ABSTRACT

REID-GRIFFIN, ANGELIA RIQUE. Observing Middle School Students' Use of Technology as a Tool for Learning. (Under the direction of Dr. Glenda Carter)

The purpose of this study was to observe middle school students' use of technology as a tool for learning science in a nine-week elective class (Exploring Technologies) offered to 7th and 8th grade students (n=23). Students' use of data collection devices and subsequent interactions were traced through audio and video recordings, field notes, interviews, and students' artifacts. A social constructivist frame is used for this study within which a Vygotskian perspective is embedded.

The first manuscript of the study describes the application of a model of scaffolding to design instruction for teaching the use of technologies. The Exploring Technologies class was structured around Cazden's scaffolding model, which was based on teacher-student interactions. The curriculum developed students' ability to use technology as a tool, first by giving them fundamental skills in using the technologies in data collection, and then providing them with experiences to conduct scientific inquiry. Findings indicated that the three phase instructional model was successful in constructing students' understanding of scientific ideas through the use of technologies.

The second manuscript of the study examines two specific incidences to elucidate the impact of using technology specifically, in the context of conducting scientific investigations. The middle school students used data collection devices and probeware (Casio) to conduct science experiments. The students used the technological tools to perform experiments related to temperature and heat. Findings indicated that the devices had the potential to promote the qualitative and quantitative nature of data collection. Further research on

instructional approaches will assist middle school teachers in developing students' use of technologies as tools to construct understanding.

Observing Middle School Students' Use of Technology as a Tool for Learning

By

ANGELIA RIQUE REID-GRIFFIN

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APPROVED BY:

Chair of Advisory Committee

DEDICATION

This dissertation is dedicated to:

My parents, Thomas and Geraldine, who have taught me the importance of having faith, determination, dedication, and self-discipline.

To my husband

The memory of family and friends, who have since passed as I continued to pursue my education.

Educators, who strive to give all students the opportunity to become successful in any career they choose.

PERSONAL BIOGRAPHY

Angelia Rique Reid-Griffin was born to Thomas and Geraldine Reid on January 21, 1972 in Pasquotank County, North Carolina. She attended Elizabeth City-Pasquotank County Public Schools and graduated from Northeastern High School in 1990. Angelia graduated high school with honors and attended East Carolina University in Greenville, North Carolina where she received the Chancellor's Leadership Scholarship. She received a Bachelors of Science degree in Biology in 1994. Angelia worked as a substitute teacher for the Elizabeth City-Pasquotank School System and Archival Assistant for Elizabeth City State University.

She later received a Masters of Arts in Education in Science Education, secondary education from East Carolina University in 1997. While obtaining her MAEd, she obtained her North Carolina Certification for General Science, 9-12. Upon graduation, she was employed by Gates County Public Schools in Gatesville, North Carolina where she taught various science courses for grade 9-12 for two years. Angelia left the classroom to pursue her doctorate in Science Education at North Carolina State University in 1999 and received her degree in 2002. She has worked with the Science Education faculty on several research projects in the public schools. The author helped to develop a curriculum for middle school science teachers using technologies such as data collection devices and served as a test reviewer and evaluator for the North Carolina Department of Public Instruction. She was the Co-Editor on the Silver Issue of Meridian: A Middle School Computer Technologies Journal at NC State in 2002 and serves on the editorial board for the electronic journal.

The author presently resides in Raleigh, North Carolina, with her husband Stacey.

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CHAPTER 1

Introduction

Technology is a social and technical process, which involves the application of knowledge, tools, and skills to solve practical problems and extend human capabilities (Johnson, 1989). In the past decades, the implementation of technology in America's classrooms has been a major focus of several educational reforms and policies (U.S. Department of Education, 2000). The launch of Sputnik and the release of Goals 2000, both earmark events in scientific history in which government has taken a firm stance in implementing the use of technology in science classrooms. After the development of the nation's first educational technology plan in 1996, American schools have noticed a significant increase in the use of instructional tools in classrooms (Office of Educational Technology, 1999). Today, technological tools used in industry and research laboratories have established new homes in many classrooms throughout the world. Therefore, at the height of a technological revolution, educators, parents, and governmental officials are challenged with offering students the technological skills needed to become successful citizens (U.S. Department of Education, 2000). However, having technology in classrooms for the purpose of producing technologically literate citizens should not be an end unto itself. Rather the challenge is to find ways to use technology as an instructional tool to improve the academic achievement of all students (Bush, 2001). Educators find themselves faced with addressing these issues, as they teach our students how to apply technologies to core subjects such as reading, mathematics, and science.

American society has a moral obligation to provide quality education to all children (Schoenfeld, 1999). According to Goals 2000 report, "a majority of the schools in the United

States have failed to prepare all students to succeed" (U.S. House of Representatives, 1994, p. 1). Technology's presence in schools can fulfill this obligation by its ability to mold and reflect the values of society (American Association for the Advancement of Science [AAAS], 1989). Collaborative efforts of the International Society for Technology in Education (ISTE) along with numerous organizations, such as the U.S. Department of Education, National Council of Teachers of Mathematics, National Science Teachers Association (NSTA), and educators across the United States developed the National Educational Technology Standards (NETS). The NETS were designed to address issues of accountability for "all students to achieve success in learning, communication and life skills while using instructional tools" (ENC Focus, 2001, p. 1). There are six Technology Foundation Standards for students, K-12. At the completion of specified grade levels students should be able to master the profiles listed for each of the standards for their grade levels. Based on the Profiles for Technology-Literate Students, by the completion of eighth grade students should be able to perform the following tasks to be considered competent in the standards. They include using content-specific tools to solve problems. Being able to apply productivity tools and other technology resources to support learning throughout the curriculum. Students should be able to work collaboratively with others using the tools to investigate problems. They also need to demonstrate a fundamental understanding of concepts when using tools to support learning, accomplish tasks and solve problems (ENC Focus, 2001). Numerous national reports have been released in the past decades indicating that many schools in America have failed to adequately educate all of its students, especially in the sciences (AAAS, 1989). This has consequently led to a steady increase in the number of educators trying to use and implement technology in their curriculum to improve students' performance in science. The million-dollar question is: How can the use and implementation of technologies impact students' learning in these classrooms?

According to Roblyer (2000), it is the responsibility of science educators to take the initiative to develop curricula that incorporate the use of technologies, since the new standards do not clearly explain the role of instructional technology in the science classroom. According to the National Science Education Standards, students in grades 5-8 should develop the skills to do scientific inquiry as well as develop understandings about scientific inquiry (National Research Council [NRC], 1996). Technological tools can provide teachers with the resources to develop activities that fulfill these standards. Through student investigations, educators give students the opportunity to appreciate the interplay of scientific concepts as well as social and economic issues. Therefore, it is imperative that science educators provide students with a variety of experiences that highlight the advances of these technological tools (Rakow, 1998).

Today many industries are marketing a variety of products geared towards helping students learn content as well as become technologically literate. These products include powerful data collection devices for middle and high school science and mathematics classes (Texas Instrument, 2001). Casio (2001), Texas Instruments (2001), and Vernier (2001) have created numerous technological tools that may assist students in bridging the gap between science, math and the real world.

Rationale

Reforms in science, mathematics, and technology education have ranked as a high priority for America's public schools for more than three decades (AAAS, 1989). "The task for reform in the sciences is seen as one of developing vision recognizing that science, technology, and society, and the quality of human existence are all interconnected" (Hurd, 1997, p. 9). Efforts to implement instructional tools in science classrooms claim technologies can create learning environments in which all students are able to benefit (U.S. House of Representatives, 1994). In accordance to Project 2061, technology as a tool provides educators and students with resources to develop advanced thinking skills associated with science, mathematics, and technology.

National Science Education Standards describe technology as a tool to help students appreciate the natural world and conduct inquiry projects (NRC, 1996). However, a broad range of scientific materials, science tools and technological resources must to be accessible for all students to develop this learning environment. Science educators are faced with the task of providing students with experiences and examining the impact of these experiences to fully understand how the presence of technology affects student learning. Studying the students' use of tools in an educational setting might also provide some evidence as to how these tools enhance the cognitive growth of adolescents.

This unique study focuses on an area for which little research data is currently available (Wetzel, 2000). Middle school students' use of Casio's data analysis system to collect various measurements is the focus of this intrinsic study. Due to the small amount of research on technological tools in context of the middle school science classroom, this study can provide valuable information about how middle school students involved perceive learning science through the use of technology (Jones et al., 2000; Wetzel, 2000). The study will also investigate how the presence of technological tools affect learning in the context of a science classroom. To accomplish this task the interactions of seventh and eighth grade students using technological tools during a 9-week elective period will be described.

According to earlier research studies, to observe the effects of technology on student learning, educators need to incorporate lessons in the science curricula that give students the chance to use technologies to solve real-world problems. The Exploring Technologies elective class, the site of the study, created such a learning environment. The lessons presented in the class offered students opportunities to construct their own learning through scientific investigations. Research affirms that student learning is enhanced by providing them opportunities to "make connections, clarify, elaborate, build alternatives, and speculate" (Tobin & Tippins, 1993, p. 11) as they use technological tools to solve problems. Students were given ample time to discuss methods of using the tools to solve problems amongst themselves and with the instructors throughout this nine-week period. Through the efforts of this study and other research projects, it is believed that educators will be able to tackle the task of preparing all students to achieve success in science.

Data Analysis System in Science

The 9-week elective class, Exploring Technologies, offered to 7th and 8th grade students served as the location of the study. This unique elective class was taught at a gifted and talented magnet middle school in southeastern region of the United States. The class was designed so that students would learn to use technologies in the context of learning science and math concepts. Through the efforts of a school-university partnership, monies were allocated for Casio graphing calculators, data analysis systems, probe ware, computers, a printer and scanner to help teachers integrate technology in their science and math classes. Studying how students used data collection tools in learning science was the focus of this particular study. The Casio data analysis system was used in the class to actively engage students in using technologies to become more knowledgeable in science, mathematics, and technology, by engaging them in various thought-provoking activities (AAAS, 1989). This real-time data collection system included the EA100 Data Analysis System, FX7400G plus graphing calculator and sensitive probes to measure temperature, light, voltage, and motion (Casio, 2001).

By integrating student presentations in many of the activities, students were able to share their findings with their peers after using the equipment. Within small group settings, students were provided the opportunity to build upon each other's suggestions and reasoning in an attempt to better understand data collection experiments. By carefully analyzing the students' use of language and gestures as they utilized the tools in their problem-solving and critical thinking tasks the potential impact of using these technologies can be explored. Studying classroom discourse and interactions of the students as they use the tools will enable the researcher to search for evidence of scientific reasoning, taking place over the nine-week period. This study represents a forthright action of examining methods in which all students can benefit from enhanced learning opportunities, afforded by new and emerging technologies (Office of Educational Technology, 1999).

Purpose

This study is part of a larger research study designed to analyze the impact of using technology as a tool on middle school students' understanding of science concepts. Specifically this study was to examine middle school students' ability to analyze and interpret readings gathered using data analysis system and temperature probes. Evidence that the presence of tools will contribute to students' skills in scientific inquiry and add to their understanding and interpretation of graphically presented data using data collection tools will be sought (Newton, 2000).

This intrinsic case study was conducted with the intent to gain insight on how the presence of tools might affect the way middle school students' respond to learning science (Stake, 1995). The broader concern of this research may have some instrumental interests for Casio, the developers of the Data Analysis System and the science education community, since the lessons were constructed exclusively for these technologies. However, my attention will draw on specific situations excerpted by the students as they interpret and analyze temperature differences while using the Data Analysis System (Settlage, 1995). Results found in this study will set precedence for additional projects examining the effects of technological tools on students' conceptual development in science and math.

By performing the study, I addressed the following research questions:

1. How might instruction be structured to allow for effective infusion of technology into the curriculum?
2. How to use technology as a tool to maximize learning?

Data Analysis System

Data Analysis system is a data collection tool developed by Casio. This system was created to compete with the Texas Instruments CBL and CBL2 data gathering devices. This real-time data collection tool is composed of the EA100 data analyzer, Casio graphing calculator (FX7400G plus) and sensor probes to measure temperature, light, voltage, and motion (Casio, 2001). The three components of the Data Analysis System have specific functions in collecting and graphing real-time data. Similar to the CBLs, the Data Analysis System is capable of transforming a graphing calculator into a mini-science laboratory (Wetzel, 2000). Figure 1 displays the features of the Data Analysis System (Casio, 2001).

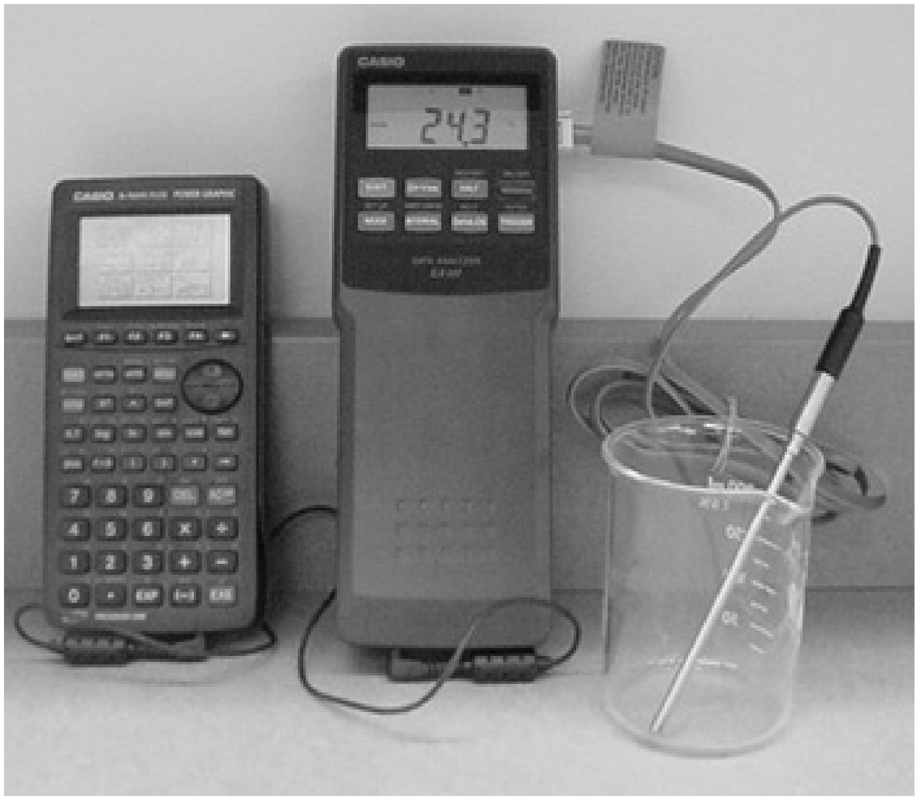

Figure 1. Photograph of the Casio Data Analysis System. In the photograph depicted, a temperature probe linked to the EA100 data analyzer, which is also connected to the graphing calculator collects temperature readings of a substance in the beaker.

