has implications for the study reported in this dissertation because it examines the effects of the microcomputer-based instructional approach on students' attitudes about science and science achievement. Potential significant findings regarding one of these variables in this dissertation research could be extended to the other as a result of Oliver and Simpson's study.

Relationship Between Critical Thinking Skills and Science Inquiry Skills

Literature establishing a relationship between the development of students' critical thinking skills and science inquiry skills is included in this section. The establishment of this relationship relates to this dissertation and its examination of the impact of a microcomputer-based instructional approach on the development of students' critical thinking skills. The findings reported in the study in this dissertation regarding critical thinking skills could be extended to science inquiry skills. This literature is detailed below.

Literature Related to Critical Thinking Skills Versus Science Inquiry Skills

The relationship between students' critical thinking skills and science inquiry skills is documented in the National Research Council's (1996) National Science Education Standards. The "new vision" of science inquiry skills presented in the "Science as Inquiry Standards" requires that students use "critical thinking to develop their understanding of science" (National Research Council, 1996, p. 105). Outlined in the "Content Standards" for fifth through eighth grade students are the "abilities necessary to do scientific inquiry", including the ability to "think critically and logically to make the relationships between evidence and explanations" (National Research Council, 1996, p. 145). This relationship is also supported by Chiappetta (1997), who classified deductive and inductive reasoning, questioning, problem solving, and other types of critical thinking skills as components of "inquiry-based science" (pp. 22, 24).

Summary

The relationship between the development of students' critical thinking skills and science inquiry skills, noted in the literature reported above, has implications for this dissertation, in that significant findings regarding critical thinking skills in the research reported in this dissertation could be extended to science inquiry skills.

Summary of Findings from the Review of the Literature

The review of the literature, reported in this chapter, indicates that, in all but one of the categories of computer-oriented science instruction analyzed, the development of students' science achievement, attitude about science, and critical thinking or inquiry skills are equal to or better than those resulting from more traditional textbook-driven instruction. While some mixed learning results from CAI-oriented instruction in science and computer tutorials were noted in the literature cited, much of reported research supports positive results related to the stated variables resulting from the computer-based approach to science instruction. It will be noted that there has been limited research reported related to these variables applied to instruction in science at the elementary school level, establishing a need for more extensive research at this level of schooling; thus supporting the research conducted and reported in this dissertation. A special emphasis in the reported study, related to the development of thinking skills as a component of inquiry-based science instruction through the use of computers, should be noted.

CHAPTER 3

METHODOLOGY

Introduction

This chapter presents the methodology for the study. The chapter is divided into the following sections: Research Design, Selection, Description, and Administration of the Instruments, and Procedure. The final section includes the Limitations of the Design.

Research Design

Study Population

The study population was a select group of fifth-grade students from a suburban school district. The school district serves a mixture of students from both upper-middle class and less affluent parents.

Obtaining the Study Population

A letter (Appendix A) requesting permission to involve students in this study was sent to the parents or other guardians of each fifth-grade student at three of the four elementary schools in the school district. The district's fourth school was not included in the study because it only serves students in kindergarten through third grade. A 74 percent positive return from the original permission letter was received from parents and guardians at two of the three elementary schools. To obtain a similar return from the third school, the researcher personally attended a Back To School Night at which the nature of the research was described. This activity was followed by sending a second permission letter to those parents and guardians who had not responded to the initial request. A final reminder was made by a telephone call to all remaining parents and guardians.

The results of these letters and phone calls yielded a total of 233 affirmative and 20 negative responses. No response at all was obtained from the parents or guardians of 50 of the 303 students.

At this point, two of the six fifth-grade teachers at one of the three schools expressed concern that a comparatively low number of students (10 and 14 pupils, respectively) had parent approval to participate in the study. These teachers indicated that the time required to implement the instructional treatment and to administer the study instruments would detract from the instruction of those students who would not participate in the study. Therefore, these teachers and their classes were removed from the study. This left a total of 11 classes, 11 teachers, and 209 students that comprised the study population. The breakdown of these classes, teachers, and students by school building is indicated in Table 1.

As noted in Table 1, the fifth-grade students utilized for this study were placed into three non-randomly-selected, intact school groups. The groups differed in the science instruction treatment received, emphasizing a textbook-based approach or

Table 1. *Initial Study Population*

School	Number of Classes	Number of Teachers	Number of Students
A*	4	4	76
B*	4	4	73
C*	3	3	60
Totals	11	11	209

*These were considered comparison groups.

combinations of computer-based and textbook-based approaches for varying proportions of time. Descriptions of these treatments are presented in the Procedure section of this chapter.

These groups were considered comparison groups because the data collected for the students in each group was compared across the dependent variables studied. This comparison is presented in Chapter 4: Data Presentation and Findings. Conclusions regarding differences resulting from the science instruction treatments are drawn from this comparison of data. These are presented in Chapter 5: Conclusions and Discussion.

Some sources of population attrition were encountered during the study, resulting in a reduction of the initial study population. Information regarding this population attrition is considered in Chapter 4: Data Presentation and Findings.

Selection, Description, and Administration of the Instruments

Introduction

This study took place during the 1995-96 school year. As detailed within subsequent sections, the administration of the instruments and associated data collection occurred during this time period. In order to account for the age of the data collected and to establish the original and unique nature of this dissertation, an extensive literature search was conducted. This literature search revealed no studies that considered the same study questions, or similar questions, to those addressed here.

Selection of the Metropolitan Achievement Tests, Seventh Edition

The instruments used to measure the following three dependent variables: (a) science achievement, (b) critical thinking, and (c) language development were the Metropolitan Achievement Tests, Seventh Edition (MAT7), Form S (Balow, Farr, & Hogan, 1993b), and the MAT7 Short Form (Balow, Farr, & Hogan, 1994). Both the MAT7 and the MAT7 Short Form tests are designed to provide "reliable and valid assessment of achievement in the nation's schools" through "a series of careful analyses" of curriculum materials, including the most widely used textbooks/programs; state-mandated syllabi and guidelines; recent educational research; and the literature produced by recognized national professional organizations within education (The Psychological Corporation, 1993, p. 7).

The documentation of these tests was thoroughly reviewed to determine if they could be used to validly ascertain data related to each of the research questions and whether they had determined adequate levels of reliability and validity with comparable student populations. Data and discussion defending the levels of reliability and validity for these tests are presented in Chapter 4: Data Presentation and Findings. The selection of these instruments was based specifically on the fact that they tested for students' science achievement, critical thinking, and language development.

Description of the Metropolitan Achievement Tests, Seventh Edition

Initial student science achievement, critical thinking skills, and language development scores were collected, using the full-length battery of the Elementary 2 (fourth-grade) level of the MAT7 (Balow, Farr, & Hogan, 1993a), for each of the three comparison groups prior to treatment. The "Science" section of the full-length battery of the MAT7 at the fourth-grade level has a total of 35 items. The MAT7 "Science" test assesses "students' understanding of the natural world, the fundamental scientific principles that govern it, and the skills required to interpret it" through an emphasis upon "process skills and reasoning ability within life science, physical science, and earth science" (The Psychological Corporation, 1995, p. 16). The publishers of the MAT7 assert that a major science educational standards setting project, Project 2061 developed by the American Association for the Advancement of Science, also is reflected in the MAT7 "Science" test.

At the fourth-grade level, the "Thinking Skills" section of the full-length battery of the MAT7, including 83 items, assesses abilities of students to “integrate, process, and apply a variety of thinking strategies and skills to a specific content area" in order to "look at the big picture-to analyze, find patterns, estimate, classify, check conclusions, and reason" (The Psychological Corporation, 1995, p. 12). The efforts towards the creation of American school curricula which incorporate an emphasis upon interactive learning, highlighted by the use of critical thinking skills, have been reflected in the creation of the MAT7 "Thinking Skills" test.

Language development data was measured by combining results from the fourth-grade level "Reading" and "Language" sections of the full-length battery of the MAT7. This test, consisting of 85 items (thirty of which are designated to measure "Reading Vocabulary"), is designed to assess "content area vocabulary" that is “encountered in school and everyday life" (The Psychological Corporation, 1995, p. 15). The remaining 55 items are combined to form the "Reading Comprehension" test. This portion of the MAT7 encourages students to become "actively engaged in the reading process" allowing the test to measure "their ability to construct meaning with texts of varying difficulty levels and types" (The Psychological Corporation, 1995, p. 15).

The MAT7 fourth-grade level "Language" section contains 54 items designed to measure "the developmental nature of the writing process itself" and to evaluate "linguistic achievement in a holistic fashion" (The Psychological Corporation, 1995, p. 16). The 15 "Prewriting", 15 "Composing", and 24 "Editing" items represent three stages of the writing process within the "Language" test. Spelling and grammar skills also are measured in context within the "Editing" portion of the test.

During the school year in which this study was carried out, the decision was made to utilize the MAT7 Short Form as an annual standardized test for the fifth-grade student population rather than the full-length battery used at the fourth-grade level. This decision was based upon financial and time considerations.

Unlike the full-length battery of the MAT7, the MAT7 Short Form measures achievement only in the areas of "Reading," "Mathematics," "Language," and "Thinking Skills." Each of the sections of the MAT7 Short Form, containing "30 items that were selected from Form S of the full-length battery", "reflects the content of the full-length battery" (The Psychological Corporation, 1994, p. 11). The maximum reliability of the MAT7 Short Form was achieved through "the selection of the statistically strongest items" (The Psychological Corporation, 1994, p. 11).

The "Thinking Skills", "Reading", and "Language" sections of the MAT7 Short Form were utilized to collect data. The MAT7 Short Form "Language" and "Thinking Skills" sections, for the fifth-grade level, contain 30 items each. As with the fourth-grade data, language development was measured by combining results from the "Reading" and "Language" sections of the fifth-grade level MAT7 Short Form. The MAT7 Short Form "Reading" test at this level, containing 30 items, focuses on "Reading Comprehension".

The MAT7 Short Form used, at the fifth-grade level, did not have a science achievement section. Therefore, the fifth-grade "Science" test from the full-length battery of the MAT7, Form S (Balow, Farr, & Hogan, 1993), containing 40 items, was utilized.

Administration of the Metropolitan Achievement Tests, Seventh Edition

Pre-test data, for all three comparison groups of students, were collected at the end of the school year prior to the treatment. This data included scores in student science achievement, critical thinking skills, and language development, determined through the use of the full-length battery of the Elementary 2 (fourth-grade) level of the MAT7. This instrument was administered by each of the fourth-grade classroom teachers.

The MAT7 Short Form was administered to students in the three comparison groups, now in the fifth grade, by their classroom teachers during the spring of the 1995-96 school year as a post-test. The researcher administered the fifth-grade "Science" test from the full-length battery of the MAT7, Form S (Balow, Farr, & Hogan, 1993), to the students in each of the eleven classrooms in May and June of the school year in which the study occurred as a post-test.

Selection of the Children's Academic Intrinsic Motivation Inventory

The Children's Academic Intrinsic Motivation Inventory (CAIMI) was used to determine the dependent variable "attitude toward science learning" of the study population. Adele E. Gottfried, who developed this instrument, is a noted researcher in the area of "intrinsic motivation of children to learn." Published by Psychological

Assessment Resources, Incorporated (1986), CAIMI is designed "to measure enjoyment of learning", in grades four through eight (Gottfried, 1986, p. 5). As defined earlier within the Definition of Terms section of Chapter 1, science attitude, or one's state of mind, feeling, or disposition towards the discipline of science and science learning, is considered to be synonymous with one's "enjoyment of learning" in the area of science and can, therefore, be measured by CAIMI.