Definition of Terms

CBLs- Calculator Based Laboratory systems; includes graphing calculator, data analyzer or digital interface, and probes or sensor; Trademark of Texas Instrument

Data Analysis System- created by Casio; includes data analyzer EA100, graphing calculator, and probes for collecting temperature, light, motion and voltage measurements

Digitizing video- placing video on computer using software such as DAZZLE; process of capturing video images in order to view on computer screen

EA-100 - also known as data analysis system; developed by Casio

MBL- Microcomputer-Based Laboratory; includes computer, interface device and sensors

Probe ware- include probes and sensors for collecting “real-time” data for temperature, light, pH, motion, sound, humidity and force

Technological tools- instruments, equipment used in the classroom to aid in student learning or teaching of scientific or mathematical concepts

Technologies- plural of technology; any instrument or equipment used in the classroom to aid in the teaching and learning process

V-Prism- Video software program for transcribing and coding digitized videocassettes; v-Prism Video Computing is a trademark of LessonLab Inc.

CHAPTER 2

Literature Review

Based on the initiatives of the Technology Foundation Standards for All Students, technology should be used as a tool to help students achieve success in learning, communication, and life skills (ENC Focus, 2001). As mentioned in Chapter 1, there has been a significant growth of the number of technologies in schools, along with an increase in the number of questions being asked about the extent to which these tools are being used in classrooms and for what purpose (U.S. Department of Education, 2000). The strong efforts of the Clinton administration in making technology accessible to all students has resulted in tremendous growth in the availability of computers and other technological tools in many of America's poor and rural schools.

The National Center for Education Statistics (NCES) of the U.S. Department of Education has provided significant evidence of growth in the use and availability of technology in many schools and classrooms throughout the country. The Fast Response Survey System (FRSS) developed by NCES has been administered to randomly selected public school teachers since 1994 to measure the growth of technology use in classrooms and schools throughout the United States. Results of the 1999 survey indicated that ninety-eight percent of the schools had access to the Internet (Cattagni, Farris, & Westat, 2001) and approximately half of all the public school teachers used computers and technological tools for classroom instruction (U.S. Department of Education, 2000). This increase of Internet and technology access is credited to the allocation of funds from government organizations such as the Education rate (E-rate) program. Programs such as E-rate offer Internet services and technological tools at discounted prices for schools and classroom teachers (Cattagni et al., 2001). The development of Goals 2000 and the National Educational Technology Goals are two ways in which the government has shown commitment in providing all students and teachers access to technology (U.S. Department of Education, 2000). This effort on the part of the federal government has been based on a belief that "technological tools are a necessity for American citizens and therefore, all children should be provided with the basic tools of this technological age" (Gore, 1998, p. 54). This belief is further supported by research reports from the U.S. Department of Education indicating students provided with access to technological tools show more "enthusiasm, higher attendance rates, and a greater capacity to communicate effectively about complex problems" (Gore, 1998, p. 54).

Technological tools should not be considered an end unto themselves rather they are a means to improving science teaching and learning (Bush, 2001; Mergendoller, 1996; U.S. Dept. of Education, 1995). President Bush declared in his 2001 State of the Union address, entitled "No Child Left Behind" that the administration strongly believes schools should use technology as a tool to improve academic achievement of all children (Bush, 2001).

This review of literature provides an overview of how technology is currently used in U. S. schools and the impact of this usage on learning. The first section will provide a summary of technology use in American schools by exploring the roles of the federal government and Standards in promoting the use of these tools in science classrooms. The second section offers a brief description of Microcomputer-Based Laboratories (MBLs) and

Calculator-Based Laboratories (CBLs). The next section of the review of literature examines research on the use of technological tools in science and mathematics classrooms as it relates to students' and teachers feelings towards technology. Results of students' learning in technology rich environments will be addressed as they correspond more directly with the current study.

The fifth section of the review explores how technology as a tool is perceived from a constructivist approach and how it influences principles of science teaching and learning. The final section of the review examines research on discourse and how the presence of technology could impact student conversations and learning.

Why Technology?

In addition to governmental initiatives of making technology a major focus of educational policy and reform, the National Science Education Standards (NSES) also supports the use of technology in science classrooms (NRC, 1996). According to the NSES, technological tools provide students and teachers opportunities to conduct inquiry experiments and in doing so participate in the process of understanding science. Therefore, these tools are an important part in the contemporary reform of science education. However, there remains many unanswered questions about the effectiveness of tools in science learning (Gallagher, 2000). Huang and Waxman (1996) recommend using research to answer these questions, focusing specifically at how tools are being used by students to process, manipulate and analyze real-time data.

Introducing technology as a tool into science classrooms has presented many challenges in the instruction of science. A review of literature implied "technological tools can spur pedagogical changes but the utility of such changes must be measured by their impact on student learning" (Mergendoller, 1996, p. 45). Cohen and Barnes (1993) suggest that many of the changes and challenges in classroom instruction are a result of the current restructuring of pedagogy and policy initiated by both federal and local government on classroom teachers. Reformers are interested in the impact of technological tools on the traditional science classroom pedagogy, which has generally been didactic and teacher-centered (Cohen & Barnes, 1993).

Critical pedagogy addresses the use of technology in classrooms by encouraging the use of real-world problems in teaching the subject of problem-based inquiry. McCurry (2000) suggests U.S. schools provide a democratic education that embraces this pedagogy of making real-world problems the subject of problem-based inquiry in science classrooms. Newman (1990) believes the use of technological tools in science classrooms can also provide additional collaboration among students and teachers as well as afford transformations in instructional designs. According to McCurry (2000), critical pedagogy has viewed technology as "a tool used primarily in advancing the dominant forms of pedagogy and cultural transmission that are the object of critical pedagogical theory and discourse" (p. 103). Technological tools can present potential changes in the way students learn science. These tools can offer "a greater opportunity for critical pedagogical reform in America's schools" (p. 104). Additional research is needed to examine how the technological tools in the science classroom can lead to richer, more distributed learning among all students (Mergendoller, 1996). "The potential benefits would be that the use of technology allows teachers to concentrate the remaining instructional time on the content and skills they want students to be learning" (Kreuger & Rawls, 1998, p. 281).

The National Science Education Standards suggests that middle school students can develop the necessary skills to conduct meaningful investigations as well as understand science inquiry when they have access to the appropriate technologies, instruction and curriculum (NRC, 1996). The implementation of tools in the science classroom should be aided by the development of a curriculum that supports the use of tools as well as provides an opportunity for all students to succeed in science. However to ensure that all students benefit, there needs to be a change in the current science curricula to help students become scientifically literate citizens (AAAS, 1989).

"To achieve increased scientific literacy, science classrooms need to be centered around activities that allow students to develop and practice process skills" (McGinn & Roth, 1999, p. 14). In addition to these new classrooms a new innovative science curricula needs to be developed with the intent for all students to engage in hands-on activities as they discover the physical world for themselves. They suggest this new science curricula should offer students the chance to not only carry out experiments but also incorporate the use of tools so that students can conduct authentic tasks. By implementing tool use in the science curriculum, students are provided the chance to understand the nature of science and scientific knowledge not from the traditional science textbook but through genuine inquiry made possible by the use of graphing calculators, computers, and data collection tools.

Microcomputer-Based Laboratories (MBLs) & Calculator-Based Laboratories (CBLs).

Burnett (1994) suggests that technological tools can occur in many forms, from "pre-packaged games to word processing and graphics packages, complex multimedia systems, and telecommunications networks, such as the Internet" (Burnett, 1994, p. 1). Based on the Standards, "inquiry is a step beyond in which students learn skills of observation, inference and experimentation to develop their understanding of science" (NRC, 1996, p. 105). Technological tools afford students the opportunity to act in manners associated with inquiry standards. In science classrooms there has been a special interest in devices that allow students and teachers to carry out scientific investigations.

Microcomputer-Based Laboratories and Calculator-Based Laboratories are technological tools that allow immediate real-time data collection through the use of compatible probes and sensors. These data collection tools also provide graphical representations of data gathered by students using a computer or graphing calculator (Lapp & Cyrus, 2000). According to Hale (2000) these instruments offer a powerful learning environment by permitting students to use advanced technologies to solve problems and do real science. MBLs and CBLs provide devices that enable students to collect data in a matter of minutes, rather than taking up the entire class period to complete an exercise (Kreuger & Rawls, 1998). Students can spend extra time afforded from using these technological tools to develop their skills to interpret scientific data.

MBLs are composed of a computer or minicomputer, an interface device, and probeware to collect and display real-time data in a graphical presentation. The computer or minicomputer involved in the system can be interfaced with probeware to measure phenomena such as temperature, motion, and sound (Mokros & Tinker, 1987). "MBLs relieve students of the tedious aspects of collecting, manipulating, and displaying data that otherwise divert their attention from interpreting and understanding the data" (Brasell, 1987, p. 387). CBLs are inexpensive, portable data collection devices created by Texas Instrument. They include devices such as graphing calculators, interface devices and probes that support student-directed explorations (Grable & Curto, 2001).

Leading producers of portable real-time data collection systems, such as Texas Instruments, Casio and Vernier Software are continuously creating new products that promise students and teachers numerous opportunities to collect, analyze, and interpret data from a variety of sources. Roblyer and Edwards (2000) suggests these technological tools are becoming prominent devices in the mathematics and science curricula. The increasingly low costs and availability of these devices make technologies more visible in mathematics and science classrooms of all grade levels. According to Wetzel (2000) technological tools can serve as the eyes and ears of data collection because of their high capacity to provide authentic scientific experiences for students.

Comparing various types of data collection devices, Kreuger and Rawls (1998) propose that tools allow students to gain higher order thinking skills. Krueger evaluated his experiences with using a thermometer to show his students how to collect temperature data. He noted how time consuming it was for students to collect data at 30 seconds or 1-minute intervals using the thermometer and concluded that the use of the temperature probe and other data collection tools significantly reduced time spent collecting data. Kreuger and

Rawls (1998) suggest technologies such as data collection tools help students understand information by connecting concrete experiences with symbolic representations. They mention these technologies provide students with more time addressing "what-if" statements, interpreting and their analyzing data. There is less class time spent by students collecting data. The next section of the literature review examines research on how the presence of technological tools such as MBLs and CBLs, affect students' and teachers' feelings about technology and using it in learning science.

Attitudes towards Technology.

In order to provide a classroom setting that addresses the needs of all students we must be conscious of students' feelings and how the presence of technology may affect their attitude towards science. Teachers determine how technology is used in their classrooms and by having a positive attitude towards the use of these tools they can positively influence their students' feelings. Being aware of the attitudes of the subjects involved in the study provides insight on how technology affects their use of tools to learn science. Students' feelings about technology can be greatly influenced by teachers' use of this tool and their attitudes towards using them in the classroom. Some teachers view technology as a useful instrument if they are equipped with the proper skills and training. Wetzel (2000) investigated the effect of using Calculator-Based Laboratories (CBLs) on the attitudes of middle school teachers. The study involved interviewing and observing the instructional methods of five middle school science teachers as they used CBL probeware in their classes. The Stages of Concern (SoCQ) questionnaire was administered to the subjects to track their attitudes during the implementation process. Findings indicated teachers' initial uncertainty with using tools was due partly to their lack of experience and limited access to technologies. After four months, (Aug.- Dec., 1999), teachers participating in the study reported that they could use CBLs as powerful tools to teach their students scientific concepts. Wetzel (2000) noticed an increase in many of the teachers' use of higher-order thinking in their instruction as a result of using this new kind of technology.

Sherman and Weber (1999) support the claim that students and teachers are able to use tools, such as CBLs to engage in problem solving tasks. While working with the New Jersey Statewide Systemic Initiative (NJ/SSI), they found that technology made science more meaningful for children at all grade levels from elementary to secondary schools. The 18-month study involved a cohort of 35 teachers from eighteen elementary schools, four middle schools and one high school in New Jersey. Each of the participants developed a Thematic Learning Unit (TLU) and then field-tested the unit. During this time they also were provided with professional development related to the project. The researchers visited the classrooms to observe teachers' implementation of technology in the curriculum. Results indicated that most teachers believed technology made students think more concretely about mathematics and science. One teacher commented, "the use of technological tools helped students to make connections as well as discuss and explain in detail what they have learned from completing a task, as opposed to limited recall that occurs after facts are memorized" (Sherman & Weber, 1999, p. 72). Based on the results, researchers concluded that technology use has a positive impact in strengthening science and mathematics instruction. Not only do the students benefit from using technology but the teacher also learns how to make connections in their teaching.

Lehman (1994) reported that accessibility and pedagogical understanding of technology greatly influences the use of technological tools in science and mathematics classrooms. A 22-item questionnaire developed by mathematics educators at Slippery Rock University was used to gather data about the use of technology in public elementary science and math classrooms. Surveys were completed and returned by principals from 80 elementary schools concerning the instructional methods of their classroom teachers. Results of the survey indicated that only forty percent of the teachers used microcomputers as a part of their science and mathematics instruction. However, this limited use of technology was brought on by the reduced availability and access to computers and few training opportunities. Based on the responses from the survey the researcher reported that 55% of the teachers actually used microcomputers in science instruction versus 82.5% for mathematics instruction. The researcher suggested that differences in percentages might account for the reduction of instructional time spent on teaching science in grades K-6. Overall, findings point out that microcomputers are used more often than calculators by teachers in both science and mathematics instruction.

Several research studies (Adams & Shrum, 1990; Boone & Edson, 1994; Nicaise, Gibney, & Crane, 2000; Pedretti, Woodrow, & Mayer-Smith, 1998), examine students' attitudes towards using technological tools to construct an understanding about specific scientific concepts.

Pedretti et al. (1998) reported on the use of technology in secondary science classrooms from the perspectives of high school science students (n=144). The longitudinal study was based on Technology-Enhanced Secondary Science Instruction (TESSI), a project focused on increasing student learning by integrating multiple technologies into the science curriculum. Data about students' attitudes towards and perceptions of technology were collected through the use of 80 semi-structured interviews with the students. Exit questionnaires were given to the students in the study population. The authors noticed that TESSI students considered the classroom different and special partly due to the technologies and changes in pedagogy. Students believed that the technologies enhanced their thinking by helping them with their communication and writing skills. Some of the students indicated that viewing technology as an instrument improved the learning process in the classroom and labs. From these responses the authors concluded that implementing technology in classroom as commonplace has a positive effect on students' participation, understanding and learning of scientific concepts.

Nicaise et al. (2000) investigated how high school students reacted to a class developed to provide aeronautic and engineering experiences through the use of technologies. The assistance of mentors from the community provided opportunities for students to learn how to conduct biological research experiments, develop communication systems for a mock space mission, construct their own orbiters, network computers for data collection and design a heating and cooling system for their shuttle. The researchers used multiple methods of data collection such as classroom observations, informal interviews and student artifacts to examine the learning impact of this unique classroom environment on participating students. Findings indicated many of the students enjoyed performing the hands-on activities involving technologies and working with professionals. Students reported that the "experiences were life-like [italics added] and were preparing them for work in industry" (Nicaise et al., 2000, p. 86). The students (n=18) who considered this to be an unsuccessful experience attributed their lack of success to their weak background in computers and other technologies. Nicaise et al. (2000) concluded that the majority of students involved in this authentic learning environment considered it to be successful.

Boone and Edson (1994) conducted a study to assess the attitudes of students towards using technologies. The researchers evaluated the responses of ninth graders (n=240) using a 28-item Likert survey that addressed the students' attitudes towards computers for communication, and data collection, specifically temperature measurements. The survey was administrated at the beginning of the school year. The students responded most favorably to having a computer available in their science class, and least favorably to using the computer to take temperature measurements. The researchers concluded that overall the students had a positive attitude towards selected uses of technology. Perhaps, students' attitudes about using the computer to measure temperature were least favorable due to their prior experiences with measuring temperature using a traditional thermometer. The researchers later observed that some students changed their attitudes about using the computer to measure temperature once they discovered how quickly and accurately data could be collected.

Changes in students' attitudes toward the use of technology were also indicated in a study of high school students working in a Microcomputer-Based Laboratory (MBL) environment (Adams & Shrum, 1990). In the study, an open-ended version of McKenzie & Padilla's Test of Graphing in Science (TOGS) instrument, Individualized Test of Graphing in Science (I-TOGS) was used to assess students' level of cognitive development and line-graphing skills in the MBL setting. The study involved 20 high school students who were assigned to groups based on cognitive development levels as indicated by their scores on the Group Assessment of Logical Thinking (GALT) instrument. Ten students participated in the experimental group in which MBL intervention was used to complete laboratory exercises; ten students made up the conventional group who performed the same laboratory activities using traditional, non- MBL tools. Data about attitudes were collected by interview and observation data. Although the experimental group initially spent as much time performing the lab exercises as the conventional group eventually they began completing other tasks as the computer collected their data rather than wasting valuable instructional time watching the computer. Researchers summarized that the group of high school students became aware of its value as a tool in making efficient use of their time after using MBL instruments.

Overall, the above studies conclude that students view the use of technology in classrooms positively. Many students became aware of the value of using these tools in constructing their own understanding of scientific concepts and principles. As Pedretti et al. (1998) noted, students are very conscious of their futures and the impact technology may have on them. In summary, attitudes of students can invariably affect the implementation of new technologies in science classrooms. In reviewing literature Boone and Edson (1994) noticed that there were few or no reports involving students' attitudes towards the use of technologies in a physical science classroom. There have also been few research studies in regard to middle school students' learning as a result of using technological tools, such as MBLs, CBLs, and Data Analysis Systems in the context of the science classroom (Boone & Edson, 1994; Jones et al., 2000; Wetzel, 2000).

In accordance with Hurd (1997), researchers seek to find evidence that technologies such as MBLs and CBLs affect learning in science and math classrooms. In conducting this review of literature, I came across few studies examining the effects of implementing technology, such as MBLs and CBLs, on students' learning in the middle grade science classroom. This section of the review will address the impact of technologies on students' construction of conceptual knowledge.

Thornton and Sokoloff (1990) believe technological tools play an important role in students' learning of science. These tools provide science classrooms, ranging from elementary to college level with the resources needed to allow students to make connections between science-technology and the physical world, by constructing their own knowledge-based learning activities. Over a three-year period, Thornton and Sokoloff (1990) compared the effectiveness of using MBL tools and kinematics curriculum in a college setting. The study involved more than 1500 undergraduate college students. Pre-and post-testing instruments were used to compare the effectiveness of using this technologically based curriculum with traditional instructional practices for helping students learn kinematics concepts. Results indicated students who worked with MBL tools in conjunction with the curriculum showed improvement in understanding kinematics concepts, while students who only listened to lectures did not. The researchers conclude that MBL tools along with the curriculum offer science learners the ability to explore, measure, and learn from their surroundings.

Linn and Songer's (1991) work with the Computer as Lab Partner (CLP) curriculum project allowed them to conduct studies using over 200 middle school students focusing on the effects of implementing this curriculum along with MBL tools. The studies focused on teaching students how to construct and apply complex ideas about thermodynamics as they used technologies. Linn & Songer (1991) described the following six key reasons that emerged as a result of conducting studies using tools to teach thermodynamics (pp. 889-890):

1. Tools allowed students to resolve doubts due to more time to duplicate experiments.

2. Students had more time to interpret and analyze data since the use of tools allowed experiments to take place more quickly.

3. Tools provided multiple representations of data allowing for students a better understanding of the concepts.

4. Technological tools support constructivist perspective of building on knowledge through the use of hands-on, inquiry-based activities.

5. Tools provide opportunities for collaboration among students and discourse among students and teacher.

6. Technological tools provide opportunities for students to use scientific reasoning and process skills while performing experiments

Results indicated that the middle school students who used data collection tools in the study were able to transfer their understanding of graphing through the use of motion experiments. There was an increase in the students' ability to detect reliable data as a result of using these tools with the CLP curriculum. The researchers also found that through the use of technological tools students were able to grasp an understanding of the variables involved in measuring heat energy and temperature as well as interpret data. Linn and

Songer (1991) concluded through the use of MBL experiments along with the curriculum, students gained a robust understanding of graph interpretation and were able to evaluate computer-presented data. They also gained a greater understanding of experimentation and were able to make distinctions between heat energy and temperature.

Cohen (1997) investigated technology as a cognitive tool in learning science. A constructive approach, in which students are encouraged to construct their own understanding through the use of discourse and discussions, was used to introduce technologies at the "magnet" high school. The teachers directed students throughout this process by encouraging them to create their own knowledge base as they used the technologies. Data collected from 15 gifted high school students over the period of one school year included field observations, pre-post interviews of the students, the Dunn and Dunn's Learning Style Inventory (LSI) and a questionnaire. Field notes collected during the study indicated some students were highly motivated and acted more responsibly towards the class assignments, which they believed were challenging. The researcher noted that students seemed to be actively engaged in most of the classroom activities involving the use of technology. The students involved in the classes indicated that they enjoyed using the technologies in pre- and post interviews. At the beginning of the study, students were motivated and engaged towards tasks using technology. However, results on LSI revealed a trend of students' being less motivated even with the technologies after a one-year period at the school. There were no significant changes in the social interactions or discourse of students as a result of these new tools. There was also no evidence of change in students' cognitive understandings as a result of using technological tools. Cohen (1997) concluded that although learning styles did not change after a one-year immersion in a technology-rich setting, students' learning styles were positively affected from the exposure to the technologies based on observations. She suggests that additional research studies need to be conducted to determine what changes occur in students' learning styles in specific curricula.

Huang and Waxman (1996) investigated how technology was being used in middle school mathematics. Over one thousand middle school students were randomly selected to participate in the study. During the instructional lessons, the Classroom Observation Scheduling (COS) was used to record the students' behaviors. Results revealed that students were not using any form of technology over half of the time in their mathematics classes. A shocking fifty-four percent commented that they had never used calculators prior to the study. From the findings, the researchers conclude that computers as well as other technological tools were rarely used in middle school mathematics classrooms.

Hale (1996) conducted a semester long study to investigate how Calculator-Based Laboratories (CBLs) affect undergraduate students' understanding of graphs. She used cooperative grouping to promote student discourse in the presence of these technologies. The study involved one hundred twenty-one students from two classes of integral calculus. A pre-test administered to assess students' understanding of kinematics and graphing revealed that many students did not understand how to interpret area under curves. Three labs were designed for the purpose of this study two of the labs incorporated the use of CBL tools. CBL labs were used to "promote understandings of the relationships between the physical variables they were graphing" (p. 55). In one CBL-lab, students worked in groups while students in the other CBL-lab worked on activities individually. Differences between

CBL and non-CBL labs were that in non- CBL labs students were given algebraic equations to generate graphs while students in the CBL labs, observed the physical movements creating the graphs. Results indicated that students' understanding of kinematics and graphing did not improve as a result of using the CBL tools. Hale (1996) concluded that the lack of improvement in students' understanding was due to their inability to use the tools properly. However, she believes the novelty of technological tools in this particular setting presented issues of skepticism among the students causing them to retain many of their misconceptions about graphing. Students failed to discuss or correct their misconceptions as they worked on the laboratory activity. Comparing research findings of students' misinterpretations of kinematics and graphs with other studies, the researcher suggests that discourse between students and teacher is required to repair students' conceptual understanding of graphing.

Lapp and Cyrus (2000) studied high school students' use of Calculator-Based Ranger (CBR) to understand distance information presented on a graph. They observed a group of students at a Mathematics, Physics, and Advanced Technology Exploration Day as they attempted, but failed to reproduce a graph using the CBR. The researchers concluded that students' failure to understand how to reproduce the graph was due to their inability to understand how graphs are generated using data collection devices. Providing students opportunities to make connections through the use of data collection devices allows them to act out and view data in "real time." The researchers bring to mind that through the use of technology teachers can use prediction and repetition of activities as a method of connecting graphs with actual physical events. Lapp and Cyrus (2000) evoke that future research should address issues of real-time graphing to link the graphs to tangible concepts of natural phenomena.

Mokros and Tinker (1987) researched the impact of MBL on middle school students' graphing skills as part of a five-year effort by the Technical Education Research Centers (TERC). Changes in students (n=125) graphing skills over a three-month period were calculated using pre-and post- test measures. Results indicated that many problems students had with graphing distance and velocity were resolved by exposure to MBL devices. Mokros and Tinker (1987) stated, "the multimodal approach to learning enables students to use their intelligences or learning styles and at the same time encourages them to build upon learning weaker modalities" (p. 381). They also suggested that using technological tools such as MBLs encourages students to be motivated and to become better learners. MBLs provide students a natural vehicle for expressing their own ideas about science. The researchers concluded that there were four reasons why MBLs should be considered powerful instruments for teaching graphing skills: 1) use of multiple modalities, 2) opportunity to pair real-time events with symbolic representations, 3) use of genuine scientific experiences, and 4) elimination of the hassle of producing graphs manually.

Brasell (1987) investigated the impact of MBL intervention on high school physics students and found that the technologies actually improved students' comprehension of distance and velocity. The study involved ninety-three high school students enrolled in physics and assigned to one of four groups; the Standard-MBL group, delayed-MBL group, control group and the Test-only group. Results indicated students in the Standard-MBL treatment groups made significantly lower ($p < .05$) errors when graphing distance and therefore showed more improvement on graphing distance than the other treatment groups. The Standard-MBL students also scored higher ($p < 0.001$) for the distance subtest but there were no significant differences among the groups in the Velocity subtest scores. The pre- and post- test scores indicated that differences between Standard-MBL and Delayed-MBL accounted for about 90% of improvement within Standard-MBL groups relative to the Control groups. Brasell (1987) concluded that MBLs real-time graphing component was valuable in improving students' graphing skills.

Adams and Shrum (1990) suggest using MBLs in science classrooms can influence the cognitive development of students by producing concrete examples of abstract representations in the form of graphs. Results indicated students using MBL tools outperformed those students not exposed to MBLs ($p < 0.10$) on graph construction tasks. Students identified as operating at a high level scored higher on graph-construction than those identified as operating at a low cognitive developmental level ($p < 0.10$). Adams and Shrum (1990) suggest using MBL with the laboratory exercises to give students a "mind's eye" picture of events not available to them using traditional, non-MBL tools.