The documentation of this test was thoroughly reviewed to determine whether adequate levels of reliability and validity existed as a basis for selecting this instrument for use in the study. The selection was made based on resultant high reliability and validity levels and because it is a readily available tool for measuring attitudinal data specifically "in the subject areas of reading, math, social studies, and science" (Gottfried, 1986, p. 5). The CAIMI also is administered easily to groups of elementary students. Data concerning the reliability and validity of this instrument is presented in Chapter 4: Data Presentation and Findings.

Description of the Children's Academic Intrinsic Motivation Inventory

CAIMI is divided into subject area subscales for "Reading," "Math," "Social Studies," and "Science." A fifth subscale also indicates a general measure of school motivation/attitude. Each subject area subscale contains 26 items and the "General Motivation" subscale includes 18 items. Twenty-four of the 26 items in each subscale are answered using a five-point Likert scale ranging from strongly agree to strongly disagree (with an equal number of items from both a positive and negative orientation).

The other two items require a choice between an intrinsic and non-intrinsic response. The instrument is designed to be administered to groups or individuals.

Administration of the Children's Academic Intrinsic Motivation Inventory

Student attitude toward science learning, prior to treatment, was established by pre-testing the students early during treatment using the CAIMI "Science" subtest. The same instrument was administered to the students in each of the classrooms by the researcher as a post-test at the end of the school year following treatment.

Selection of the Inventory of Piaget's Developmental Tasks

The dependent variable, level of cognitive development of the students, was measured using the Inventory of Piaget's Developmental Tasks (IPDT), which is designed to establish the Piagetian level of cognitive development of subjects who are eight years of age or older (Furth, 1970). This measure is accomplished through the translation of "some of Piaget's concrete and formal operational tasks into an objective, quick, standardized paper-and-pencil format requiring minimal reading ability" (Patterson & Milakofsky, 1980, p. 342).

The documentation of this test was reviewed thoroughly to determine whether adequate levels of reliability and validity existed in support of its selection for use in the study. The selection was based on resultant high reliability and validity levels and because it is an easily administered tool for use with groups of elementary students. In addition, it does not call upon high levels of reading ability. Data and discussion defending the reliability and validity of this instrument are presented in Chapter 4: Data Presentation and Findings.

Description of the Inventory of Piaget's Developmental Tasks

The IPDT consists of 18 sets of tasks, each with a subtest of one example and four multiple-choice questions. The resulting 72 items cover the following five problem areas: (a) conservation (four subtests); (b) images (four subtests); (c) relations (three subtests); (d) classification (three subtests); and (e) laws (three subtests). This instrument was designed for individual or group administration and is untimed (Furth, 1970).

Administration of the Inventory of Piaget's Developmental Tasks

The IPDT was administered to the students in the comparison groups by the researcher as a pre-test early in the school year during which the treatment was given. The same instrument was administered as a post-test in the same school year.

Description of the Background Survey

An informal background survey (Appendix B) was given to each of the participating classroom teachers. This survey contained seven questions designed to gather relevant information on the level of their professional experience. Included were questions about the number of years of science teaching experience and how long they had been using computers and other technological resources in instruction. The teachers also were asked to provide self-ratings, using a five-point Likert scale, concerning their abilities and attitudes related to teaching science and to using computers and other technological instructional tools.

This data was collected to establish whether significant differences in the level of experience, abilities, and attitudes among the classroom teachers within each of the three groups were present. This procedure was employed to account for possible extraneous variables resulting from extreme differences in the instructional treatments delivered by individual teachers with significantly different experiential, knowledge, and attitudinal backgrounds. The results of this survey of classroom teachers within each of the three treatment groups is included in Chapter 4: Data Presentation and Findings.

Administration of the Background Survey

The background survey, used to gather data about the experience, ability, and attitudes of the classroom teachers, was administered by the researcher early in the school year in which the study occurred.

Method of Analyzing Student Scores

A series of General Linear Models (GLM's) was utilized to compare statistically the post-test data collected for each of the dependent variables across the three student study groups. The GLM statistic was chosen due to its ability to control for pre-existing differences of significance with regard to the dependent variables (as indicated by pre-test data collected) inherent among more than two comparison groups of unequal subjects prior to treatment (MiniTab Users Guide 2: Data Analysis and Quality Tools Release 12 for Windows, 1998).

Method of Analyzing Teacher Scores

The data collected from the background survey was analyzed using the non-parametric statistic Kruskal-Wallis ANOVA. This statistic was chosen due to its ability to compare data collected from more than two groups (Wolpert, 1991). The analysis and results are presented in Chapter 4: Data Presentation and Findings.

Procedure

Types of Science Instruction

As stated earlier in the Study Population section of this chapter, the fifth-grade students utilized for this study were placed into three non-randomly-selected, intact grade-level groups based upon the type of science instruction they received. The approach to science instruction, for each of the three groups, emphasized a textbook-based treatment or combinations of a computer-based and textbook-based treatment for varying proportions of time.

Textbook-Based Science Instruction

The textbook approach to instruction used for varying proportions of time by each of the three groups utilized Discover the Wonder (Heil et al., 1993). Although a textbook, Discover the Wonder contains hands-on activities that are designed to have students “construct their own explanations, solutions, and understandings” (Heil et al., 1993, p. FM3). The authors state that “traditional scientific methods and practices are still evident”, presenting students with a question, problem, or discrepant event that leads to gathering information from the text and formulating and testing hypotheses in order to provide explanations, solutions, and conclusions (Heil et al., 1993, p. FM3).

The authors of Discover the Wonder also claim that their approach to instruction emphasizes the development of scientific literacy and decision-making skills through the interface of Science, Technology, and Society (STS). They state that students are guided towards making conceptual "connections between science and the world we live in ... where they [students] use their science knowledge and ways of thinking for individual, social, and environmental concerns" (Heil et al., 1993, p. FM3). The textbook is organized into six thematic modules, each of which consists of three chapters addressing subtopics that relate to the theme of the module.

The formal professional training of teachers for the implementation of this text-oriented program consisted of two optional, six-hour long in-service days held during the summer of its adoption. As an elementary teacher in the district at that time, the researcher was a participant in this staff development. In his professional judgment, none of the training focused upon the skills necessary for teachers to learn how to teach emphasizing hands-on science instruction, or the reasoning behind STS or other integrated models for science instruction. The probability is great, therefore, that without additional well-structured, special professional training, the elementary teachers involved in this study teach science as they have always taught it: as a textbook-based approach. This approach leads to students gaining information through reading the science textbook and listening to lectures given by the teacher.

While computerized instructional tools also were available as ancillary components of the Discover the Wonder program, these tools were not included in the "basic package" purchased by the school district and, therefore, were not used in this study.

Computer-Based Science Instruction

The computer-based science instruction treatment utilized is called The Voyage of the Mimi (The Bank Street College of Education, 1984). The creators of this science instructional approach assert that it integrates science concepts with language arts, mathematics, and social studies through a multimedia combination of computer software, videodiscs, videotapes, and printed materials recommended for upper-elementary and junior-high school students (grades four through eight), utilizing the topic of "whales" as a research basis for the science program.

The authors of The Voyage of the Mimi claim that "traditional boundaries" of scientific disciplines are broken down in favor of a language-based, interdisciplinary focus upon "real world phenomena and on those aspects of the scientific enterprise which are common to its various parishes" (The Bank Street College Project in Science and Mathematics, 1984, p. iii). Scientific topics incorporated into The Voyage of the

Mimi include biological adaptation and survival, the food chain, interdependence of species, navigation, and meteorology.

Each "Learning Module" of The Voyage of the Mimi incorporates computer technology as a "centerpiece" of the "exploration" to be conducted (The Bank Street College Project in Science and Mathematics, 1984, p. iv). The forms of computer-based instruction included are computer simulations and modeling, microcomputer-based laboratory data collection and analysis, and interactive videodiscs. The authors of The Voyage of the Mimi emphasize, more than once within the documentation accompanying the program, that the computer applications are used instructionally for the teaching of scientific and other multidisciplinary concepts and "exemplify ways ... computer technology is reshaping our understanding of our world and the ways we represent it to ourselves," arguably one of the key goals of science itself (The Bank Street College Project in Science and Mathematics, 1984, p. IV).

The content of each of the four "Learning Modules" of The Voyage of the Mimi revolve around microcomputer-based instruction as indicated below:

1. "Introduction to Computing"-Seven computerized "games" incorporate programming activities utilizing a language similar to Logo that is designed to develop geometry, problem solving, and computer programming skills.

2. "Maps and Navigation"-Three computerized instructional activities designed to build basic map skills are then applied in a computer simulation where student teams must use their science, mathematical, and navigational knowledge to help save a humpback whale caught in the net of a fishing trawler.
3. "Ecosystems"-Two computerized simulations presenting information related to ecosystems allow students to observe the results caused by changes in the populations of plant and animal species in a "balanced" ecosystem and develop an understanding of the interdependence amongst humans, plants, and animals inhabiting our world.
4. "Whales and Their Environment"-Hands-on, microcomputer-based laboratory activities involve students in the collection of data about temperature, light, and sound in order to test hypotheses "related to physical phenomena that effect the lives and environment of whales" (Rathje, 1986. p. 55).

Science Instruction Treatment-Mixed (A)

As summarized in Table 2, the science instruction treatment for the four fifth-grade classrooms comprising the comparison group at School A was primarily textbook-based instruction in conjunction with one portion of the computerized approach. Therefore, this comparison group is referred to as the Mixed (A) group.

Table 2. Comparison of Treatments for Each of the Groups Involved in Each Type of Instruction

Treatment Characteristic	Study Population by Group Involved in Each Type of Instruction		
	Mixed (A)	Non-Traditional, Technology-Based (B)	Traditional, Textbook-Based (C)
School	A	B	C
Number of Classrooms Included in Each Group	4	4	3
Percent of Science Instruction: Traditional, Textbook-Based-Discover the Wonder	93	63	100
Percent of Science Instruction: Non-Traditional, Technology-Based-The Voyage of the Mimi	7	37	0
Used Hands-On, MBL* Component of The Voyage of the Mimi	Yes**	Yes**	No**
Used Videodisc Component of The Voyage of the Mimi	No**	Yes**	No**
Used Simulations Components of The Voyage of the Mimi	No**	Yes**	No**
Used Multidisciplinary Components of The Voyage of the Mimi	No**	Yes**	No**
Attended MimiFest Field Trip	No**	Yes**	No**

*MBL=microcomputer-based laboratory
**Group involved or not

The computer-based portion of the treatment for Mixed (A) consisted of engaging the subjects in the "hands-on," microcomputer-based laboratory (MBL) component of The Voyage of the Mimi, entitled "Whales and Their Environment". As presented in Table 2, no other components of the computer-based instructional program were used with group.

According to the science curriculum approved by the school district, 105 hours of science instruction is scheduled during the fifth-grade school year through four 45-minute periods per week over the length of 140 days. The MBL instructional component of The Voyage of the Mimi was utilized for 7 percent of the yearly time for science (7 hours out of 105 total science hours). This measurement, based upon researcher observations, is presented within Table 2.

The delivery of this portion of the instructional treatment for Mixed (A) was accomplished on a class-by-class basis. Seven one-hour sessions were conducted with one MBL experiment on temperature, sound, or light concepts from the "Whales and Their Environment" portion of The Voyage of the Mimi forming the basis for instruction. All seven experiments were chosen collaboratively by the researcher and the classroom teachers to ensure that the concepts being emphasized were among those included within the fifth-grade science curriculum approved by school district. These experiments were conducted with each of the four classrooms in Mixed (A) between February and April of the 1995-96 school year.

During these sessions, the students in each classroom were divided into four consisting of one microcomputer connected to temperature, sound, or light probes through an interface module.

Two "Technology Assistants", employed by the school district, were trained by the researcher, who is a "Technology Specialist" in the district, in the technical use of the MBL resources from "Whales and Their Environment". The researcher conducted this training because he was the only "Technology Specialist" in the school district with expertise in the use of these MBL tools.

Researcher bias was reduced by confining the training to the technical use of the MBL interface, probes, and software. The instructional approach behind the integration of these resources into the experiments conducted was not addressed by the researcher in this training. The "Technology Assistants" followed the instructional procedure outlined in the teacher materials for "Whales and Their Environment". The training consisted of an initial four-hour session two weeks prior to the first classroom experiment and six subsequent sessions lasting between 30 minutes and one hour approximately two to three days before each subsequent activity.

The two "Technology Assistants", when instructing, presented an overview of the entire activity to the students and generated hypotheses to be tested. The students then would divide into four groups to conduct the experiment with the two "Technology Assistants" and the classroom teacher moving among the four groups to guide them. At the end of the session, the "Technology Assistants" would again bring the classroom together to share the data and results collected by each group, reject or accept the hypotheses, and draw conclusions.

Seven experiments involved all students in Mixed (A), with inclusion of MBL experiences. The first two of the seven activities were "Experiment 2-T: Comparing Fahrenheit and Celsius" and "Experiment 4-T: Testing Insulators" from the "Whales and Their Environment" learning module of The Voyage of the Mimi. These two experiments both involved the use of temperature probes in learning about the measurement of temperature using the Fahrenheit and Celsius scales and the difference between conductors and insulators.

The third, fourth, and fifth sessions involved students in "Experiment 3-S: Humming a Graph of Loudness", "Experiment 5-S: Higher and Lower-Changing the Frequency of Sound", and "Experiment 7-S: Frequency and Loudness". These experiments addressed the loudness and frequencies of sound and how they are related.

The final two sessions involved students in "Experiment 1-L: Exploring Light Levels" and "Experiment 3-L: Spreading Light". These activities involved students in exploring the relationship among illumination, distance, and the brightness of light.

By subtracting the number of hours utilized for the MBL instructional component of The Voyage of the Mimi from the total annual instructional time scheduled for fifth-grade science in the district, the time accounted for by use of the textbook-based instructional program was determined to be approximately 93 percent (98 hours out of 105 total science hours). This information also is presented in Table 2.

This textbook-based portion of the instructional treatment was delivered exclusively by each of the four individual classroom teachers.

Science Instruction Treatment-Non-Traditional, Technology-Based (B)

As summarized in Table 2, science instruction for the four fifth-grade classrooms comprising the comparison group at School B was based more on the implementation of a greater number of components from the interdisciplinary, computer technology-based instructional program The Voyage of the Mimi. Therefore, this comparison group is referred to as Non-Traditional, Technology-Based (B).

As presented in Table 2, components from The Voyage of the Mimi comprised 39 of 105 hours of science instruction, or approximately 37 percent of the annual instructional time allotted for fifth-grade science for Non-Traditional, Technology-Based (B). Twenty-two 90- to 105-minute sessions were conducted (mostly on Friday afternoons) between January and June of the 1995-96 school year with various activities from The Voyage of the Mimi forming the basis for instruction. These measurements were based upon researcher observation.

The delivery of The Voyage of the Mimi portion of the instruction for Non-Traditional, Technology-Based (B) occurred by teaming the four classroom teachers, the two "Technology Assistants" also utilized with Mixed (A), and a second "Technology Specialist" (not the researcher) employed by the school district.

During the activity sessions, the Non-Traditional, Technology-Based (B) students and all other fifth-grade students at the school were divided into four heterogeneous groups of equal size with approximately 22 students. Four stations were created, each centering around a learning activity from The Voyage of the Mimi based upon one of the following four curricular themes: (a) science, (b) technology, (c) language arts, and (d) research. Each of the four classroom teachers selected to be responsible for one of these stations which included planning the learning activities implemented throughout the 22 sessions. The "Technology Specialist" worked closely with the teacher responsible for the "Technology" station and the two "Technology Assistants", along with other school district personnel such as the school librarian, served as resources in implementing the activities occurring at the other stations, on an "as needed" basis.

During these instructional sessions, the four groups of students were cycled through the four thematic stations. Each activity lasted from 20 to 30 minutes. The 13 videodisc "episodes" relaying the story and adventures of the whale research vessel "Mimi", upon which the instructional program The Voyage of the Mimi is based, were shown on a classroom-by-classroom basis by each of the teachers during the week prior to the activity session. The accompanying videodisc "expeditions" to various museums, laboratories, institutes, and on-site locations to meet with "real-life" scientists and researchers, which are a major part of The Voyage of the Mimi, also were shown separately by each classroom teacher in conjunction with the relevant "episode".

Examples of the activities from The Voyage of the Mimi conducted during the "Science" portion of the sessions include the same seven MBL temperature, sound, and light experiments from the "Whales and Their Environment" learning module which were completed with Mixed (A). The same two "Technology Assistants" who provided this portion of the treatment for Mixed (A) did so with Non-Traditional, Technology-Based (B), utilizing the same instructional methodology and strategies with the same technological resources. The main difference in the delivery of this instructional treatment was due to the fact that only 30 minutes of time was allotted for each experiment with Non-Traditional, Technology-Based (B) whereas one hour was available for Mixed (A). While the students in Non-Traditional, Technology-Based (B) were able to successfully complete the experiments during the allotted period, noticeably less time was available for pre-discussion and hypothesis (hypotheses) generation along with significantly decreased post-discussion of data collected and conclusions drawn.

In another science activity, from The Voyage of the Mimi, the students create a concrete representation of a food chain. Using index cards and string, each subject took on the identity of a plant or animal within specified ecosystems. The students were then responsible for using research resources made available by the teacher for deciding what other plants and/or animals in the ecosystem they ate or by which they were eaten. String was then used to create physical connections between those animals and/or plants. In this way, the students were supported in visualizing the complexity of the food chain within each ecosystem and in appreciating the interdependence of species of animals and plants.

Activities for the "Technology" component of the sessions were directly from the "Introduction to Computing", "Maps and Navigation", and "Ecosystems" computer modules of The Voyage of the Mimi. The students also utilized a commercial multimedia authoring application, HyperStudio (Wagner & O'Keefe, 1995), to create an interactive presentation on whales utilizing information gathered throughout the "Research" oriented activity sessions.

Examples of "Language Arts" activities from The Voyage of the Mimi, conducted during the sessions comprising this portion of the instructional treatment for Non-Traditional, Technology-Based (B), included the creation of nautical journals documenting the passage of the whale research vessel "Mimi". Students experienced journalistic writing as they developed "newspapers" informing their parents about the whale research being conducted and the adventures encountered by the crew of the "Mimi". Folk songs and sea chanties were studied and composed. Students learned the American Sign Language and Morse Code alphabets. Opportunities for public speaking, debating, and poetry writing also were provided.

Finally, the major focus of the "Research" component of The Voyage of the Mimi consisted of an in-depth study of the scientific order "Cetacea", which includes marine mammals such as whales, dolphins, and porpoises. Many students decided to zero their study onto the different species of whales, such as the beluga, right, sperm, narwhal, blue, gray, and humpback. Information regarding the physical characteristics, behavioral attributes, geographic locations, and nutritional needs and preferences of these animals was collected via the Internet and CD-ROM encyclopedias, including Encyclopedia of Science (Dorling Kindersley Multimedia, Incorporated, 1996); First Connections: The Golden Book Encyclopedia (Jostens Learning Corporation, 1995);

and The 1996 Grolier Multimedia Encyclopedia (Grolier Interactive, Incorporated, 1995); hard copy references (encyclopedias, magazines, journals, and books); as well as through interactions and conversations with scientists and researchers in the field of marine biology. This "Research" experience culminated in a variety of student projects, such as written research reports and interactive, computerized multimedia presentations created through the use of HyperStudio.

These "Research" oriented activities led to other avenues of exploration, such as a study of ocean pollution and the development of potential solutions and an investigation into laboratories surrounded by water, where scientists lived for weeks at a time to conduct experiments.

Also included in the computerized science instructional treatment for the students in Non-Traditional, Technology-Based (B) was a five-hour field trip to Penn's Landing in Philadelphia, PA for the event known as MimiFest. For this field trip, the students were divided into groups of approximately 30 to 35. Each group then cycled through a series of five learning activities emphasized in The Voyage of the Mimi. These learning activities, sponsored and presented by local museums and educational institutions, such as The Franklin Institute, The Academy of Natural Sciences, and The Maritime Museum, included, for example, exploring a portable planetarium, touring a vintage World War II submarine, and viewing a variety of sea animals and plants. This field trip took place in April of the 1995-96 school year.

By subtracting the number of hours utilized for the components of The Voyage of the Mimi from the total annual instructional time scheduled for fifth-grade science in the district, the use of the textbook-based instructional program was determined to be 63 percent of the time for science (66 hours out of 105 hours). This information also is presented in Table 2. As was the case with Mixed (A), the textbook-based portion of the instructional treatment for Non-Traditional, Technology-Based (B) was delivered exclusively by each of the four classroom teachers.

Science Instruction Treatment-Traditional, Textbook-Based (C)

As summarized in Table 2, the science instruction treatment for the three fifth-grade classrooms comprising the comparison group at School C completely relied upon utilization of the Discover the Wonder textbook-based instructional program. Therefore, this comparison group will be called Traditional, Textbook-Based (C).

As presented in Table 2, the textbook-based instructional program accounted for 100 percent of the 105 hours of instructional time scheduled for fifth-grade science during the 1995-96 school year. As was the case with Mixed (A) and Non-Traditional, Technology-Based (B), the textbook-based portion of the instructional treatment was delivered exclusively by each of the three classroom teachers.

Limitations of the Design

The principal limitation of the design of this study was imposed by the use of non-random, intact grade-level/classroom groups of students. This limitation introduced the potential for initial pre-existing differences among the students in the groups with regard to the dependent variables as well as other extraneous variables threatening the validity of the study.

Statistical controls for this limitation were incorporated into the design of the study. These controls incorporated the use of the fourth-grade MAT7 Science, Reading/Language, and Thinking skills scores and the CAIMI and IPDT pre-test scores to establish baseline, or pre-treatment, levels for each of the variables analyzed during this research. Use of these statistical controls will be detailed in Chapter 4: Data Presentation and Findings.

Another control incorporated into the design of the research was the use of the background survey given by the researcher to each of the classroom teachers to gather relevant information on the level of experience, ability, and attitudes relating to the teaching of science and the use of computers and other technological instructional tools. The data collected was used to establish the existence of a similar level of experience, ability, and attitudes among the classroom teachers within each of the three groups.

The results of this research are generalizable to comparable affluent, technology-rich schools across the country with similar student/teacher populations characterized by socioeconomic status, national and state standardized test scores, and per pupil expenditures which are all above state and national norms. This generalizability is strengthened by the controls built into the design of the study presented previously.

CHAPTER 4

DATA PRESENTATION AND FINDINGS

Introduction

This chapter presents analyses of the data gathered following the procedure described in Chapter 3, as well as the associated findings. The chapter is divided into the following sections: Reliability and Validity of the Instruments, Changes to the Study Population, Analysis of the Student Data, and Analysis of Data Related to Teachers' Backgrounds. The final section, Summary of Findings, summarizes the major outcomes of the data analysis.