Friedler, Nachmias, and Linn (1990) studied how middle grade students apply observation and prediction skills in the scientific reasoning process while in a MBL environment. Their semester-long study of temperature and energy involved eighth-grade students (n=110) in four middle school physical science classes of one teacher. Two of the classes received instruction emphasizing observation skills while the other two received instruction emphasizing prediction skills. Three assessment tools were used to analyze students' observation and prediction skills. The Scientific Reasoning Test (SRT) was developed to assess the scientific reasoning of students as they contemplate how the surface area of a swimming pool affects the cooling rate of the water. Results indicated that less than half of the students in the observation group could answer the question, while sixty-seven percent of the other groups were able to accurately predict the difference in cooling rate of the water while using the MBL tools. The Subject Matter Test (SMT) designed by Songer and Linn was used to assess students' understanding of the effects of variables on the heating and cooling process using MBL intervention. The tests results indicated that half of the prediction groups could verify their assumptions from their prior experiences while thirty-seven percent of the observation groups justified their predictions on the SMT after using MBL tools. The researchers concluded that teaching eighth graders observation and prediction skills in a technology-rich environment can motivate them to use these scientific reasoning skills in problem solving. Using these technological tools can afford students' opportunities to logically evaluate and process real-time data.

In an 8-week study of elementary children using light sensing probes, Settlage (1995) investigated how these technologies affected students' conception of light. The study involved 23 students (13 girls), in a third grade science classroom in an urban district in Boston. The researcher discussed the impact of using MBL tools with students after videotaping three lessons. The focus of the study was to teach students about the refractivity and reflectivity of light while using MBL probeware. At the conclusion of the three lessons, students presented orally their data to the class. Results indicated students could relate the phenomena of blocking light to data gathered and shown on the computer. Students explained how glitter in the snow globe interfered with the amount of light collected from the light sensor with little intervention from their teacher. Results revealed that students could discuss how these tools allowed them to measure light. The researcher suggests from investigating the third graders that the use of MBLs contributed to students' learning, in the mode of increased scientific inquiry facilities. Through the use of MBLs, the third graders developed an increasingly sophisticated understanding of graphs and how they relate to light. Settlage (1995) concluded the use of MBLs resulted in students constructing their own understanding of light as well as improving their skills of collecting, interpreting, and analyzing data.

Magnusson, Borko, Krajcik, and Layman (1992) conducted a study to examine the relationship between the knowledge of teachers and changes in student learning after experimenting with MBLs about heat energy and temperature. The study was based on an outgrowth of the University of Maryland Middle School Probeware Project (UMMPP), which focused on showing teachers how to use MBLs for instruction about heat energy and temperature. Participants in the study included six experienced eighth grade teachers and their students (n=22). The researchers used classroom observations and interviews of teacher and students in analyzing the impact of MBLs on the teacher and students. Findings of the study indicated students who performed more laboratory activities emphasizing the difference between heat energy and temperature show the most improvement in knowledge. Results suggest a relationship exists between the total number of MBL activities presented by teachers emphasizing the difference between heat energy and temperature and changes in students' knowledge. Using data from only those teachers who used the most or least number of activities, the researchers concluded that a more complex relationship could exist between the MBL activities and changes in student learning. One of the teachers who used no activities to emphasize differences in heat and temperature noted his students had the least amount of change in content knowledge in comparison to students who were exposed to these activities. The research findings suggest that MBL instruction is more powerful than traditional instruction for promoting the acquisition of scientific knowledge of heat energy and temperature. The researchers concluded that teachers' ability to use technologies with the instructional activities resulted in positive changes in the knowledge of students involved in the study. They also felt that the MBL activities that were presented in their study were powerful resources that account for changes in the students' learning of the concepts.

Stuessy and Rowland (1989) investigated the advantages of using MBLs in science labs. Specifically the researchers wanted to know if electronic data collecting capability, computerized graphing, or both influenced the effect of these technologies in science labs. The study involved 75 tenth grade high school biology students. The lab experiences were designed based on two methods, in which students had access to various electronic devices. One method involved using a mercury thermometer, a digital thermometer or computer probe for gathering temperature measurements. The second consisted of graphing results either by hand, delayed-time computer, or real-time graphing. Students were randomly assigned to five treatment groups using one of the measurement devices and one of the graphing methods. The Graphing Skills Test (GST) and the Content Test were used to measure students' abilities to interpret graphs and understand science concepts of heat of fusion and heat of vaporization. Results indicated that students who used the MBL tools scored significantly higher than those who used non-computer data acquisition techniques. They conclude that the real-time MBL intervention proved to be superior and the advantage of using these tools is the combination of electronic data gathering and computerized graphing.

The presence of technology in schools has resulted in changes in pedagogy and curriculum. The next section of this review examines relevant literature on these changes from a constructivist perspective. The section begins with a description of constructivism and explores how the presence of technological tools can impact student learning and classroom instruction.

Constructivism

Constructivism is a principle that has been eagerly accepted by many practitioners, in various subject areas, as a theoretical framework to structure classroom activities (Tobin & Tippins, 1993). To interpret the impact of the introduction of technological tools into science instruction a constructivist framework is employed. Constructivism in essence is based on the tenet that students through experience build their own knowledge. The presence of technological tools in a science classroom provides an environment rich in engaging experiences for students to construct their own knowledge. Rieber (1993) suggests the role of technology from a constructivist perspective is that of a tool to support the construction of knowledge by enhancing the interactions occurring in the child's environment and culture.

Learning is based on experiences. In the science classroom knowledge can be constructed in the context of performing experiments. The presence of technological tools in classrooms broadens the range of possible experiments, and increases the opportunity for students to develop their own understandings about what took place. Tobin and Tippins

(1993) suggest a constructivist setting allows students to "make connections, clarify, elaborate, build alternatives, and speculate as they use tools to solve problems" (p. 11).

Jakubowski's (1993) perspective of the role of tools in a constructivist environment is that they provide students the opportunity to take responsibility for their own learning. She believes tools empower students to be challenged and to use their prior experiences in learning new concepts. The presence of technological tools can enhance the exploration of phenomena giving students time to construct a deeper understanding of scientific principles.

According to Jonassen, Peck, and Wilson (1999), the presence of technologies can help students in constructing both personal and socially shared understandings of the scientific phenomena they are exploring. Five areas of learning that students should be engaged in while using technology as a tool in the science classroom (p. 218):

1. Active learning- students are able to explore, manipulate tools
2. Constructive learning- students discuss and reflect on using tools to complete a task
3. Intentional learning- students establish their own goals and procedures to carry out a task
4. Authentic learning- attempt to use reasoning and skills to solve real-world problem
5. Cooperative learning- work with others to solve a task

Each of these five areas of learning in a constructivist setting that uses technology provides students the ability to reflect and articulate their ideas with their peers and teacher. Therefore, it is the role of the teacher to provide a classroom environment where students are able to actively participate in constructing knowledge about scientific concepts as well as achieve one or more of the levels of learning (Jonassen et al., 1999).

Carter et al. (1999) investigated students' use of tools in constructing an understanding of circuits. The study involved 26, ninth-grade students in a Physical Science/Algebra I class. Results indicated students who were actively involved in using tools were more verbally active. However, the researchers concluded that tools did not serve as mediators of students' learning. Limited experience with tools and circuit components impeded students' ability to mediate their understanding of the concepts using the technologies. "Children at this age have the ability to manipulate, analyze and construct their own theories" (Inhelder & Piaget, 1958, p. 340) as they use tools. Therefore, efforts to provide students experiences with using technological tools gives them more time to engage in meaningful learning. In accordance Howe (1996) suggests Vygotsky and Piaget were constructivists who believed adolescents have the ability to construct their own meaning through the use of tools.

<u>Classroom Discourse</u>

Classroom discourse is often viewed as a <u>mode of social action</u> in which some form of learning is taking place in the context of speech (Lemke, 1990). It takes place as students use their reasoning skills to piece together the meaning of concepts learned during classroom activity in a logical manner and involves discussing the meaning of vocabulary terms and the expression of learning through verbal communications, gestures, or written text. Lemke (1990) noted that the ability to master science could be based on one's capability to use scientific discourse. Meaningful classroom discourse allows students to share some common terms and symbols that are used in the context of a science classroom (Jones & Carter, 1998). "Verbal mediation of knowledge may come about as a more capable student interprets directions, defines unfamiliar terms and functions as a verbal interpreter during discourse" (Jones & Carter, 1998, p. 265).

In today's science classrooms students need to connect reasoning, and other forms of communication skills as they use technologies to collect real time measurements. However, there is little known yet about how discourse of both students and teacher, is used around technological tools, such as the computers in science classroom (Lemke, 1990). According to Vygotsky (1978) children use speech as well as gestures to solve problems. Language allows them to share what they know with their peers and teacher as they work to resolve problems. Vygotsky (1978) suggests social interactions are critical in order for students to be able to construct their own knowledge. An essential feature of learning is that it creates a zone of proximal development, a term coined by the Russian psychologist, which suggests that learning blends various developmental processes that operate only when individuals interact with people in their environment and in cooperation with their peers (Vygotsky, 1978). "Language is not just a device for verbal and written communication, but also a tool through which students come to share ideas and feelings" (Dewey, 1959, p. 27).

In accordance with the Vygotskian perspective of knowledge construction, technological tools allow students to solve practical tasks through the use of speech and social interactions (Vygotsky, 1978). The presence of these technologies in the science classroom supports this method of learning in which students work collaboratively using the tools to solve and reason through complex problems (Newman, 1990). Jakubowski (1993) suggests an ideal learning environment exists when students can make sense of their own experiences and can logically communicate these experiences with others.

Jones et al. (2000) investigated how elementary students use science equipment and tools in constructing their own knowledge. The study focused on the students' conversations as they manipulate tools in solving problems, while working in same gender dyads. The study targeted on 30 students: 2 fifth grade classes and 3 second grade classes. Findings focused on specific patterns and context of discourse in the presence of tools, such as verbal and nonverbal behavior patterns, language and tool use, and model of resource use and context. Results indicated that males had higher interactions with tools and used more self-centered language while the girls were more sensitive to their classmates' ideas and feelings. The authors suggest having limited access to tools in the classroom positively affected discourse among dyad groups. Students were not as competitive and commanding as they used the tools to complete assigned tasks.

Investigating how elementary children conceive an understanding of light in an MBL environment, Settlage (1995) noticed that many of the students were able to thoroughly discuss the phenomena of light reflectivity and refractivity. As the students presented the data they collected using the light sensing probes, they explained in great detail what their graphs represented what took place during the activity. The researcher also noticed a difference in the repertoire of the students as they explain their findings to their classmates. It appears that the MBLs assisted in these students developing an increased understanding of graphs and how it relates to light. Settlage (1995) concluded that the students developed a certain measure of fluency with graphs. Students understood the relationship of the light intensity by using the light probes. They could interpret the path of light beam and some could actually depict modifications in light intensity over time using a line graph. The author summarized that the presence of MBLs in the science classrooms allow students to successfully interpret, analyze, and synthesize data.

Kelly and Crawford (1996) also sought to investigate how the presence of technological tools affects high school students' discourse. The study involved examining the social and conversational processes engaged by high school students enrolled in an Advance Placement Physics course using MBL tools. The students worked in lab groups of 3 or 4 and were novices to using the equipment. The study consisted of analyzing four 45-minute videotaped sessions of the students as they work on lab exercised using MBL devices. The study used Green and Wallat's multiple levels of interpretation for discourse analysis in examining results. Findings indicated in all four groups of students targeted for analysis, the computer was viewed as a partner by referencing to it in their conversations during each of the 45-minute sessions. Students detected that the some physical movements were irreconcilable with graphs presented by tools. Leading to them understanding the physics of their task of deciding what is constant velocity. Kelly and Crawford (1996) summarized their study by suggesting that an interchange exists as students seek support from the computer and it in turn offers support to the students. The researchers developed seven ways to categorized the students' conversations using the means-end domain analysis (pp. 702-704).

1. Computer representation is used to make a claim.
2. Computer is employed by students to make predications.

3. Students bring in the computer by demonstrating a feature of a representation.
4. Look for computer to make sense or clarify a physical phenomenon.
5. Use computer to find information.
6. Respond to computer as a member in the group.
7. Students recognize anomalies to either their own initial conceptions or to the expected results of experiment based on standard physics account.

According to Pedretti et al. (1998) discourse was also examined to find out how it was affected in the presence of technologies. Findings indicated that many of the students who participated in this project believed that discourse plays an integral part in learning science. "Most of the students emphasized that the conversations supported complex learning issues, whereas the small group focused on short-term, superficial gains from peer discourse" (Pedretti et al., 1998, p. 584). Interview responses revealed that students who used short cut perspectives on discourse viewed working and talking with peers as a means of completing their assignment quickly. They concluded that students were able to recognize through their use of discourse if really understood concepts. Overall, in these research studies, it appears that the discourse patterns of students are significantly affected by the presence of these new tools. The next section will explore research studies on students' conversations and physical behaviors in technology-rich classrooms.

<u>Conversations in Science</u>

In an effort to create a learning environment in which students develop an understanding of electricity, Cosgrove and Schaverien (1996) conducted a case study of nine-year old students using technologies. The study involved three parts in which the students used various technologies from an electricity learning and teaching package. The researchers identified four kinds of conversations they observed as a result of conducting the study. The conversations involved Coffee-table conversations, Feynman discussions, Critical or Galilean conversations, and Philosophical conversations. Coffee-table conversations occur as students discuss their ideas and indicate what they set out to do. Feynman discussions are conversations prompting students to engage in exploration. Critical or Galilean conversations occur as students bring their own ideas to discriminate between possibilities or defend suggestions. Lastly, Philosophical conversations take place as students "articulate new or partly formed ideas" (Cosgrove & Schaverien, 1996, p. 113). This kind of conversation reveals the depth of children's knowledge.