Reliability and Validity of the Instruments

Reliability of the Metropolitan Achievement Tests, Seventh Edition

The Metropolitan Achievement Tests, Seventh Edition (MAT7) and the MAT7 Short Form have undergone rigorous editorial revisions to assure that they emphasize content accuracy, measurability, and equity. A "National Item Tryout" also had been conducted to establish appropriate levels of item difficulty; the ability of items to differentiate among students with varying levels of achievement; and the degree to which the item "distracters" divert students who lack the knowledge necessary to correctly respond to the items (The Psychological Corporation, 1993, p. 8).

The "National Research Programs" for the MAT7 and the MAT7 Short Form established normative data regarding the instrument relative to the overall "achievement in the nation's schools" and provided statistical information on the reliability and validity of these tests (The Psychological Corporation, 1993, p. 9). Stratified random samples were utilized for the standardization of the MAT7 and MAT7 Short Form in order to ensure that the groups tested accurately represented the nation's school population in terms of ethnicity, socioeconomic status, urbanicity, as well as other significant variables.

As stated in Chapter 3, initial student science achievement, language development, and critical thinking skills data was collected prior to treatment for each of the three comparison groups using the results from the full-length battery of the Elementary 2 (fourth-grade) level of the MAT7. The reported reliability data for the relevant portions of this instrument is indicated in Table 3.

The “Reading,” “Language,” and “Thinking Skills” sections of the MAT7 Short Form were utilized as a post-test to collect data following the treatment. The reported reliabilities for these sections are indicated in Table 4.

The MAT7 Short Form used, at the fifth-grade level, did not include a science achievement section. Therefore, the fifth-grade “Science” test from the full-length battery of the MAT7, Form S, was utilized. The reported internal consistency reliability for this portion of the test was 0.84, determined using the Kuder-Richardson Formula #20. The alternate-forms reliability was reported as 0.75 (The Psychological Corporation, 1993).

Table 3. Data Related to Reliability for the Components of Metropolitan Achievement Tests, Seventh Edition (MAT7), Elementary 2 (Fourth Grade), Form S

Section Names	Internal Consistency Reliability-Kuder-Richardson Formula #20	Alternate-Forms Reliability
Science	0.82	0.75
Reading Vocabulary	0.87	0.83
Reading Comprehension	0.94	0.85
Total Reading	0.95	0.90
Prewriting	0.73	0.60
Composing	0.74	0.68
Editing	0.85	0.74
Total Language	0.91	0.81
Thinking Skills	0.93	Not Reported

Table 4. Internal Consistency Reliability Data (Kuder-Richardson Formula #20) of the Metropolitan Achievement Tests, Seventh Edition, Short Form (MAT7), Intermediate 1 (Fifth Grade)

	Titles of Sections of the Test		
	Reading	Language	ThinkingSkills
Reliability	0.89	0.84	0.87

Validity of the Metropolitan Achievement Tests, Seventh Edition

The content validity of each section of the MAT7 and the MAT7 Short Form was ensured through the following validation process:

1. Item development was based upon extensive analysis of "the most recent editions of the major textbook series in every subject area, the most recent state and district school curricula and educational objectives, and the most important trends and directions in education according to national professional organizations" (The Psychological Corporation, 1993, p. 7).
2. Item appropriateness was demonstrated through representative student performance during extensive development research.
3. Objectives were validated as matching those currently being emphasized by schools based upon input from administrators, curriculum specialists, teachers, parents, and students from across the nation.

The criterion-related validity of the full-length battery of the MAT7 was confirmed through intercorrelations with the Metropolitan Achievement Tests, Sixth Edition, or the MAT6 (Prescott et al., 1986). The comparison between the MAT7 and the MAT6 was conducted through an "equating study ... to determine comparable scores for the two editions" (The Psychological Corporation, 1993, p. 12). While exact numerical results of this study were not reported in the MAT7 Multilevel Norms Book, the written explanation regarding this information indicated that acceptable levels of correlation between the content area components of the two instruments were noted.

The criterion-related validity of the MAT7 Short Form also was confirmed through intercorrelations with the reliability and item difficulty values of the full-length battery of the MAT7 itself and the Otis Lennon School Ability Test, Sixth Edition (OLSAT). The comparison between the MAT7 Short Form and the OLSAT total scores yielded a positive correlation of 0.78 (The Psychological Corporation, 1994).

Reliability of the Children's Academic Intrinsic Motivation Inventory

As stated in Chapter 3: Methodology, the Children's Academic Intrinsic Motivation Inventory (CAIMI) was used to determine the dependent variable "attitude toward science learning" of the students in the study population. Three major studies covering a period of six years served as the developmental backdrop for the CAIMI.

In the first study, a group of sixty items was analyzed for internal consistency using the Coefficient Alpha for each of the subscales. The second study attempted to increase this internal consistency through the addition of items consistent in nature with those found to be reliable in the first study. The reliability data gained was replicated in the third study.

A panel of elementary and junior high school teachers also reviewed the wording of the items "to ensure the appropriateness of vocabulary and syntactic constructions" (Gottfried, 1986, p. 12). The reported reliabilities of the CAIMI are indicated in Table 5.

Table 5. Reliability Data for the Children's Academic Intrinsic Motivation Inventory (CAIMI) "Science" Subscale

	First Study	Second Study	Third Study
Internal Consistency Reliability	Not Reported	0.90	0.91
Test-Retest Reliability	0.66-0.76	0.69-0.75	Not Reported

The average intercorrelation between the subscales of the CAIMI of 0.39 indicated that each subscale measured "variance unique to each separate area" (Gottfried, 1986, p. 12). A multivariate analysis of group differences resulting from grade, sex, or race indicated no significant differences based on gender or race. Grade differences did exist in the first and second studies with "Reading" motivation significantly decreasing with advancing grades. Grade differences also were noted in the first and third studies with "Social Studies" motivation significantly increasing with advancing grades.

Validity of the Children's Academic Intrinsic Motivation Inventory

The construct validity of the CAIMI was established through its development based upon "theoretical foundations of academic intrinsic motivation" (Gottfried, 1986, p. 13). Criterion-related validity was demonstrated through correlations between the CAIMI and established research instruments used to concurrently measure related variables. For instance, correlations between science anxiety (as measured by the Children's Academic Anxiety Inventory (Gottfried, 1982) and the "Science" subscale of the CAIMI produced results which were significant at either the 0.01 or 0.001 level for all three studies. Significant correlations also were noted between the CAIMI "Science" subscale and standardized science achievement results in the third study. An instrument developed by Harter (1981) for measuring children's intrinsic versus extrinsic motivational orientation in the classroom also correlated significantly with the CAIMI "Science" subscale on two out of the three subscales analyzed. Through the significance of these correlations between the CAIMI and other valid instruments, the validity of the CAIMI is implied.

Reliability of the Inventory of Piaget's Developmental Tasks

As stated in Chapter 3: Methodology, the dependent variable, level of cognitive development of the students, was measured using the Inventory of Piaget's

Developmental Tasks (IPDT). The IPDT has not been standardized and offers no norms for various age levels or socioeconomic groups. However, reliability and validity studies have been conducted by Patterson and Milakofsky (1980).

Reliability data for the IPDT was measured and presented in three different ways. Results from split-half reliabilities at the third and fifth-grade levels are indicated in Table 6. Test-retest reliability data from four groups of 19 or 20 subjects (two at third grade and two at sixth grade) also is shown in Table 6.

Table 6. Reliability Data for the Inventory of Piaget's Developmental Tasks (IPDT)

	Grade Levels		
	Third	Fifth	Sixth
Split-Half Reliability-Spearman-Brown Formula	0.71	0.63	Not Reported
Test-Retest Reliability-Pearson Product-Moment Correlation	0.87	Not Reported	0.40
	0.75		0.62

The final determination of reliability involved an Analysis of Variance (ANOVA) comparing the total IPDT "Group Test" and retest scores. The researchers reported that "a significant phase effect was found (F (1,120) = 6.242, $p < .02$)" with indications that the only significant difference in the test-retest scores occurred with one of the third-grade groups (Patterson & Milakofsky, 1980, p. 348). Patterson and

Milakofsky (1980, p. 348) concluded from these results that scores from the IPDT are "reasonably stable over a short period for a wide range of age groups" and "are not seriously affected by situational testing variables". They also indicated that this instrument has "considerable internal consistency and appears to be measuring a general lasting trait rather than a specific temporary trait" (Patterson & Milakofsky, 1980, p. 348).

Validity of the Inventory of Piaget's Developmental Tasks

The concurrent validity of the IPDT was assessed through an ANOVA of identical items on the "Individual" and "Group Tests." No differences of significance were found between the "Individual" and "Group Test" scores at any grade level ($p>0.20$).

The construct validity of the IPDT was backed by ANOVA's showing a significant grade effect in the mean scores attained by each group. This pattern of increasing mean scores on both the "Group" and "Individual Tests" as the grade level of the subjects increases was confirmed by the number of subtests mastered by a group. Following the criteria: 75 percent or more correct responses on a subtest being attained by 75 percent or more of a group, produced data that indicated that mastery increased with age. Major increments noted between the third, sixth, and ninth-grade groups were consistent with the Piagetian stages of cognitive development.

The IPDT group scores displayed significant correlations when compared with the results from other standardized instruments. For example, significant correlations were determined between the IPDT and the Iowa Test of Basic Skills at the third ($p<0.01$) and the sixth ($p<0.001$) grade levels. The IPDT also correlated significantly with the Lorge-Thorndike Intelligence Test for the sixth-grade groups.

Patterson and Milakofsky (1980, p. 349) summarized the general findings concerning the validity of the IPDT stating that it "basically shows the developmental progression of reasoning found by Piaget".

Reliability and Validity of the Background Survey

As stated in Chapter 3, the background survey, used to gather data about the experience, ability, and attitudes of the classroom teachers, was an informal instrument designed by the researcher. This instrument was validated by two university professors, who are experts in the field of science education.

Changes in the Study Population

Recall from Chapter 3 that 209 students comprised the initial study population. While administering the instruments, students, at times, were absent. Attempts were made by the researcher to test absent students by arranging to include them during administration of the instruments in another classroom within the same school. While successful in many cases, 11 students were absent for multiple days or were otherwise unavailable. Alternative times could not be planned.

Fourteen students were not enrolled in the school district during the school year prior to which the study was performed. Therefore, no fourth-grade MAT7 pre-test data was available for them. Two students moved from the district during the school year in which the study was implemented. The parent of one student included in the initial study population requested to have the student withdrawn from the study. Table 7 presents the major factors leading to exclusion of the 28 students due to attrition.

Table 7. Major Causes for Student Attrition from the Study Population

Causes for Student Attrition	Number of Students Involved
Not Enrolled in District in Fourth Grade/Lack of Fourth-Grade MAT7 Pre-Test Scores	14
Absent During Pre-Test and/or Post-Test Administration and Make-Up Sessions	11
Moved Out of District During Study Implementation	2
Parent Rescinded Permission for Participation During Study Implementation	1
Total	28

To ensure a consistent study population across all the variables of study, 181 students who were present for the administration of all the instruments were included within the final data analyses. The breakdown of the 181 students is indicated in Table 8.

Table 8. Make-Up of the Study Population Following Attrition

Comparison Groups	Number of Classes	Number of Teachers	Number of Students
Mixed (A)	4	4	66
Non-Traditional, Technology-Based (B)	4	4	61
Traditional, Textbook-Based (C)	3	3	54
Totals	11	11	181

Analysis of the Student Data

Introduction

As stated in Chapter 3, a series of General Linear Models (GLM's) was utilized to compare statistically the post-test data collected for each of the dependent variables across the three groups while controlling for pre-existing differences of significance with regard to the dependent variables (as indicated by pre-test data collected). The pre-test data, in this case, served as a covariate. As stated by Wolpert (1991, p. 220), "the results of the correlation analysis between the pretest and posttest will be used to adjust the posttest means so as to reflect the preinstruction differences which existed".

Establishing the Prerequisite Criteria for Use of Analysis of Covariance

To analyze data statistically using a form of Analysis of Covariance (ANCOVA), such as the GLM, three prerequisite criteria must be met. These criteria are (a) existence of a linear relationship between pre- and post-tests, (b) homogeneity of variance, and (c) homogeneity of slopes (MiniTab Users Guide 2: Data Analysis and Quality Tools Release 12 for Windows, 1998). The computerized statistics package, MiniTab Release 12 for Windows (MiniTab, Incorporated, 1998), was used to establish these prerequisite criteria for the data collected.

Criterion 1: Existence of a Linear Relationship Between Pre-Tests and Post-Tests

Pearson correlations of the pre-test and post-test data were conducted for each of the dependent variables to establish the existence of a linear relationship. The results of these correlations are presented in Table 9.

These correlations indicated a moderate to high positive linear relationship between the pre-test and post-test data for each of the dependent variables.

Criterion 2: Homogeneity of Variance

Using MiniTab Release 12 for Windows, Levene's tests were conducted for each of the dependent variables to establish homogeneity of variance. The results of these statistics are presented in Table 10.

Table 9. Pearson Correlations Between Pre-Test and Post-Test Data for the Dependent Variables (N=181)

Dependent Variables	Instruments	Pearson Correlations
Science Achievement	MAT7	0.610
Science Attitude	CAIMI	0.572
Critical Thinking	MAT7	0.712
Cognitive Development	IPDT	0.569
Language Development	MAT7	0.773

Table 10. Levene's Test P-Values for Homogeneity of Variance for the Dependent Variables (N=181)

Dependent Variables	Instruments	Levene's Test P-Values
Science Achievement	MAT7	0.001
Science Attitude	CAIMI	0.460
Critical Thinking	MAT7	0.496
Cognitive Development	IPDT	0.166
Language Development	MAT7	0.358

The resultant p-value of less than 0.05 for science achievement indicated that the variance among the post-test data across the comparison groups was significantly different, failing to satisfy the criterion for homogeneity of variance.

The researcher attempted to achieve homogeneity of variance for this variable by statistically transforming the post-test data using the log, natural log, square root, arcsin, and reciprocal functions. Homogeneity of variance still was not established through these transformations. Therefore, the researcher decided to remove scores statistically determined to be "outliers" from the post-test data to attempt to establish homogeneity of variance. This was accomplished by determining the means of the dependent variables and removing scores two standard deviations above or below these points. This process removed approximately 10 percent of the test scores as outliers, resulting in lowering the study population from 181 to 163. The breakdown of the resultant final study population is indicated in Table 11.

Pearson correlations of the pre-test and post-test data again were conducted with the final study population for each of the dependent variables to reestablish the existence of a linear relationship. The results of these correlations are presented in Table 12.

These correlations, again, indicate a moderate to high positive linear relationship between the pre-test and post-test data for each of the dependent variables.

Levene's Tests also were conducted again with the final study population for each of the dependent variables to establish homogeneity of variance. The results of these statistics are presented in Table 13.

Table 11. Final Study Population After Removal of Dependent Variable Outliers

Comparison Groups	Number of Classes	Number of Teachers	Number of Students
Mixed (A)	4	4	54
Non-Traditional, Technology-Based (B)	4	4	57
Traditional, Textbook-Based (C)	3	3	52
Totals	11	11	163

Table 12. Pearson Correlations Between Pre-Test and Post-Test Data for the Dependent Variables (N=163)

Dependent Variables	Instruments	Pearson Correlations
Science Achievement	MAT7	0.509
Science Attitude	CAIMI	0.527
Critical Thinking	MAT7	0.669
Cognitive Development	IPDT	0.541
Language Development	MAT7	0.700

Table 13. Levene's Test P-Values for Homogeneity of Variance for the Dependent Variables (N=163)

Dependent Variables	Instruments	Levene's Test P-Values
Science Achievement	MAT7	0.054
Science Attitude	CAIMI	0.945
Critical Thinking	MAT7	0.969
Cognitive Development	IPDT	0.158
Language Development	MAT7	0.427

The resultant p-values of greater than 0.05 for all the dependent variables indicate that the variance among the post-test data across the comparison groups was not significantly different, satisfying the criterion for homogeneity of variance.

Criterion 3: Homogeneity of Slopes

Again using MiniTab Release 12 for Windows, analyses were conducted for each of the dependent variables to establish homogeneity of slopes among the pre-test and post-test data. The results of these analyses are presented in Table 14.

The resultant p-values of greater than 0.05 for all the dependent variables indicate that the slopes of the pre-test and post-test data among the comparison groups were not significantly different, satisfying the homogeneity of slopes criterion.

Table 14. Homogeneity of Slopes P-Values for Pre-Test and Post-Test Data for the Dependent Variables (N=163)

Dependent Variables	Instruments	Homogeneity of Slopes P-Values
Science Achievement	MAT7	0.585
Science Attitude	CAIMI	0.352
Critical Thinking	MAT7	0.337
Cognitive Development	IPDT	0.663
Language Development	MAT7	0.500

The three prerequisite criteria for analyzing data statistically using a form of an ANCOVA, such as the GLM, were satisfied.

Analysis of the Student Data for the Dependent Variables

Descriptive Statistics

Analyses of data for the final study population were conducted by comparison group, using MiniTab Release 12 for Windows, for each of the dependent variables to obtain descriptive statistics for the pre-test and post-test data.

The results of these analyses for the pre-test data for the final study population are presented in Table 15. The results of the descriptive statistics analyses for the post-test data for the final study population are presented in Table 16.

Table 15. Descriptive Statistics for the Pre-Test Data for the Dependent Variables for the Final Study Population (N=163)

Descriptive Statistics	Dependent Variables (Instruments)				
	Science Achievement (MAT7)	Science Attitude (CAIMI)	Critical Thinking (MAT7)	Cognitive Development (IPDT)	Language Development (MAT7)
Means	26.88	97.80	63.19	43.42	108.82
Medians	27.00	100.00	64.00	44.00	112.00
Standard Deviations	3.86	15.28	9.67	10.10	16.79
Minimums	15.00	44.00	40.00	13.00	55.00
Maximums	34.00	122.00	78.00	67.00	133.00

Table 16. Descriptive Statistics for the Post-Test Data for the Dependent Variables for the Final Study Population (N=163)

Descriptive Statistics	Dependent Variables (Instruments) Science Achievement (MAT7)	Science Attitude (CAIMI)	Critical Thinking (MAT7)	Cognitive Development (IPDT)	Language Development (MAT7)
Means	29.69	94.40	23.56	46.62	47.52
Medians	30.00	97.00	24.00	47.00	49.00
Standard Deviations	5.55	15.81	4.21	11.56	6.58
Minimums	15.00	42.00	13.00	21.00	26.00
Maximums	39.00	124.00	30.00	71.00	59.00

The results of the descriptive statistics analyses for the pre-test data for Mixed (A) are presented in Table 17. The descriptive statistics for the post-test data for Mixed (A) are presented in Table 18.

The descriptive statistics for the pre-test data for Non-Traditional, Technology-Based (B) are presented in Table 19. The descriptive statistics for the post-test data for Non-Traditional, Technology-Based (B) are presented in Table 20.

The descriptive statistics for the pre-test data for Traditional, Textbook-Based (C) are presented in Table 21. The descriptive statistics for the post-test data for Traditional, Textbook-Based (C) are presented in Table 22.

Analysis of Data for Students' Science Achievement

A General Linear Model (GLM), using MiniTab Release 12 for Windows, was conducted to statistically compare the post-test data collected for student science achievement across the three comparison groups while controlling for pre-existing differences of significance with regard to the pre-test data collected. The pre-test data, in this case, served as a covariate. The results of this analysis are presented in Table 23.

The adjusted means for the science achievement post-test data for the comparison groups are as follows: (a) Mixed (A)-29.78; (b) Non-Traditional, Technology-Based (B)-30.34; and (c) Traditional, Textbook-Based (C)-28.87.

Table 17. Descriptive Statistics for the Pre-Test Data for the Dependent Variables for Mixed (A) (N=54)

Descriptive Statistics	Science Achievement (MAT7)	Science Attitude (CAIMI)	Critical Thinking (MAT7)	Cognitive Development (IPDT)	Language Development (MAT7)
	Dependent Variables (Instruments)				
Means	26.06	97.76	60.02	42.59	104.26
Medians	26.00	99.50	61.00	42.50	106.50
Standard Deviations	4.12	15.67	11.01	10.22	18.62
Minimums	15.00	58.00	40.00	13.00	55.00
Maximums	34.00	122.00	77.00	67.00	131.00

Table 18. Descriptive Statistics for the Post-Test Data for the Dependent Variables for Mixed (A) (N=54)

Descriptive Statistics	Science Achievement (MAT7)	Science Attitude (CAIMI)	Critical Thinking (MAT7)	Cognitive Development (IPDT)	Language Development (MAT7)
	Dependent Variables (Instruments)				
Means	29.17	93.22	23.28	47.26	47.32
Medians	31.00	94.50	24.00	48.50	47.00
Standard Deviations	6.12	16.03	4.43	10.57	6.28
Minimums	16.00	42.00	13.00	25.00	31.00
Maximums	38.00	124.00	30.00	65.00	59.00

Table 19. Descriptive Statistics for the Pre-Test Data for the Dependent Variables for Non-Traditional, Technology-Based (B) (N=57)

Descriptive Statistics	Dependent Variables (Instruments)				
	Science Achievement (MAT7)	Science Attitude (CAIMI)	Critical Thinking (MAT7)	Cognitive Development (IPDT)	Language Development (MAT7)
Means	26.96	98.58	64.11	44.49	109.89
Medians	28.00	99.00	65.00	46.00	113.00
Standard Deviations	3.77	16.01	8.31	9.59	15.11
Minimums	19.00	54.00	42.00	13.00	68.00
Maximums	33.00	121.00	78.00	67.00	133.00

Table 20. Descriptive Statistics for the Post-Test Data for the Dependent Variables for Non-Traditional, Technology-Based (B) (N=57)

	Dependent Variables (Instruments)				
Descriptive Statistics	Science Achievement (MAT7)	Science Attitude (CAIMI)	Critical Thinking (MAT7)	Cognitive Development (IPDT)	Language Development (MAT7)
Means	30.40	98.82	23.63	45.07	48.16
Medians	30.00	101.00	24.00	47.00	50.00
Standard Deviations	4.26	14.75	4.01	12.79	6.34
Minimums	20.00	69.00	15.00	21.00	33.00
Maximums	38.00	122.00	30.00	71.00	58.00

Table 21. Descriptive Statistics for the Pre-Test Data for the Dependent Variables for Traditional, Textbook-Based (C) (N=52)

Descriptive Statistics	Science Achievement (MAT7)	Science Attitude (CAIMI)	Critical Thinking (MAT7)	Cognitive Development (IPDT)	Language Development (MAT7)
	Dependent Variables (Instruments)				
Means	27.65	97.00	65.48	43.12	112.37
Medians	29.00	100.00	67.50	45.00	112.50
Standard Deviations	3.66	14.27	8.85	10.62	15.78
Minimums	17.00	44.00	42.00	16.00	67.00
Maximums	33.00	122.00	78.00	67.00	132.00

Table 22. Descriptive Statistics for the Post-Test Data for the Dependent Variables for Traditional, Textbook-Based (C) (N=52)

Descriptive Statistics	Science Achievement (MAT7)	Science Attitude (CAIMI)	Critical Thinking (MAT7)	Cognitive Development (IPDT)	Language Development (MAT7)
	Dependent Variables (Instruments)				
Means	29.44	90.77	23.77	47.65	47.02
Medians	29.00	93.50	25.00	47.00	48.50
Standard Deviations	6.17	15.87	4.25	11.26	7.19
Minimums	15.00	51.00	14.00	21.00	26.00
Maximums	39.00	123.00	30.00	69.00	59.00

Table 23. Analysis of Covariance of Data for Students' Science Achievement Across the Comparison Groups Through a General Linear Model with the Pre-Test Data Serving as Covariate (N=163)

Source of Variation	df Values	SS Values	MS Values	F Values	P Values
Science Achievement-Pre-Test (MAT7)	1	1305.29	1305.29	57.13	0.000
Comparison Group-Science Instruction Treatment	2	59.14	29.57	1.29	0.277
Error	159	3632.75	22.85		
Total	162				

*p<0.05
**p<0.01

The calculated p-value of greater than 0.05 across the comparison groups indicates that student science achievement is not significantly different as a result of the science instruction treatments.