Cosgrove and Schaverien (1996) conclude the conversations observed during the study provided the students with the opportunities to talk about technology and science. In summary, they suggested the Feynman discussions offer a better method of inducting students into the use of techno-scientific investigations.

Students' conversations should not be solely viewed while examining the effects of introducing new tools or teaching practices. As Roth and Wetzel (2001) noted the physical actions or gestures of students can also be used in analyzing student discourse. The researchers sought to examine how the discourse patterns and gestures of high school students taking Physics. The study involved twelve females and seven males working together in self-selected groups. Data was centered on three assertions established by Roth and Wetzel (2001), which are as follows (p. 111):

1. Gestures enable students to construct explanations.

2. Gestures allow the coordination of phenomenal and conceptual layers of content.

3. time for the situated construction of an explanation decreases and speech increasingly takes over the representational function.

Results indicated that as the students constructed their own knowledge there were long periods filled with gestures until they could think of the correct terms or concepts. The researchers concluded that gestures and gesture-talk episodes could lead to unintentional understanding by the speaker. "The presence of materials, such as tools allow students to communicate before they are able to represent them in discourse merely by the use of gestures to enact them" (p. 128).

In investigating the social interactions and cognition of fifth grade students using levers, Jones and Carter (1994) analyze the verbal and nonverbal behaviors of the students working in ability-paired dyads. Grouping was based on students' prior California Achievement Test (CAT) scores. Three quartile ability groups were used in grouping students. Highs were paired with high or low. Lows with high or low and average were paired with other average students. Results revealed that high ability groups verbally expressed their ideas with their partners as they used the tools. The low achieving dyads had little discourse. Jones and Carter (1994) conclude that the high achieving students were able to verbally express their ideas and strategies to their partners as well as use equipment properly.

Keys (1999) investigated the ability of students to generate meanings for scientific data through written discourse. The study involved thirty-four students ranging in grades from seventh to tenth. Students participated in various inquiry projects on animal behavior and water quality. The researcher analyzed the students writings based on eight report propositions: "topical, affective, methodological, observational, factual, inferential, observation-inferential, and definitive" (Keys, 1999, p. 1051). Results indicated that student were able use metaphors correctly and were able to link inferences with their observations. Keys (1999) found that some of the students were able to produce linguistic patterns that expanded their scientific ideas and generated meaningful inferences.

O'Connor and Michaels (1993) sought to observe the discourse strategy of one classroom in microanalysis study. From prior work with discourse the authors, had an interest to better understand the processes of language in teaching and learning. From their research of one particular classroom they observed the teachers' discourse strategy of revoicing. Findings indicated that as the teacher uses the technique resulted in a mainstreamed student participating in the class discussion. They concluded that the use of this strategy allowed the student to gain confidence in her response and align herself with others in the class.

Svensson (2000) found through her research of the interactions of young children that they more communication occurs while they use computers than compared to other activities. The students tend to be more engaged in what they are doing as they use this form of technology. The author suggested that there were more discussions concerning how to solve the problem when the students work with computers. The study involved thirty-three eight-year children in nine different classes. Four different learning situations, along with student interviews were recorded and analyzed for the study to determine if the use of technology influenced the communication interactions of the students. Two of the learning situations involved the students working on computer-related exercises. Overall the interviews indicated that the children had a positive attitude towards using the computers. In summary, Svensson suggests a collaborative-oriented and positive interaction occurs when students are permitted to work with computers either as <u>computer-active</u> (controlling the mouse) or as a <u>computer-peer</u> (sitting beside <u>computer-active</u> student). "Students working in front of the computer can engage themselves in eventful, captivating, fun and meaningful learning" (Svensson, 2000, p. 448).

<u>Technology: Student Learning & Reasoning</u>

Teaching scientific inquiry to middle level students involves instruction in the purpose and skills of inquiry as well as how to carry out a set of tasks for scientific purposes (Flick, 2000). Friedler et al. (1990) studies of middle school students' use of scientific reasoning, while in an MBL environment indicated that proper instruction of reasoning skills is needed for students to make clearer observations and predictions while engaging in scientific learning. The researchers suggest technologies facilitate learning with its ability to present data in multiple forms such as tables and graphs. Children at this age are equipped with the rules of inference, which allows them to draw valid predictions from using tools to perform problem-solving tasks (Girotto & Light, 1993).

Based on <u>NSTA's Pathways</u>, students at the middle school level are able to understand the effects of using technologies in learning science and its influence on society (Rakow, 1998). In accordance with Inhelder and Piaget (1958), adolescents are conscious of their environment and the future. Introducing technologies in middle school science classrooms gives students the opportunity to develop more advanced reasoning skills.

Linn (2000) suggests the Knowledge Integration Environment (KIE) project supports middle school students learning by offering resources and tools to link science to their interests and concerns. "Knowledge integration is the dynamic process of linking, connecting, distinguishing, organizing and structuring models of scientific phenomena" (p. 783). The researcher suggests the presence of tools make students thinking visible as they engage in activities. The KIE project has been able to create a community of learners, where students are permitted to take responsibility for their own learning. "Students negotiate shared criteria for scientific reasoning and shared standards for scientific argument" (p. 788). Linn (2000) described the KIE project as a partnership inquiry process that encourages students to build on their ideas as "building blocks" through the use of instruction that invites students to "expand, revise, restructure, reconnect and reprioritize their models" (p. 783). This new approach to science instruction in the presence of technologies could result in transformations in the science pedagogy and curriculum.

As implied by (Jonassen et al., 1999; Jones & Carter, 1998) technological tools could be used in the pursuit of meaningful learning. Jones and Carter (1998) suggest "students share some understanding of the concepts and have the ability to use the tools in the science classroom" (p. 265). Therefore to fully understand the role and effectiveness of technological tools in science classrooms, teachers should provide activities that engage students in meaningful learning.

Comments: The Value of Technology in Schools

Technology applications such as spreadsheets, word-processing, and Microcomputer-Based Laboratories now have an indispensable part in science instruction (Nakhleh, 1994). Research has indicated that it is difficult for students to change their misconception, but tools such as MBLs and CBLs are capable to help students in restructuring their understandings. Technological tools can enhance students' abilities in learning new concepts. In order to realize the potential of these tools, Mergendoller (1996) suggests schools open their classrooms for new possibilities for learning by implementing some of the ideas showcased at the National Education Summit.

Summary

As stated in the National Science Education Standards "technology is essential to science, it supplies the tools and techniques that enable observations of objects and phenomena that are otherwise unobservable due to a variety of factors and the tools for investigations, inquiry, and analysis" (NRC, 1996, p. 66). This detailed review provided evidence of the limited amount of research performed on the cognition and reasoning ability of middle school students using technological tools, such as CBL devices. Technology has the ability to transform many aspects of science classroom instruction. Technologies can empower students to enter a world of high power thinkers and analysts. It can also serve as powerful devices to assist teachers in addressing the needs of diverse learners. Therefore, as suggested by Wetzel (2000) and Jones et al. (2000) there is a great need for additional research on the impact of technological tools, such as CBLs in middle school science classrooms. This study will hopefully set the precedence of additional investigations on how the presence of technologies, such as data collection tools, impact students' learning.

Technology as a Tool: Applying an Instructional Model to Teach Middle School Students to Use Technology as a Mediator of Learning

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Abstract

The science education community has been challenged to develop curricula that offer science educators and students a variety of experiences that highlight the advances of technologies. Although many approaches have been suggested for using technologies in school there has been little research on its use as a tool with middle school students. Students' use of data collection technologies transitioned from novelty to a tool capable of mediating understanding of scientific phenomena. A nine-week elective class, “Exploring Technologies,” was developed using a three phase model of scaffolding taught to 7th and 8th grade students (n=23). The interactions of the students throughout each of the phases of instruction were recorded and analyzed through audio and videotape transcriptions. A socio-constructivist frame was used in interpreting the findings of the study. Analysis of students’ interactions during the three phases of instruction indicated that the use of the scaffolding model for designing instruction allows for the effective infusion of technology into the curriculum.

Technology as a Tool: Applying an Instructional Model to Teach Middle School Students to Use Technology as a Mediator of Learning

Technology has the ability to transform many aspects of science classroom instruction. As the need for a scientifically and technologically literate society increases, the relationship between science and technology in the context of learning has increasingly become a focus of reform in science education (American Association for the Advancement of Science [AAAS], 1998; Rakow, 1998; Roblyer & Edwards, 2000). Therefore many science educators have purposely increased their use of technology, such as computers, media equipment, and data collection devices in the classroom to prepare students for the demands of a technological workforce. However, a more important reason for infusing technology into the curriculum is its potential of serving as a powerful learning tool that can enhance student learning of science concepts (Adams & Shrum, 1990; AAAS, 1989a, 1993b, 1998c; Mokros & Tinker, 1987; Roblyer, 2000; Settlage, 1995).

The <u>Blueprints for Reform in Science, Mathematics, and Technology Education</u>, reemphasizes the need for curricula that addresses the question of how to use technologies in schools in order to provide quality education for all (AAAS, 1998). Research studies have indicated that students using technology as tools tend to develop higher-order thinking skills, robust understanding of graph interpretation and advanced experimentation skills (Brasell, 1987; Kreuger & Rawls, 1998; Linn & Songer, 1991; Thornton & Sokoloff, 1990). However, infusing technology into the curriculum is not sufficient to guarantee enhanced learning. In some cases technology has been found to inhibit the learning process (Carter, Westbrook, & Thompkins, 1999; Hale, 1996; Lapp & Cyrus, 2000). Therefore, there remain many unanswered questions about the effective use of technology as a tool in science learning (Cajas, 2001; Gallagher, 2000).

The National Science Education Standards (National Research Council [NRC], 1996) advocate using an instructional approach that supports scientific inquiry and allows students to develop their own understanding by taking active roles in their own learning. According to this document students should use technology to develop the skills to do scientific inquiry as well as develop understandings about scientific inquiry. By providing students access to advanced technologies the possibility of conducting meaningful investigations can be enhanced. Sherman and Weber's (1999) work with the New Jersey Statewide Systemic Initiative (NJ/SSI) supports this claim that using technology in the context of scientific investigation can make learning science meaningful for students. They found that students using CBLs, "real-time" data collection devices, to complete problem-solving tasks had the opportunity to explore and design experiments on their own as well as to logically evaluate and process data. As a result of using this technology to support scientific inquiry students were able to build conceptual understanding as opposed to simply memorizing scientific facts.

Although there is evidence that technology can support inquiry researchers are quick to identify areas that need further investigation. For example there is little information available on how to teach students to effectively use technology as a tool (Huang & Waxman, 1996), to process scientific ideas using technology as a tool (Cajas, 2001), or how using technology as a tool can lead to richer, more distributed learning among students (Mergendoller, 1996). In essence, the critical question that emerges asks how instruction can be structured to allow for effective infusion of technology into the curriculum. This paper embraces this question by evaluating a potential model for just such an infusion.

Theoretical Framework

This study was framed by a socio-constructivist perspective with an emphasis on Vygotsky's mediators of learning. According to Vygotsky (1978) all knowledge is initially socially constructed before it is internalized by the individual. The movement from the social (external) plane to the individual (internal) plane is mediated by psychological and physical tools (Vygotsky, 1978). Language is recognized as the most important psychological tool; the potential use of technology as a physical tool of mediation is of primary interest in this study. However, providing psychological and physical tools in an instructional setting does not guarantee that learning will be mediated. This is best understood in terms of Vygotsky's "zone of proximal development". That is, a zone of possibilities, what the individual is able to accomplish when assisted by more capable others in the presence of mediating tools. These more capable others can be parents, teachers or other students who are further along the continuum of understanding for a targeted concept. What these more capable others do is give cues, explanations, help with using physical tools or give other forms of assistance, that provide sufficient guidance for the individual to accomplish the task.

Bruner first coined the term "scaffolding" to describe this complex process of assistance from more capable others (Cazden, 1988; Fleer, 1992). This is a complex process because a balance must be maintained between giving assistance and withholding assistance. Too little assistance leads to frustration and failure; too much assistance removes the task from the learner. In the classroom context the teacher has primary responsibility for scaffolding learning tasks. A model of scaffolding described by Cazden (1988) identifies the established roles of teacher and students in the teaching-learning process where learning is scaffolded by the teacher. The assistance provided by the teacher over time to accomplish the task is viewed as a continuum of responsibility. Initially the teacher provides significant assistance by serving as an expert and relying on techniques of direct instruction such as lecture, modeling and explicit directions. Once the teacher notices growth in the students' level of competence, joint responsibility emerges between the teacher and students as additional tasks are introduced. This joint relationship involves the gradual release of responsibilities by the teacher as students become more competent. The final step of the model involves relinquishing responsibility for the task to the students to complete tasks independently.

Vygotsky's conception of learning supports this instructional framework. Figure 1 illustrates the Cazden scaffolding model from a Vygotskian perspective. Initially in the teacher directed phase, phase 1 of the Cazden model, learning is situated in the external plane. The teacher takes primary responsibility for learning by providing direct instruction, step-by-step modeling and significant assistance to students as a new idea or skill is introduced. In phase 2 the learning task is scaffolded through the use of mediators, psychological and technical tools, and responsibility for the task is gradually relinquished. During this shared response phase the teacher moves from a mode of direct instruction to tasks that require some decision making on the part of the students. In phase 3 knowledge is internalized as support from the teacher is withdrawn and the student becomes capable of accomplishing the task independently.