Analysis of Data for Students' Attitude About Science Learning

A General Linear Model (GLM), using MiniTab Release 12 for Windows, was conducted to statistically compare the post-test data collected for students' attitude about science learning across the three comparison groups while controlling for pre-existing differences of significance with regard to the pre-test data collected. The pre-test data, in this case, served as a covariate. The results of this analysis are presented in Table 24.

The adjusted means for the attitude about science learning post-test data for the comparison groups are as follows: (a) Mixed (A)-93.25; (b) Non-Traditional, Technology-Based (B)-98.41; and (c) Traditional, Textbook-Based (C)-91.20.

The calculated p-value of less than 0.05 across the comparison groups indicates that students' attitude about science learning is significantly different as a result of the science instruction treatments.

A Tukey post hoc analysis was conducted, using MiniTab Release 12 for Windows, to determine which of the comparison groups are significantly different. The results of this analysis are presented in Table 25.

Table 24. Analysis of Covariance of Data for Students' Attitude About Science Learning Across the Comparison Groups Through a General Linear Model with the Pre-Test Data Serving as Covariate (N=163)

Sources of Variations	df Values	SS Values	MS Values	F Values	P Values
Science Attitude-Pre-Test (CAIMI)	1	10907.20	10907.20	62.54	0.000
Comparison Group-Science Instruction Treatment	2	1517.00	758.50	4.35	0.014*
Error	159	27731.60	174.40		
Total	162				

*$p<0.05$
**$p<0.01$

Table 25. Tukey Post Hoc Analysis of Data for Students' Attitude About Science Learning with 95 Percent Confidence Intervals (N=163)

Comparison Groups	Lower Bound	Upper Bound	Mean Differences	SE Values	Adjusted P Values
Mixed (A) Subtracted from Non-Traditional, Technology-Based (B)	-0.908	11.231	5.162	2.509	0.124
Mixed (A) Subtracted from Traditional, Textbook-Based (C)	-8.255	4.165	-2.045	2.566	1.000
Non-Traditional, Technology-Based (B) Subtracted from Traditional, Textbook-Based (C)	-13.340	-1.073	-7.207	2.535	0.015*

*$p<0.05$
**$p<0.01$

The results of the Tukey post hoc analysis met the 0.05 level of significance when statistically comparing the adjusted means of the attitude about science learning data for the students in the Non-Traditional, Technology-Based (B) group with those in the Traditional, Textbook-Based (C) group. This result indicates significant differences in positive attitude about science learning, favoring the group of students involved with the non-traditional, technology-based science instruction treatment compared to the attitude of students involved with the traditional, textbook-based science instruction treatment.

Analysis of Data for Students' Critical Thinking Skills

A GLM, using MiniTab Release 12 for Windows, was conducted to statistically compare the post-test data collected for student critical thinking skills across the three comparison groups while controlling for pre-existing differences of significance with regard to the pre-test data collected. The pre-test data, in this case, served as a covariate. The results of this analysis are presented in Table 26.

The adjusted means for the critical thinking skills post-test data for the comparison groups are as follows: (a) Mixed (A)-24.24; (b) Non-Traditional, Technology-Based (B)-23.35; and (c) Traditional, Textbook-Based (C)-23.07.

The calculated p-value of greater than 0.05 indicates that critical thinking skills development, across the comparison groups, is not significantly different as a result of this emphasis in science instruction.

Table 26. Analysis of Covariance of Data for Students' Critical Thinking Skills Across the Comparison Groups Through a General Linear Model with the Pre-Test Data Serving as Covariate (N=163)

Sources of Variations	df Values	SS Values	MS Values	F Values	P Values
Critical Thinking Skills-Pre-Test (MAT7)	1	1314.34	1314.34	134.91	0.000
Comparison Group-Science Instruction Treatment	2	37.36	18.68	1.92	0.150
Error	159	1548.99	9.74		
Total	162				

*p<0.05
**p<0.01

Analysis of Data Related to Students' Cognitive Level of Development

A General Linear Model (GLM), using MiniTab Release 12 for Windows, was conducted to statistically compare the post-test data collected for student cognitive development level across the three comparison groups while controlling for pre-existing differences of significance with regard to the pre-test data collected. The pre-test data, in this case, served as a covariate. The results of this analysis are presented in Table 27.

The adjusted means for the cognitive development post-test data for the comparison groups are as follows: (a) Mixed (A)-47.78; (b) Non-Traditional, Technology-Based (B)-44.39; and (c) Traditional, Textbook-Based (C)-47.85.

The calculated p-value of greater than 0.05 indicates that student cognitive development level across the comparison groups is not significantly different resulting from the computer-oriented emphasis in science instruction.

Analysis of Data for Students' Language Development

A General Linear Model (GLM), using MiniTab Release 12 for Windows, was conducted to statistically compare the post-test data collected for student language development across the three comparison groups while controlling for pre-existing differences of significance with regard to the pre-test data collected. The pre-test data, in this case, served as a covariate. The results of this analysis are presented in Table 28.

Table 27. Analysis of Covariance of Data for Students' Cognitive Level of Development Across the Comparison Groups Through a General Linear Model with the Pre-Test Data Serving as Covariate (N=163)

Sources of Variations	df Values	SS Values	MS Values	F Values	P Values
Cognitive Development Level- Pre-Test (IPDT)	1	6572.50	6572.50	69.82	0.000
Comparison Group- Science Instruction Treatment	2	431.40	215.70	2.29	0.104
Error	159	14967.40	94.10		
Total	162				

*$p<0.05$
**$p<0.01$

Table 28. Analysis of Covariance of Data for Students' Language Development Across the Comparison Groups Through a General Linear Model with the Pre-Test Data Serving as Covariate (N=163)

Sources of Variations	df Values	SS Values	MS Values	F Values	P Values
Language Development-Pre-Test (MAT7)	1	3582.10	3582.10	167.80	0.000
Comparison Group-Science Instruction Treatment	2	184.40	92.20	4.32	0.015*
Error	159	3394.10	21.30		
Total	162				

*$p<0.05$
**$p<0.01$

The adjusted means for the language development post-test data for the comparison groups are as follows: (a) Mixed (A)-48.62; (b) Non-Traditional, Technology-Based (B)-47.85; and (c) Traditional, Textbook-Based (C)-46.00.

The calculated p-value of less than 0.05 indicates that student language development across the comparison groups is significantly different resulting from the computer-oriented emphasis in science instruction.

A Tukey post hoc analysis was conducted to determine which of the comparison groups are significantly different. The results of this analysis are presented in Table 29.

The results of the Tukey post hoc analysis met the 0.05 level of significance when statistically comparing the adjusted means of the language development data for the students in the Mixed (A) group with those in the Traditional, Textbook-Based (C) group. This result indicates significant differences in the language development of the students in these groups, favoring the mixed technology-based and textbook-based science instruction treatment over the traditional, textbook-based science instruction treatment.

Analysis of Data Related to Teachers' Backgrounds

Introduction

As stated in Chapter 3, the data collected from the background survey, used to gather data about the experience, ability, and attitudes of the classroom teachers, was

Table 29. Tukey Post Hoc Analysis of Data for Students' Language Development with 95 Percent Confidence Intervals (N=163)

Comparison Groups	Lower Bound	Upper Bound	Mean Differences	SE Values	Adjusted P Values
Mixed (A) Subtracted from Non-Traditional, Technology-Based (B)	-2.912	1.377	-0.768	0.886	1.000
Mixed (A) Subtracted from Traditional, Textbook-Based (C)	-4.827	-0.398	-2.612	0.915	0.015*
Non-Traditional, Technology-Based (B) Subtracted from Traditional, Textbook-Based (C)	-3.993	0.303	-1.845	0.888	0.118

*$p<0.05$
**$p<0.01$

analyzed using the non-parametric statistic Kruskal-Wallis ANOVA. This statistic was chosen due to its ability to compare data collected from more than two groups.

Analysis of the Background Survey Data

Using MiniTab Release 12 for Windows, a series of Kruskal-Wallis ANOVA's were conducted, for the seven questions related to the teacher background survey yielding data, to determine if significant differences in the level of professional experience existed among the teachers in the comparison groups. The results of these analyses are presented in Table 30.

The resultant p-values of greater than 0.05, for responses to each of the seven questions on the teacher background survey, indicate that significant differences with regard to the level of teaching experience, abilities, and attitudes do not exist among the teachers across the comparison groups.

Summary of Findings

The above analysis of the students' data indicates the following significant differences: (a) increased attitude toward science learning favoring students who received the non-traditional, technology-based science instruction treatment over those receiving the traditional, textbook-based science instruction treatment; and (b) increased level of language development favoring the students receiving the mixed technology-based and textbook-based science instruction treatment over those receiving the traditional, textbook-based science instruction treatment.

Table 30. Kruskal-Wallis Analyses of Variance of Teacher Background Data (N=11)

Question Topic-#	df	H	P
Number of Years of Teaching Experience-#1	2	3.27	0.195
Number of Years of Science Teaching Experience-#2	2	2.18	0.335
Number of Years of Teaching Experience Using Computers and Other Technological Resources-#3	2	2.11	0.348
Ability to Teach Science-#4	2	2.44	0.295
Ability to Use Computers and Other Technological Resources-#5	2	3.20	0.202
Attitude toward Science Teaching-#6	2	0.18	0.916
Attitude toward the Use of Computers and Other Technological Resources-#7	2	3.58	0.167

*$p<0.05$
**$p<0.01$

No differences of statistical significance are indicated for students' science achievement, development of critical thinking skills, or level of cognitive development. Conclusions from these findings as well as discussion of their significance, or lack thereof, are presented in Chapter 5: Conclusions, Discussion, Implications, and Recommendations for Further Study.

CHAPTER 5

CONCLUSIONS, DISCUSSION, IMPLICATIONS, AND RECOMMENDATIONS FOR FURTHER STUDY

Introduction

This final chapter of the dissertation includes a summation of the problem that has been addressed in the research, as well as the procedure followed in addressing this problem. These two sections are followed by a statement of each conclusion made related to each of the research questions. The final sections consider implications from these conclusions, recommendations for further research, and a final statement.

Summary of the Problem and Procedure

The research reported herein examined the impact of emphasizing use of microcomputers as the major component of science instruction on student learning (as opposed to the more traditional textbook-centered emphasis). Learning included achievement in science, attitude toward science learning, critical thinking or inquiry skills development, level of cognitive development, and language development.

The study sample was a selected group of fifth-grade students from three school buildings in a suburban school district, divided into three groups, each receiving one of the following instructional treatments: (a) Mixed-instruction primarily based on the use of a hardcopy textbook in conjunction with computer-based instructional materials as one component of the science course; (b) Non-Traditional, Technology-Based-instruction fully utilizing computer-based material; and (c) Traditional, Textbook-Based-instruction utilizing only the textbook as the basis for instruction.

Students' science achievement, critical thinking or inquiry skills, and language development were determined through use of the Metropolitan Achievement Tests, Seventh Edition (MAT7). Students' attitude toward science learning was determined through use of the Children's Academic Intrinsic Motivation Inventory (CAIMI). The cognitive development level of students was determined through use of the Inventory of Piaget's Developmental Tasks (IPDT). Pre-test, or pre-treatment, data was collected at the beginning of the school year and post-test data was collected at the end of the school year. Statistical analyses of pre-test data were used as a covariate to account for possible pre-existing differences with regard to the variables examined among the three student groups.

Data, related to the nature of professional experiences of the teachers, involved in the study, were determined using a brief validated background survey instrument. Statistical analysis of the data from this survey was conducted to verify that differences in professional background did not vary significantly across these teachers. Background information was collected related to the extent of teaching experience, professional abilities, and attitudes related to teaching science and the use of technology-based instruction.

Conclusions

Findings from the study are summarized in Table 31 as they relate to each of the learning outcomes studied. The results for each of these learning outcomes are classified as significant or non-significant, resulting from the use of the computer-based instructional materials. Positive trends for these learning outcomes, resulting from the use of the computer-based instructional materials, also are indicated.

Table 31. Summary of Significance of Findings from the Study

Learning Outcomes	Findings		
	Significant	Non-Significant	Positive Trend
Science Achievement	No	Yes	Yes
Attitude Toward Science Learning	Yes	No	Yes
Critical Thinking-Inquiry	No	Yes	Yes
Cognitive Development Level	No	Yes	No
Language Development	Yes	No	Yes

Science Achievement

The adjusted means for the science achievement post-test data indicated that students in the Non-Traditional, Technology-Based group attained the highest science achievement scores (30.34), followed by students in the Mixed group (29.78). The lowest score of 28.87 was attained by the Traditional, Textbook-Based group of students. In spite of these decreasing scores and the associated positive trend resulting from the use of the computer-based instructional materials, the null hypothesis for the research question addressing students' science achievement failed to be rejected since no statistically significant differences were determined among the three groups.

Attitude Toward Science Learning

The adjusted means for the attitude toward science learning post-test scores indicated that students in the Non-Traditional, Technology-Based group displayed the most favorable attitude toward science learning (98.41), followed by a mean score of 93.25 for the Mixed group. The students in the Traditional, Textbook-Based group displayed the least favorable attitude toward science learning with a score of 91.20. The null hypothesis related to attitude toward science learning had to be rejected since analysis of data related this outcome indicated significant differences among students across the groups (p=0.014). The post hoc analysis indicated that students in the Non-Traditional, Technology-Based group displayed significantly increased favorable attitudes toward science learning compared to the students in the Traditional, Textbook-Based group.

Critical Thinking-Inquiry Skills

The adjusted means for the critical thinking-inquiry skills post-test data indicated that students in the two computer-based instruction groups, Mixed and Non-Traditional, Technology-Based, attained higher levels of critical thinking skills (24.24 and 23.35, respectively) compared to the 23.07 score attained by the Traditional, Textbook-Based group. In this case, the null hypothesis for the research question addressing students' critical thinking-inquiry skills failed to be rejected since no statistically significant differences in students' scores were found among the three student groups.

Level of Cognitive Development

The adjusted means for post-test scores related to level of cognitive development indicated that students in the Traditional, Textbook-Based and Mixed groups, exhibited similarly higher levels of cognitive development (47.85 and 47.78, respectively) than scores for students in the Non-Traditional, Technology-Based group. This group exhibited the lowest level of cognitive development (44.39). In this case, the null hypothesis for the research question addressing this learning outcome failed to be rejected since no statistically significant differences in scores were found across the student groups.

Language Development

The adjusted means for the language development post-test data indicated that students in the computer-based science instruction groups, Mixed and Non-Traditional, Technology-Based, displayed the highest levels of English language development (48.62 and 47.85, respectively), followed by the scores for the students in the Traditional, Textbook-Based group. This group displayed the lowest level of language development with a mean score of 46.00. Therefore, the null hypothesis related to English language development had to be rejected since analysis of the data related to this learning outcome indicated significant differences in mean scores among students in the three groups (p=0.015). The post hoc analysis indicated that students in the Mixed group displayed significantly higher levels of language development than students in the Traditional, Textbook-Based group.

Teachers' Professional Background

Analysis of the responses to the seven questions yielding data related to the professional background of the teachers involved in teaching the three groups of students indicated no significant differences in the level of professional experience, abilities, or attitudes about science teaching and extent to which they used computers in science instruction. This made it possible to conclude that differences in learning outcomes among the students in the three groups resulted from the approach emphasized in science instruction.

Table 32 (Appendix C) summarizes all of the above conclusions. Significant differences were found only in two of the learning outcomes, namely attitude toward science learning and English language development.

Discussion and Implications

Based upon the conclusions indicated in the previous section, the following implications are made. These are presented as they relate to the learning outcomes studied.

Science Achievement and Attitude Toward Science Learning

The similar positive trend, relating increased amounts of computer-based science instruction to increased test scores by students, that exists for the student learning outcomes of science achievement and attitude toward science learning supports the positive correlation between students' attitude about instruction and academic achievement reported by Oliver and Simpson (1988) in their study, reported in Chapter 2 of this dissertation. While this trend was significant only in the case of students' attitude toward science learning, the combined results indicate that increasing the amount of instructional time students are involved in meaningful computer-based science instruction over extended periods of time will result in more positive attitudes toward science learning, in turn, leading to increased science achievement.

The effectiveness of education in science in schools across America is presently a hotly contested issue. American students at the fourth, eighth, and twelfth grade levels generally have performed relatively poorly in science and math on an international level as reported by the Third International Mathematics and Science Study (TIMSS). A trend toward relative decreasing science achievement also was indicated in the TIMSS report, as American students progressed from the elementary school level to the secondary school level (Baker, 1997). These results raise questions surrounding the effectiveness of current approaches to science instruction, including emphasis on the traditional use of a single textbook.

The standards contained in the National Science Education Standards (National Research Council, 1996) call for non-traditional approaches to science instruction that are constructivist oriented, rather than the more traditional, behaviorist approach. These standards also state that the current modes of science instruction must "change emphases" to improve the science education system as a whole, including increased emphasis on "understanding and responding to individual students' interests, strengths, experiences, and needs" (1995, p. 52). The Voyage of the Mimi and other comparable science programs that are computer technology-based, appear to, at the very least, move toward accomplishing this "call", with a "change in emphasis" captured through the use of "several technologies" as instructional resources "to engage and hold students' interests" and produce an approach to science instruction that is "appropriate to the capabilities and interests of elementary school children" (The Bank Street College Project in Science and Mathematics, 1984, p. iii).

The appeal for the strengthening of science education is reflected in computer-based approaches to science instruction, exemplified by The Voyage of the Mimi curriculum, which, as a major component of American science education development, can help produce students with improved attitudes toward science learning, leading to higher levels of science learning and literacy that will better help them become productive members of an increasingly technological global society.

Critical Thinking-Inquiry Skills

Although not as significant as might be expected, the higher levels of development of critical thinking-inquiry skills evident among the students experiencing computer-based instruction indicates some potential value from the use of this type of instruction for development of these skills.

In contrast to the traditional, textbook-oriented approach, the non-traditional, computer-based approach to science instruction used in The Voyage of the Mimi highlights the development of higher order reasoning and inquiry skills through constructivist learning activities designed to enhance students' ability to question and search for answers from a variety of sources, such as the Internet or electronic collaboration with scientists and other experts. The question to ask is why would students develop statistically equivalent levels of critical thinking-inquiry skills when the two approaches to science instruction were compared? Could it be that The Voyage of the Mimi does not offer real opportunity for students to ask questions, inquire, and use critical thinking skills?

Perhaps such a curriculum cannot, on its own, impact whether teachers' carry out science instruction emphasizing critical thinking and inquiry skills. Teachers may require special training to develop an instructional approach that develops inquiry strategies. Teachers also need to decide when certain instructional approaches, such as the use of computers, are appropriate. Studies by W.J. Priestley (1997) and H.D. Priestley (1996) do indicate that extended modeling and practice of these skills does significantly impact teachers' abilities to design instruction that uses inquiry-based instructional strategies.

Another possible explanation for the less significant than expected critical thinking-inquiry results is that after a number of years of traditional, didactic instruction, students may not be as responsive, as we would like, to non-traditional instructional approaches that call for changes in their roles during instruction. Students may need to be involved in experiences with non-traditional instructional approaches, over extended periods of time beginning at earlier ages, in order to adapt to approaches to instruction that support increasing levels of critical thinking-inquiry skills.

Level of Cognitive Development

As with students' critical thinking-inquiry skills, lack of significant results in changes of levels in cognitive development may call for: (a) changes in approaches to teacher training that are designed to prepare teachers to instruct in ways that lead to students' development of higher levels of cognition; and (b) extended exposure of students to non-traditional instructional approaches specifically designed to meet this objective.

Language Development

The significant language development findings, resulting from the use of the computer-based instructional materials, may result from the fact that The Voyage of the Mimi curriculum is consciously designed to integrate language with science concepts and other content through the use of computers. The authors of The Voyage of the Mimi claim that "traditional boundaries" of scientific disciplines are broken down in favor of a language-based, interdisciplinary focus, which inherently emphasizes students' language development. A large variety of language arts activities evolve naturally from the scientific exploration upon which The Voyage of the Mimi curriculum is built. The research projects, poetry writing, public speaking, and other language development activities are connected directly to the science themes and content of The Voyage of the Mimi.

The significantly increased levels of English language development noted for students instructed using The Voyage of the Mimi curriculum carry implications for the use of computers for teaching language through content. Both "literature-based" and "whole language" instructional approaches emphasize interdisciplinary, content-based strategies similar to those used in The Voyage of the Mimi curriculum. Perhaps the scientific topics and content upon which The Voyage of the Mimi curriculum is built provide increased opportunities for authentic, connected communications activities that spark students' enthusiasm and interest. Perhaps this instructional approach provides students with a learning and communications vehicle that allows them to use their individualized learning styles and abilities advantageously to garner English language skills and express ideas in ways that would not be possible without these resources.

In summary, computers used in instruction do significantly impact students' English language development and attitude toward science learning. The positive trend in student scores, resulting from the use of computer-based instructional materials, for the learning outcomes of science achievement and development of critical thinking-inquiry skills, while not as significant as might be expected, do indicate some value from the use of computers. Therefore, computer-based curriculum, such as The Voyage of the Mimi, should be used for science instruction to help improve students' content learning, attitude toward science learning, and thinking-inquiry skills.