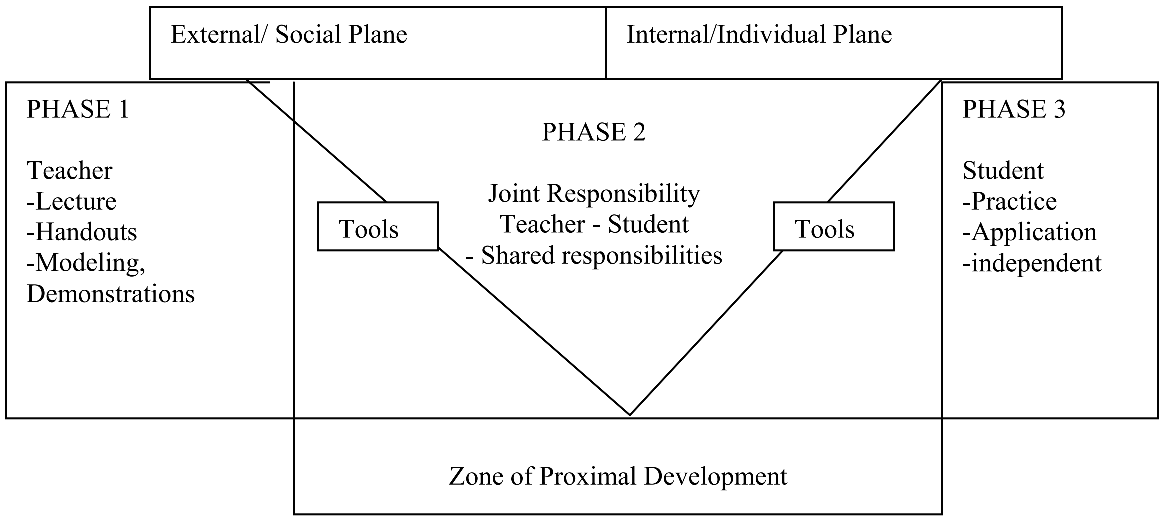

Figure 1. Instructional model illustrating scaffolding through a Vygotskian perspective. (J. Campione, in Pearson and Gallagher, 1983; Cazden, 1988; Carter et al., 1999)

The presence of tools such as the technologies previously mentioned broadens the range of experiences and increases the opportunity for students to develop their own understandings. In essence the tools can serve as mediators of higher learning (Miller, 1983) supporting the construction of knowledge by enhancing the interactions occurring in the classroom environment and culture (Rieber, 1993). Data collection devices such as the Texas Instruments CBLs and the Casio Data Analysis System offer students powerful learning experiences to use advanced technologies to solve real-world problems and do real science (Hale, 2000). These inexpensive, portable device systems enable students to collect data in a matter of minutes, allowing extra time to be spent interpreting and understanding data (Brasell, 1987; Grable & Curto, 2001; Kreuger & Rawls, 1998). However, as previously suggested, the use of technologies as tools is a complex process, requiring thoughtful planning and implementation. In summary, the mediating capability of the technologies can not be realized unless their use is scaffolded by the teacher. The application of this scaffolding model in the context of teaching students to use technologies as mediating tools will be described.

Research Methods

Research Site

The application of a scaffolding model to the development of a technology infused course was designed to examine middle school students' use of technology in the context of math and science instruction. To facilitate long term examination of the students' use of data collection and analysis devices in the context of inquiry, the researchers developed an elective course Exploring Technologies and were given permission by a local middle school to offer the class during the third nine-week term. A science teacher at the school volunteered to partner on this project and made all on-site arrangements. The middle school is a Gifted and Talented magnet in a large suburban school system located in the southeastern part of the United States. Operating on the philosophy that "all students possess gifts and talents" (GT Middle School, 2000/2001, p. iii) this middle school emphasizes the gifts and talents of its students by offering additional courses in the arts, sciences, mathematics, and technology. The Exploring Technologies elective class was consistent with this philosophy in that it allowed students to explore the use of technologies and further their interests in mathematics and science. The class met for 55 minutes per day in a general science classroom with tables arranged in a pattern that supported small group work. The classroom had lab counters with sinks along three walls and tables arranged in pairs so that students could easily work on tasks in collaborative groups (ENC Focus, 2001; National Council of Teachers of Mathematics [NCTM], 2000). Technologies present in the classroom included seven personal computers, a scanner, and a printer, which were stationed at the front to allow for easy access. There were 30 graphing calculators, 7 motion detectors and 10 data collection units each containing a Casio data analyzer and probeware to collect temperature, light, and voltage measurements. Two video camcorders were strategically placed in the classroom to capture visual images of students interacting with each other while they used the technologies. Nine audio recorders with clip on microphones were placed on the tables to capture the dialogue that occurred in student groups as they completed assignments. The authors of this article served dual roles as the researchers-instructors and were responsible for the daily lessons, data collection, and analysis tasks required in conducting this study. The participating science teacher assisted with instruction and handled routine management tasks. The teacher viewed "the situation as an opportunity for students to experience science in ways that she would otherwise not be able to provide" (Settlage, 1995, p. 537). Debriefing sessions were held daily and weekly between the researchers and the science teacher to discuss the happenings of the class and to make modifications in activities and research strategies (Roth, 2001).

Research Participants

The class consisted of 23 (9 females and 14 males) seventh and eighth grade students, who signed up to participate in the nine-week elective class, Exploring Technologies. Although students were self-selected into the study, the science teacher encouraged several students to enroll in the class and in doing so provided academic and ethnic diversity.

Students participating in the study were heterogeneously grouped for science but were placed into mathematics class according to ability. Students (n= 19) enrolled in Compacted 7th/8th grade math, Algebra, or Geometry courses were considered advanced in their level of understanding in mathematics, while students (n= 4) enrolled in the general mathematics courses were categorized as having an understanding of mathematics at grade level. Three minority students were enrolled in the class. The students' ranged in age from 12-13 years.

Case Study Research Design

A single case study design was adopted to observe the middle school students' use of technologies in the elective class. Merriam (1988) suggests that a single case study is appropriate in presenting information about an area of education where there is little research. The case study follows qualitative methodologies of (Creswell, 1994; Merriam, 1988; Spradley, 1980; Stake, 1995) as researchers collected, analyzed, and interpreted data. The researchers gathered multiple sources of data over the 9-week period (Wu, Krajcik, & Soloway, 2001). A complete field notebook of classroom observations was kept to record qualitative data in relation to data collection probeware used by students. Student notebooks and journals were collected and examined to determine how students were thinking as they were using the tools. The audio- and videotapes of student interactions during the course were transcribed for further analysis.

Interviews were used to obtain "descriptive data in the subjects' own words" (Bogdan & Biklen, 1998, p. 94) and focused on students' feelings toward using these technological tools to learn science. Eleven students were interviewed individually during the first two weeks of the course and 17 students, participated in the final interviews done in small group settings. All interviews were recorded and transcribed verbatim for analysis (Monhardt, Tillotson, & Veronesi, 1999). The interview questions evolved from a review of relevant literature and observations of middle grade students using technologies prior to the study. An interview guide was created to organize questions asked using Spradley's (1980) model. Questions focused on how students felt about using the technologies, prior experiences with the technologies and their perception of the technologies as beneficial or detrimental to their learning.

Exploring Technologies Elective Class: An Overview

The course was structured using a three phase scaffolding model in an effort to change students' conceptions of technology from artifact to knowledge and skills (Cajas, 2001). Phase I, which took two weeks, consisted of introductory activities that promoted students' learning to use the tools. During this phase, a teacher directed approach was used for instruction. Phase II provided a four-week transition period during which student responsibility for using the technologies to complete the tasks gradually increased while teacher responsibilities decreased. Phase III involved using a student-directed instructional approach, which supported the principles of scientific inquiry. During this phase, the class spent three weeks using the technologies to answer student-selected research questions.

At the beginning of Phase I students were assigned to groups by the science teacher. The science teacher made an effort to provide each group with what she anticipated would be a more capable peer. Each group of students was assigned a data analysis system, which included graphing calculators, a temperature probe, light sensor, and voltage probe. Seven motion detectors were shared by the students. Throughout the study a small group setting was used to afford opportunities of increased knowledge construction and inquiry (Jones et al., 2000). Some changes in group assignments were made during the nine-week period in an effort to enhance cooperation within groups.

Phase I: Introductory Activities

For the first two weeks of the elective, the instructors presented structured introductory activities focused on the mechanics of using the selected technologies. The graphing calculator was introduced first, with special emphasis given to the list and graph functions. A teacher-directed approach was used to give students practice learning these functions of the graphing calculator and to become comfortable with using it for later activities. Each student had access to his/her own Casio graphing calculator, although students could and did work together to learn its use. Students were given handouts with explicit, step-by-step instructions on how to enter and edit numbers in a list and how to generate various types of graphs from these lists. Using these directions students completed two activities, "Mystery Pictures" and "Mystery Numbers." Although these two activities required little effort from the students other than following directions, students who successfully completed the tasks were rewarded with a visual display sufficient to keep them engaged. Students also learned to transfer programs from one calculator to another and had the option of learning how to write simple graphing calculator programs. The instructors offered guidance as students worked at their own pace to complete the graphing calculator assignments.

After achieving competency with the graphing calculator, students were introduced to the data analysis unit. The first activity with the unit involved students using the voltage probe to take measurements of the battery potential of selected fruits. The handouts provided clear, precise directions on how to set up the system to collect accurate readings. After instructors demonstrated collection of voltage measurements, the students collected their own data. This was the least complex task using the unit since voltage readings were taken directly from the data analysis unit and the calculator was not required.

The next set of tasks required the use of the graphing calculator with the unit. As a way of teaching students to use the temperature probe, instructors gave students step-by-step directions on how to collect temperature readings of liquids. The temperature activities were repetitive and explicit to the extent that even the data table was provided for students' use. In the same manner, that is through the use of repetitive, closely monitored instruction students became competent with the light and motion detectors. As students became more comfortable with the system they were asked to evaluate the reliability and quality of data generated by the unit and how their use might impact the data collected:

> Teacher: This was another one where there were great variations in the data collected. What reasons would there be for that? Why is this, another one where people would get different things? Grant.
>
> Grant: The way you were holding the probe.
>
> Teacher: The way you were holding the probe?
>
> Grant: Yeah, at an angle or something.
>
> Teacher: Could have been angled. Found out when we did the light readings before that made a big difference.

Throughout all of the activities in Phase I the teacher and the instructors provided assistance to students who were experiencing difficulty using the unit. When necessary the instructors extended the introductory lessons to make sure all of students were able to complete activities, felt comfortable about using the tools, and understood how using the technology would assist them in completing other lessons.

During Phase I the conversations recorded reflected students' focus on learning to use the technologies. Procedural details were of the most concern and there was very little spontaneous discussion of the ideas being explored.

Jane: Don't move…wait till it stops ticking.

Amy: Got to go back to menu, there you go.

Jane & Amy: Press STAT.

Amy: Um huh.

Jane & Amy: There you go.

Amy: Okay. It is supposed to be set up line.

Jane: Oh.

Amy: And with the dots.

Jane: X graph, okay x with the list 1 y list 4 and M-type dot. Here x, list 4 and frequency is 1 and M-type.

Phase II: Transition

Although the novelty of the tools was sufficient to motivate students during the first two weeks of the course, the researchers had the goal of developing activities to introduce students to data collection tools and methods in "a natural and meaningful manner" (AAAS, 1993, p. 44). They also sought to "channel the students' inventive energy and to increase their purposeful use of tools- and in the process- broaden their understanding of what constitutes as a tool" (AAAS, 1993, p. 44). Therefore two projects that required students to apply their new skills were implemented. For the first project students had to develop and test a carnival game which met certain probability criteria. The second activity required the students to solve a “crime” using clues provided by the instructors. Both projects involved tasks closely aligned with the tasks completed during Phase I. The instructors did not identify the related tasks so students had to recognize the appropriate use of the data analysis unit. Students often referred to their handouts from Phase I and continued to ask for assistance as they used the technologies to accomplish the tasks. However, during this time the instructors began to withdraw some of their earlier support and encouraged students to attempt to develop their own strategies or to rely on each other for support. In addition, students were required to be accountable for their activities in the context of a whole class discussion. For example, in turn, each group had to provide a brief report explaining their selection of suspect(s) and to document their selection with evidence. Students were encouraged to challenge the findings of any group that were not supported by the data. This served to further instill the notion of accountability for the use of the technologies and shifted the responsibility towards the students. Although much of the conversations recorded during this phase focused on procedural issues, some of the dialogue reflected a shift from a primary focus on using the unit to the tasks at hand. The conversation below occurred as students used ball bounce data from a Phase I activity to interpret a clue given in the mystery project.

Jo: [in mid-sentence]…the bounce ratio is um 80% and dodge ball had a…

Brent: Go look under bounce and see what they had

Jo: Dodge ball had 81.9%, which is the closest, Soccer, I had the second one with 83.5, um.

James: Dodge

Jo: So I did dodge ball and the three people who had the dodge ball were Ms. H., Mr. G., and Ms. B.

Phase III: Inquiry

The culminating project for the course was a scientific investigation that required students to use the technologies to answer student-selected research questions. The groups had the option of selecting a question from an instructor-generated list or developing their own research question to investigate. Each group was responsible for designing their own experiment and determining what type of materials and equipment would be needed.

Seven groups selected questions that involved the use of the temperature probes. One group tested the light reflectivity of several different types of paper and one group used the motion detector to compare the velocities of toy cars. During the research investigations instructors limited direct instruction to issues of safety. When students asked for help, instructors would sometimes respond with a question designed to guide the students to think about the problem in appropriate terms. The instructors frequently asked the students to work together to solve the problem. During this third phase the primary responsibility for accomplishing the task shifted from the instructors to the students. During their presentations, groups were asked to state their hypotheses and explain whether they had conducted a “fair” experiment. The explanations that students offered during these presentations provided evidence that the technologies had been used to help students develop scientific ideas.

All nine groups were successful in using the probes to collect data. In the sense making process six of the groups extended their understanding of scientific phenomena. In the three groups for which there was no evidence of conceptual growth there was evidence of growth in the process of scientific investigations. Cognitive growth was measured by observing the students' explanations of their findings as it related to the scientific phenomena investigated. Figure 2 indicates the nature of the inquiries and summaries the outcomes for each group.

Group	Research Question	Area of Cognitive Growth
1	How does the temperature of the classroom differ in different areas?	Thermal gradients
2	What heats up faster? (Orange juice, water, syrup, ice)	Heat of Fusion
3	Which gloves will keep your hands the warmest?	Properties of Insulators
4	How does the slope affect the velocity of a toy car?	Relationship between slope and velocity
5	Which paper reflects light best?	Reflectivity as Related to Color
6	Does adding salt to ice water affect the temperature of the water?	Effect of Particle Size on Solubility
7	Which gloves will keep your hands warmest?	Evaluation of Data Quality
8	Which potato chip produces the most heat?	Recognition of procedural error-controlling variables
9	Does adding certain materials to water affect the temperature?	None noted

Figure 2. Summary of the scientific investigations and learning outcome for each group.

Group 1 wanted to explore the temperature differences in the classroom and used the temperature probe to collect temperature measurements at different distances from the floor.

As a result of their investigation the students were able to develop a new understanding of temperature zones by recognizing the gradient created by the heat generated by humans. Group 2 students investigated the heat capacities of various substances. After constructing a time/temperature graph for ice, students correctly identified the place on the line where melting was completed and articulated their notion of the heat of fusion. The students in group 3 also use the temperature probe to gather data about the effectiveness of several different types of gloves. After identifying the glove that was the best insulator they were able to link properties of the glove to the properties of effective insulators. Group 4 used the motion detector to determine the effect of slope on the velocity of a toy car. The students conducted six trials using a piece of wood for a slope, starting at a 10 degree angle and changing the slope by 10 degrees for each trial. Students were able to conclude that increase in slope resulted in an increase in velocity. Students in group 5 used the light probe and a flashlight to measure the reflectivity of different types of paper. After discovering that the white paper had the greatest reflectivity index, they were able to link that finding to the idea that white is the reflection of all colors. Group 6 students were interested in measuring the effect of adding salt to ice water. Students were able to detect a difference between results using rock salt and table salt. They concluded that the surface areas were different and may have impacted solubility. By "mashing up" the rock salt the students believed they could test their idea about surface area.

Although groups 7, 8, and 9 did not show evidence of conceptual growth, two of the groups improved scientific investigations skills. Group 7 used the temperature probe to collect data about gloves as insulators. Although the sense making process was inhibited by discrepancies in their data sets they eventually recognized the discrepant data. During their class presentation, they explained that data for Glove 2 would need to be recollected before they could make a conclusion. Group 8 burned different types of potato chips using a primitive calorimeter. This idea was sparked from an investigation they had recently completed in science class comparing the amount of heat given off by burning peanuts. During their presentation, questions concerning their procedures and the accuracy of temperature readings led to their realization that they had not controlled all variables and that their findings were invalid. Group 9 students used temperature probes to detect differences in water temperature when substances such as effervescent tablets were added. Although they reported their findings they were unable to suggest any explanations.

Throughout this student-centered phase, the researchers noted students using the technologies as tools to solve problems and answer questions pertaining to natural phenomenon. The shift of students' views of the technologies from novelty to tools was also evidenced by the way students talked about the tools during presentations and during final interviews. During the post interview students discussed how these experiences using the tools enabled them to apply technologies to understanding of science concepts.

> Interviewer: On the inquiry projects you choose to do different things, some of you did temperature with the potato chip and… you did temperature with the syrup. Why did you choose the temperature probes?
>
> Pierce: I liked using the temperature probes better because…
>
> Claire: It gives more accurate readings.
>
> Pierce: Yeah it's more accurate than the thermometer…. Just works best.

Trent: I really liked the motion detectors, they were really nifty and like the graphs they do and stuff and how they graph what happens.

Juliet: Like using the different probes and stuff. Helps you to understand better.

Jena: Um the calculators yes they are easier to use and then I will know how to do when we have to figure out something or we have to do an experiment we know how to use some technology to figure out the answer.

Sid: Yeah, I would get probably the EA100 cause I am very comfortable about using it. I know like how to get stuff done by it.

Discussion

The three phase design of the Exploring Technologies elective followed Cazden's model of scaffolding. During the initial phase a teacher directed approach provided students with detailed instruction, a modeled use of the technologies, and frequent assistance. The intensive training and repetitive nature of the tasks helped decrease the novelty effect of the technologies and enhanced students' skills in using them.

Phase II served to "wean" students from reliance on teacher assistance, although some assistance continued to be provided. This gradual release of responsibility by the teacher served to prevent frustration and further enhanced students' skill to use the technologies independently. During this phase students learned to recognize the appropriate situations for using the tools.

During Phase III the shift of responsibility for use of technologies was realized with the result that using tools to mediate understanding was accomplished by most of the groups. Although preceding statements summarize designing instruction using Cazden's model, several other strategies implemented during the phases served to facilitate the movement along the scaffolding continuum.

Student presentations were used in Phases II and III to ensure that students' own ideas and experiences from using the tools were discussed, so that "alternative views were on the table" (Lemke, 1990, p. 174). Requiring students to defend their ideas further established expectations of student responsibility. The students were engaged in "oral, and occasionally written, practice in class in restating scientific expressions in their own colloquial words, and in translating colloquial arguments into formal scientific language" (Lemke, 1990, p. 173). The group setting was also an important aspect of design since it provided an additional scaffolding source. Although at the beginning of the course no students had prior experiences with the technologies used, some students learned to use them more quickly and within the groups served as a more capable peer, facilitating other students' use of the technologies. This curriculum allowed students to use technology as a tool, first by giving them fundamental skills in using the tools in data collection, and then providing them with several experiences to use the tools to conduct scientific inquiry and engage in scientific discourse.

Conclusion

Teachers have reported that attempts to teach students to use new technologies and at the same time expect students to construct understanding of scientific ideas have led to failure and frustration. Instruction for teaching students to use the tools of science must be as carefully planned as any other form of instruction. From a Vygotskian perspective, this means planning instruction within students' ZPD and requires scaffolding by a more capable other if the potential for leaning is to be realized. For higher learning to occur, that is movement from an external to an internal plane, responsibility must be gradually relinquished to the individual. Relinquishing responsibility means allowing students to make mistakes and sometimes travel down a dead end street. Since time is a primary consideration for classroom teachers, at first glance this may appear to be an inefficient use of instructional time. However, making mistakes, learning to diagnosis and correct one's own errors is a critical part of becoming an <u>independent</u> learner, one capable of advanced problem-solving. The authors of the paper strongly suggest that scaffolding the use of technologies is not essentially different from scaffolding other types of learning tasks. By using Cazden's model of scaffolding, this instructional approach appears to be a viable strategy for changing the use of technology as a novelty, to a tool capable of mediating higher learning. The data collected provides evidence that students' perceptions of technologies as tools developed gradually in the course of the study. Students were able to offer complete explanations of their findings during small group and whole group discussions. They were able to use data collected to develop their own understanding of scientific phenomena. These three instructional phases: <u>teacher directed</u>, <u>teacher/student directed</u>, and <u>student directed</u> were effective in providing students with the necessary knowledge and skills to use technologies as tools. Students gradually developed the ability to ask critical questions about their presentations, which afforded them further opportunities to develop competence in using the technologies.

Science reformers are interested in the impact of technologies on the traditional science classroom pedagogy, which has generally been didactic and teacher-centered (Cohen & Barnes, 1993). If the instructional approaches are used in presenting technologies in the context of general science classrooms perhaps these tools will no longer be considered an end unto themselves rather as a means to improving science teaching and learning (Bush, 2001; Mergendoller, 1996; U.S. Department of Education, 1995). The three phases of instruction used in this study was able to provide support for students to use technology as a tool.

Science educators need to be conscious of the instructional approaches used in this study and how these methods can affect the way students view technology use in learning science concepts. The researchers were able to create a learning environment in which middle school students were able to process scientific and technological ideas and skills using technology as a tool.

Huang and Waxman (1996) suggest the regular use of technologies in middle schools could positively affect students' performance and confidence towards the subject. Living in such a competitive world, failing to define the proper role of technology can have adverse consequences on students being scientifically and technologically literate (AAAS, 1998).

If, in fact, the novice takes over more and more responsibility for the task at hand as demonstrably happens in all the examples we have seen, then we can infer, retrospectively, that our help was well timed and well tuned, and that the novice was functioning in his or her zone of proximal development, doing at first with help what he or she could very soon do alone (Cazden, 1988, p. 107).

In this research study, a class of 23 middle school students participated in a structured set of activities, which resulted in their eventual use of technology as a tool to explore scientific ideas. Although there has not been much research on using technology as a tool in the context of a middle school science classroom, the Exploring Technologies elective class provided evidence that the three-tiered structure of scaffolding can be used to design instruction of use of relevant technologies. Further research is needed to determine how these instructional approaches can affect students' use of technology as a tool to process, manipulate and analyze data.

"We must prepare learners for their future, not for our past" (Thornburg, 1999, p.10).

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Running head: UNCOVERING THE POTENTIAL

Uncovering the Potential: The Influence of Technologies on Science Learning of Middle School Students

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Abstract

There is, no doubt, untapped potential in using technological tools to enhance understanding of science concepts. This study examines the potential by observing middle school students' using technologies as tools in a nine-week elective class. The Exploring Technologies elective class was offered to 7th and 8th grade students (n=23). To illustrate the use of technology as a tool to mediate understanding, the investigations of two groups of students are described. Students' use of data collection devices and subsequent interactions were traced through audio and videotape recordings. In examining the two specific incidences of middle school students using the tools there was evidence of technology maximizing student learning in science. The middle school students were able to use the Casio data analysis systems in the context of investigations to develop scientific ideas related to temperature and heat. The findings of the study indicated that students were able to use the tools to conduct scientific inquiry and engage in scientific discourse. Further research on instructional approaches that allow students to develop expertise in using technologies as tools to construct knowledge about complex phenomena is encouraged.

Uncovering the Potential: The Influence of Technologies on Science Learning of Middle School Students

There is widespread belief that the use of technology in schools is critical to the development of our children as evidenced by the billions of dollars spent annually to outfit classrooms with the latest technologies (American Association for the Advancement of Science [AAAS], 1989a, 1993b, 1998c; Bush, 2001; ENC Focus, 2001; Office of Educational Technology, 1999; Roblyer & Edwards, 2000; U.S. Department of Education, 2000; U.S. House of Representatives, 1994). This belief about the importance of access to technology is shared by many education communities including the science education community. AAAS (1993) suggests that effective integration of technology can result in an increase in science learning among students. The National Science Education Standards (NSES) recommends providing students with equitable and frequent opportunities to use a wide range of technologies to support investigations of phenomena and to develop understanding of fundamental concepts taught in science classrooms (National Research Council [NRC], 1996). Yet there is scant information for science educators on how to effectively use technology in the context of the science classroom (Roblyer & Edwards, 2000). As funding for providing technologies in schools has increased, so have questions about the extent to which it is being used in classrooms and for what purpose (U.S. Department of Education, 2000). The catalyst for these questions arises from recognition that providing technologies for students and teachers does not necessarily provide for its effective infusion into the curriculum. How to use technology as a tool to maximize learning is an important research question and the focus of this paper.

That the potential exists for using technology to improve learning in science has been substantiated in several research studies. Using tools such as the graphing calculator and data collection probeware can enhance the development of higher order thinking skills (Kreuger & Rawls, 1998), the ability to graph data (Brasell, 1987), and the ability to interpret graphical representations (Adams & Shrum, 1990). Using technological tools in classrooms has also been found to support providing genuine, authentic science experiences (Mokros & Tinker, 1987; Nicaise, Gibney, & Crane, 2000; Wetzel, 2000) by offering numerous opportunities to logically evaluate and process real-time data (Friedler, Nachmias, & Linn, 1990). However, there is evidence that using tools with which students have had limited experience may be ineffective and in fact can impede cognitive development (Hale, 1996). The novelty of the tools may distract students from the original purpose of the lesson (Carter, Westbrook, & Thompkins, 1999), may interfere with making connections to tangible concepts of natural phenomena (Lapp & Cyrus, 2000), and may promote skepticism about the data collected thus leading to retention of misconceptions (Hale, 1996).

Although the role of technology in science learning has been viewed as a virtual unknown (Jones et al., 2000) its use in the science classroom has been known to afford numerous opportunities of scientific discourse, scientific reasoning, and a greater understanding of experimentation by making thinking visible as individuals engage in activities (Linn, 2000; Linn & Songer, 1991). The research literature does suggest that technologies can be effectively used as tools by offering learners the ability to explore, measure, and make connections between science-technology and the physical world (Thornton & Sokoloff, 1990). Despite the evidence that tool usage may not enhance all students' conceptual development, the frequent use of technologies in the science classroom has promoted improved scientific reasoning and process skills in problem solving and an improved understanding of science concepts such as thermodynamics (Friedler et al., 1990; Linn & Songer, 1991). There is, no doubt, untapped potential in using technological tools to enhance understanding of science concepts. However, conflicting research findings indicate that the mechanisms by which this can occur need significant examination. Intensive studies, which examine and describe the use of these technologies is needed to form a global framework from which a model of technology infusion into the curriculum can be developed.