Recommendations for Further Study

This study presented findings indicating non-significant, positive trends in student scores, resulting from the use of computer-based instructional materials, for the learning outcomes of science achievement and development of critical thinking-inquiry skills. A recommendation for further study would examine why the impact of the use of the computer materials was positive, but not significantly so. Perhaps an expanded study of non-traditional, computer-based approaches to science instruction, using a design that examines the impact on student learning and thinking, over time, would reveal whether longer-term investment with this form of instruction has a significant impact on other student learning outcomes, such as science achievement and development of critical thinking-inquiry skills.

A second recommendation for further study would examine the impact of the use of computer-based instructional approaches on the learning, attitudes, and thinking skills of other diverse student populations, such as those at other grade levels. Another recommendation for further study would explore the impact of varying levels of professional experience among teachers using non-traditional, computer-based instructional approaches on students' learning, attitudes, and thinking skills. Also, the issue of learning computer skills in relation to a content area, such as science; as opposed to learning such skills in isolation, out of the context of such content areas, warrants examination. Lastly, the impact of the availability of computer resources requires exploration.

Final Statement

As national efforts toward the strengthening of science education curriculum and practices continue, the potential impact of non-traditional, computer-oriented instructional approaches, such as The Voyage of the Mimi, on students' learning, thinking, and attitudes versus the financial expenditures necessary to purchase these resources will continue to be a hotly contested educational issue. The Panel on Educational Technology's (1997) Report to the President on the Use of Educational Technology to Strengthen K-12 Education in the United States indicates that research in the field of educational technology must include studies conducted within authentic educational environments, such as the one reported herein, designed to provide educators and the public with sound empirical data necessary to examine the effectiveness of instructional approaches making use of various technologies and provide justification for these financial expenditures.

This study indicates that non-traditional, computer-based approaches to science instruction can significantly improve students' attitudes toward science learning and their level of English language development. The positive trends found for the student learning outcomes of science achievement and critical thinking-inquiry skills add even more potential value to the use of computers as instructional tools. The results of the study reported herein confirm the value of non-traditional, computer-based instructional approaches, such as exemplified by The Voyage of the Mimi, within the context of science education reform, which should be used in schools across the nation to reverse the trend toward what has been perceived to be poor science performance by American students documented by reports such as the Third International Mathematics and Science Study. At the same time, educators need to keep in mind that even as important as the effective use of computers in science instruction is, it should not be considered a panacea. The so-called "computer approach" needs to be considered for use along with other components of instruction and within the context of appropriate professional development of teachers.

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APPENDIX A

PERMISSION LETTER FOR STUDENTS TO PARTICIPATE IN THE STUDY

September, 1995

Dear Parents/Guardians:

As many of you might already know, I serve in the position of Elementary Computer Specialist for Wissahickon School District. As part of my professional development, I am currently working towards a doctoral degree in education.

For my dissertation research, I will be studying the academic and attitudinal effects of various teaching strategies being used in the science program in Wissahickon's fifth-grade classrooms. I would like your permission to include anonymous information about the science achievement and attitude; language skills; and general reasoning skills of your child in this study.

The tests to measure science achievement and attitude; language skills; and general reasoning skills will be given once during the fall of 1995 and then again during the spring of 1996. The tests require approximately three hours to administer. In no way will the results of the tests be related to or affect the progress report grades of your child. Once again, all information gathered will be used in a totally anonymous fashion. At the conclusion of the research study, I would be happy to share the results with you if you so desire.

Please fill out the permission form at the bottom of this letter and return it to school via your child. Feel free to call me at (215) 628-1902 if you have questions or require further information.

I wish to thank you in advance for your cooperation and assistance with this request.

Sincerely,

Alan H. Rothman
Computer Specialist
Wissahickon School District

Parent/Guardian's Name____________Child's Name_______________
Teacher's Name____________________School____________________

_____**YES**, I give my permission for science achievement and attitude; language skills; and general reasoning skills information about my child to be gathered and anonymously used in the context of Alan H. Rothman's dissertation research study.

_____**NO**, I do not give my permission for science achievement and attitude; language skills; and general reasoning skills information about my child to be gathered and anonymously used in the context of Alan H. Rothman's dissertation research study.

Parents/guardians, please return this form to your child's school.
Teachers/secretaries, please forward this form to Alan Rothman at Shady Grove.

APPENDIX B

TEACHER SURVEY OF PROFESSIONAL EXPERIENCE, ABILITIES, AND ATTITUDES TOWARD SCIENCE AND THE USE OF COMPUTERS AS INSTRUCTIONAL RESOURCES

Teacher Survey of Professional Experience, Abilities, and Attitudes toward Science and the Use of Computers as Instructional Resources

Directions: Please read and answer each of the following questions. Respond to Questions 1 through 3 by writing an appropriate number, in the space provided, based on your personal professional experience.

1) How many years have you been teaching? ______

2) How many years have you been teaching science? ______

3) How many years have you been using computers and other instructional resources? (If you have not used computers place a "0" in the space provided.) ______

For Questions 4 through 7, choose a number from the accompanying scale that best characterizes your perception of your ability or attitude in the areas described.

4) How would you rate your ability to teach science?

1	2	3	4	5
Unsatisfactory	Satisfactory	Good	Very Good	Outstanding

5) How would you rate your ability to use computers and other technological instructional resources?

1	2	3	4	5
Unsatisfactory	Satisfactory	Good	Very Good	Outstanding

6) How would you describe your attitude toward the teaching of science?

1	2	3	4	5
Very Unfavorable	Unfavorable	Neutral	Favorable	Very Favorable

7) How would you describe your attitude toward the use of computers and other technological instructional resources?

1	2	3	4	5
Very Unfavorable	Unfavorable	Neutral	Favorable	Very Favorable

Thank you for your responses.

APPENDIX C

TABLE 32. SUMMARY OF CONCLUSIONS FROM THE STUDY

Table 32. Summary of Conclusions from the Study

Research Questions	Null Hypotheses	Findings	Conclusions
Question 1: Are there differences in the science achievement attained by elementary school level students whose science instruction emphasizes microcomputer-based experiences when compared to the levels of scienceachievement attained by elementary school level students whose instruction includes only textbook-oriented experiences?	Null Hypothesis 1: There will be no statistically significant difference in the science achievement attained between the elementary school level students taught with the methods indicated previously.	<u>Mixed</u>: Statistical analysis indicated no significant differences in students' science achievement attained as a result of the mixed non-traditional, technology-based and traditional, textbook-based science instruction. <u>Non-Traditional, Technology-Based</u>: Statistical analysis indicated no significant differences in students' science achievement attained as a result of the non-traditional, technology-based science instruction. <u>Traditional, Textbook-Based</u>: Statistical analysis indicated no significant differences in students' science achievement attained as a result of the traditional, textbook-based science instruction.	None of the three approaches to science instruction had an advantage over any other approach in improving students' achievement in science.

Table 32. (continued)

Research Questions	Null Hypotheses	Findings	Conclusions
Question 2: Are there differences in the attitude toward science developed by elementary school level students whose science instruction emphasizes microcomputer-based experiences when compared to the attitude toward science learning developed by elementary school level students whose instruction includes only textbook-oriented experiences?	Null Hypothesis 2: There will be no statistically significantdifference in the attitude toward science learningdeveloped between the elementary school level students taught with the methods indicated previously.	Mixed: Statistical analysis indicated no significant differences in students' attitudes toward science learning developed as a result of the mixed non-traditional, technology-based and traditional, textbook-based science instruction. Non-Traditional, Technology-Based: Statistical analysis indicated significantly more positive student attitudes toward science learning developed compared to students taught with the traditional, textbook-based science instruction. Traditional, Textbook-Based: Statistical analysis indicated significantly less positive student attitudes toward science learning developed compared to students taught with the non-traditional, technology-based science instruction.	The mixed non-traditional, technology-based and traditional, textbook-based science instruction did not significantly improve the attitudes toward science learning developed by elementary school level students. However, the non-traditional, technology-based science instruction resulted in significantly improved attitudes toward science learning and the traditional, textbook-based science instruction resulted in significantly less positive attitudes toward science learning developed by elementary school level students.

Table 32. *(continued)*

Research Questions	Null Hypotheses	Findings	Conclusions
Question 3: Are there differences in the levels of critical thinking or basic science inquiry skills developed by elementary school level students whose science instruction emphasizes microcomputer-based experiences when compared to the levels of critical thinking or basic science inquiry skills developed by elementary school level students whose instruction includes only textbook-oriented experiences?	Null Hypothesis 3: There will be no statistically significant difference in the levels of critical thinking or basic science inquiry skills developed between the elementary school level students taught with the methods indicated previously.	Mixed: Statistical analysis indicated no significant differences in students' levels of critical thinking or basic science inquiry skills developed as a result of the mixed non-traditional, technology-based and traditional, textbook-based science instruction. Non-Traditional, Technology-Based: Statistical analysis indicated no significant differences in students' levels of critical thinking or basic science inquiry skills developed as a result of the non-traditional, technology-based science instruction. Traditional, Textbook-Based: Statistical analysis indicated no significant differences in students' levels of critical thinking or basic science inquiry skills developed as a result of the traditional, textbook-based science instruction.	None of the three approaches to science instruction had an advantage over any other approach in improving students' levels of critical thinking or basic science inquiry skills.

Table 32. (continued)

Research Questions	Null Hypotheses	Findings	Conclusions
Question 4: Are there differences in the levels of cognitive development exhibited by elementary school level students whose science instruction emphasizes microcomputer-based experiences when compared to the levels of cognitive development exhibited by elementary school level students whose instruction includes only textbook-oriented experiences?	Null Hypothesis 4: There will be no statistically significant difference in the levels of cognitive development exhibited between the elementary school level students taught with the methods indicated previously.	Mixed: Statistical analysis indicated no significant differences in students' levels of cognitive development exhibited as a result of the mixed non-traditional, technology-based and traditional, textbook-based science instruction. Non-Traditional, Technology-Based: Statistical analysis indicated no significant differences in students' levels of cognitive development exhibited as a result of the non-traditional, technology-based science instruction. Traditional, Textbook-Based: Statistical analysis indicated no significant differences in students' levels of cognitive development exhibited as a result of the traditional, textbook-based science instruction.	None of the three approaches to science instruction had an advantage over any other approach in improving students' levels of cognitive development.

Table 32. (continued)

Research Questions	Null Hypotheses	Findings	Conclusions
Question 5: Are there differences in the levels of language development attained by elementary school level students whose science instruction emphasizes microcomputer-based experiences when compared to the levels of language development attained by elementary school level students whose instruction includes only textbook-oriented experiences?	Null Hypothesis 5: There will be no statistically significant difference in the levels of language development attained between the elementary school level students taught with the methods indicated previously.	Mixed: Statistical analysis indicated significantly higher levels of student language development compared to students taught with the traditional, textbook-based science instruction. Non-Traditional, Technology-Based: Statistical analysis indicated no significant differences in students' levels of language development attained as a result of the non-traditional, technology-based science instruction. Traditional, Textbook-Based: Statistical analysis indicated significantly lower levels of student language development compared to students taught with the mixed non-traditional, technology-based and traditional, textbook-based science instruction.	The mixed non-traditional, technology-based and traditional, textbook-based science instruction significantly improved the levels of language development attained by elementary school level students. However, the levels of language development attained by elementary school level students were not significantly improved through the non-traditional, technology-based science instruction and traditional, textbook-based science instruction resulted in significantly lower levels of student language development attained by elementary school level students.