The purpose of this study is to provide research information about the effective use of targeted technologies as instructional tools in a middle school setting. Specifically this study uncovers the potential of middle school students using technologies, such as Casio's Data Analysis System to develop an understanding of temperature concepts. The researchers adopted a broad theoretical framework to provide insight on how to design the research study and how to interpret the findings.

Theoretical framework: Tools as mediators

A social constructivist frame is used for this study within which a Vygotskian perspective is embedded. From this perspective, all learning initially takes place on a social plane before being internalized by the individual. Vygotsky (1978) described this movement of understanding from a social, external plane to the internal plane as mediated by the use of both psychological tools and technical tools. Psychological tools include language systems, counting systems, and diagrams; technical tools can include equipment such as microscopes, circuit boards, data collection devices, and calculators (Carter et al., 1999; Miller, 1983).

Even though technical tools are externally oriented, they influence thinking. For example these tools can serve as mediators when students use them to connect classroom activities with their physical and social world (Miller, 1983). In instances where technology is not used as a tool, (i.e. novelty of tool causes tool to become focus of activity) then the mediating capability is not realized. Tool use in the context of the science classroom limitlessly broadens the range of activities within which the new psychological functions operate (Vygotsky, 1978).

The Vygotskian perspective also includes viewing the potential for learning dependent upon a <u>zone of proximal development</u>. This zone is best described as a psychological sector in which the promise for an individual’s learning can be realized. In this zone there is the potential for intellectual growth as a student interacts with more capable peers through the use of psychological and/or technical tools (Vygotsky, 1978). Therefore the students' use of technology as a mediating tool has the potential of improving and enriching classroom learning in a variety of subjects (Taylor, 1980). Both tools help to shape thinking, and the use of technical tools by students as they express their thoughts to others can increase conceptual development (Miller, 1983). Therefore, theoretically, a learning environment is maximized when learning is mediated by technical tools in conjunction with the use of psychological tools such as student dialogue.

Method

A case study approach was selected with the intent to gain insight on how the presence of technological tools might affect the way middle school students respond to learning science (Stake, 1995). This case study involves a descriptive approach and is "useful in presenting basic information about an area of education where little research has been conducted" (Merriam, 1988, p. 27). Following qualitative methodologies of data collection (Creswell, 1994; Merriam, 1988; Spradley, 1980; Stake, 1995), the researchers were able to capture critical moments of knowledge construction by students using the technologies as tools. Video and audiotapes were used throughout the study to gather data on student interactions in small groups and during class presentations. Transcripts from video and audiotapes were "examined to create a representation of what went on in the classes and to generate a description of the interactions that took place" (Seiler, Tobin, & Sokolic, 2001, p. 750). Field notes and students' work were analyzed to assess performance of students using technological tools, such as the temperature probe to perform experiments. Data were analyzed to examine how students' use technology in the context of scientific inquiry. Two specific incidences related to the development of ideas about heat and temperature will be described to elucidate the impact of instruction when instruction has been designed to facilitate the use of technology as a tool.

Context of the Study

In setting up the parameters for the research study it became apparent that no existing classroom was available to researchers to support the long-term investigation. Therefore the local middle school with whom a formal partnership existed was contacted and subsequently agreed that the researchers could offer a nine week technology elective class, providing an enrichment opportunity for their students and a study site for us. This middle school is a Gifted and Talented magnet whose philosophy is based on the belief that "all students possess gifts and talents" (GT Middle School, 2000/2001, p. iii). Students at this school are given the opportunity to explore their gifts and talents through the selection each quarter of 2-3 elective classes of interest to them.

Working with a science teacher at the school, the researchers developed a nine-week class, Exploring Technologies, and offered it as an elective for the third quarter of the school year. As an elective course students were self-selected into the class. However, the science teacher recommended the elective to a cross section of students, in doing so provided academic and ethnic diversity. Scheduling constraints eliminated this elective as an option for sixth graders. The class that resulted consisted of 23, 7^{th} and 8^{th} graders who elected to take this class in addition to their core math and science classes. In this school all students were enrolled in heterogeneously grouped science classes but were grouped by ability for their mathematics classes. Students (n= 19) enrolled in Compacted $7^{th}/8^{th}$ Math, an accelerated mathematics course for 7th graders, Algebra I, and Geometry were considered advanced in their level of understanding in mathematics, while students (n=4) enrolled in the general mathematics courses were considered to be at grade level in their understanding of mathematics. The makeup of the class was 9 females and 14 males. Three minority students were enrolled in the class and students' ranged in age from 12-13 years.

The elective class was held in a science classroom with tables arranged in a pattern so that students were able to work collaboratively in groups while using the technologies. Seven personal computers, one scanner and a printer were stationed at the front of the classroom to allow easy access. The arrangement of the class provided an adequate and safe space to enhance the collaborative, learning environment (NRC, 1996). Video camcorders were placed at the front and rear of the classroom to obtain an all-inclusive view of the students and instructors using the technologies. The two video camcorders were able to provide the researchers visual images of students interacting in cooperative groups as they used a wide range of technologies to investigate natural phenomena. Nine audio recorders with clip-on microphones were used to capture the dialogue that occurred in small groups as students engaged in investigations. The recordings were transcribed for analysis. The authors served dual roles in the study, as teachers and researchers. The teacher-researchers were involved in the contingencies of teaching, collecting, and analyzing data collected. Daily and weekly debriefing meetings between the teacher-researchers and classroom teacher were used to make changes in activities, to discuss what was happening in the classroom, and to reflect on research strategies (Roth, 2001).

Design of the course

The researchers specifically designed the course to introduce and facilitate students' use of a data analysis system that included a graphing calculator, a data collection device, a temperature probe, a voltage probe, a light probe and a motion detector. The nine-week elective was purposefully designed and implemented in three phases in an effort to change students' conceptions of technology from artifact to knowledge construction devices (Cajas, 2001). The researchers had the goal of developing activities to introduce students to data collection tools and methods in "a natural and meaningful manner" (AAAS, 1993, p. 44).

These activities were designed to give students fundamental skills in using the equipment as a tool in data collection. One goal was to eliminate novelty effects and eventually enable students to use the equipment as tools. The researchers designed and implemented the course in three phases based on Cazden's model of scaffolding (Cazden, 1988). During the first phase, a teacher-directed instructional approach was used specifically to provide intense training on how to use the equipment so that procedural tasks could eventually become routine (Carter et al., 1999; Hale, 1996). This would serve to reduce the novelty of using the technologies and enable students to understand how data is generated using the data collection devices (Lapp & Cyrus, 2000). Students were first introduced to the list and graphing functions of the graphing calculator. Then they were presented with a set of repetitive activities to establish procedural routines. After students became competent in the use of the graphing calculator, the data collection device was added to the system. Students engaged in activities using the temperature, voltage, and light probes and motion detectors until they could proficiently use the probes to collect data and could troubleshoot the devices.

After spending two weeks on the first phase, the second phase of the course was implemented. The model's joint responsibility instructional approach was used to provide structure for the students but required them to make some limited application of their knowledge of the tools to two activities (Cazden, 1988). For both activities (carnival and mystery activities) students worked in collaborative groups using the technologies to accomplish the assigned tasks. The final phase used a student-centered instructional approach. In this final phase, students worked in groups of two or three to design investigations to answer selected research questions. The students had the option of choosing their topic from a list of inquiry questions provided by the instructors or developing their own inquiry question to investigate. Each group decided on the design and the tools they would use for their experiment. As a safety precaution, each group gave the instructors a list of materials they would use to perform the experiment as well as a brief description of the procedures they would use to conduct the experiments. After receiving instructor approval, each group carried out their investigation and prepared a report on their findings. After all groups had completed their investigations, each group presented their findings to the class. During the presentations, students were asked to state their hypotheses, defend their experimental design, present their data and draw conclusions based on data analysis.

Creating the culture

Throughout the study a small group setting was used to afford opportunities of increased knowledge construction and inquiry (Jones et al., 2000). The researchers sought to create a learning environment that positively affected students' comprehension of graphs (Brasell, 1987; Hale, 1996) and afforded rich opportunities to make connections between the graphs to tangible concepts of natural phenomena (Lapp & Cyrus, 2000). To maximize the potential of increasing students' conceptual development, collaborative grouping was used throughout the nine-week period. This addressed the issue of limited available equipment but more importantly increased the opportunity for peer interactions (Settlage, 1995). Group assignments were based on seating arrangements and observations of students' performance during Phase I. Using the tools to support a constructivist perspective of building on knowledge through the use of hands-on, inquiry-based activities and providing opportunities for collaboration among students and teachers was the goal of the study (Linn & Songer, 1991).

Since this elective course was being taken in conjunction with general science classes the researchers centered lessons around teaching the students to use technology in furthering their understanding of science concepts. The students used the technologies to design and conduct investigations focused on one of the following: temperature, light, voltage, or motion. The structure of the lessons not only encouraged students to construct personal and socially shared understandings of scientific concepts but to also use the technologies to conduct investigations and engage in meaningful learning (Jonassen, Peck, & Wilson, 1999). The use of presentations to the whole class afforded further opportunities for students to explore and defend their ideas.

Summary

Activities in Phase I served to teach students to use and troubleshoot the data collecting equipment. Activities in Phase II gave students guided practice in applying these skills in new situations. The inquiry projects assigned during Phase III supported student-centered exploration. This assignment not only allowed students to demonstrate their mastery of using the technologies to develop an understanding about natural phenomena, such as temperature, light, and motion, it "challenged them to shape their thinking and express thoughts to others" (Miller, 1983, p. 391). Several of the students elected to design projects that involved using the temperature probe. The students worked in collaborative groups of three or four, sharing their views as they used the tools of their choosing to answer student-generated questions. As a result of conducting inquiry projects using the associated technologies, students were able to construct ideas about science concepts. Illustrating the mediatory capability of the technologies the following two scenarios were selected. The scenarios offer insight on how two groups of middle school students were able to use their mastery with the tools to develop thought (Miller, 1983). Pseudonyms are used to protect the privacy of students described in the following scenarios.

<u>Scenario One: The Human Zone</u>

The first scenario describes the interactions of Group 1 as they completed the inquiry project assigned during Phase III. This group was composed of 3 male students (Jo, James, & Brent). Jo, an 8^{th} grader, and James, a 7^{th} grade student were enrolled in Algebra 1. Brent, an 8^{th} grade student was enrolled in a general 8^{th} grade mathematics course. The students had worked together on the "carnival activity" in Phase II and were comfortable sharing ideas and understandings with each other. Jo and James dominated the group discussions as well as the physical interactions with the tools. Brent was easily distracted by others and by the equipment. The researcher noted several incidences of Brent singing in audiotape recordings throughout the course. However, he made an effort to work with the other students to complete all activities. Jo and James assigned Brent the job of recording data as they performed experiment.

Jo, James, and Brent selected the following question for their project: "How does the temperature of the classroom differ in different areas?" During the planning session the students hypothesized that since hot air rises there would be a steady increase in temperature from the floor to the ceiling. Students spent two days collecting their data. Some of the time was spent negotiating heights of readings and deciding whether or not to remove a ceiling panel to increase the possible distance from floor. After the students finished collecting data they worked as a team to analyze and interpret readings. They prepared an overhead transparency to show their data to the class as a way to document their conclusions. When their turn came to present their findings Jo placed the transparency on the overhead (see Figure 1) and began to talk. They explained their original hypothesis and how the data they collected did not support it. The students went on to give a possible explanation for the actual pattern they observed.

> Jo: Alright, um our group did an inquiry …I mean our experimental test was whether as you go up in elevation in a room you can show that the temperature increases or decreases.
>
> James: Our hypothesis is that the higher you go above the ground, the higher the temperature will be.
>
> Jo: We always measure it exactly when we put it over there. The only controlled variable, uncontrolled variable that we had was height above ground…anyway our conclusion, our hypothesis was wrong cause as you can see our data looks sort of like an upside down bowl, I guess like that, it starts sort of slow and then gets bigger, I mean higher and then flattens out and then goes back down again. And the reason we thought this was so, because at the bottom where the temperature is low we thought that the floor was cold and that sort of made the temperature low. From about 2 ft to about 7 ft above the ground the temperature was sort of the same; we called this the <u>human zone</u> [italics added] because humans giving off body heat in this area.

When questioned about the circulation of air movements, they respond by explaining that heat rises and that the warmest air in the room is at the ceiling.

> Teacher: Do you know anything about warm air vs. cold air movements?
>
> James: Heat rises.
>
> Teacher: So where would you expect to find the warmest air in the room?
>
> James: At the ceiling.

As a way to further explain their reasoning, the students diagramed how they thought the air conditioning system worked. Below Jo explains the diagram to the class:

> Jo: This is a diagram of how the air conditioning system works. And air comes out of the top of the ceiling. The air is very strong and it pushes it down to the bottom, here is sort of…goes down to the floor.

The student-centered instructional approach used during this activity allowed the students to construct the meaning of this concept in their own words. The students explained the principle of humans radiating heat and how it affected the circulation of air in the classroom in a manner that everyone in the class could understand (Lemke, 1990). They made sense of their data by linking their findings to prior experiences and in the sense making process extended their own understanding. The temperature probes allowed this group to make accurate readings, which contributed to the discovery of a phenomenon familiar to thermal engineers. Albeit couched in middle school language their explanation parallels the AHRAE Standard 55 of Thermal Comfort Zone which HVAC engineers apply when installing air conditioning systems in buildings (American Society of Heating, 2000/2002). The diagram and description of the air conditioning system is evidence of students relying on intuitive conceptions of temperature differences in a room. The boys were able to rely on their own conceptions to explain an event or phenomenon not studied in-depth in class (Lewis & Linn, 1994).

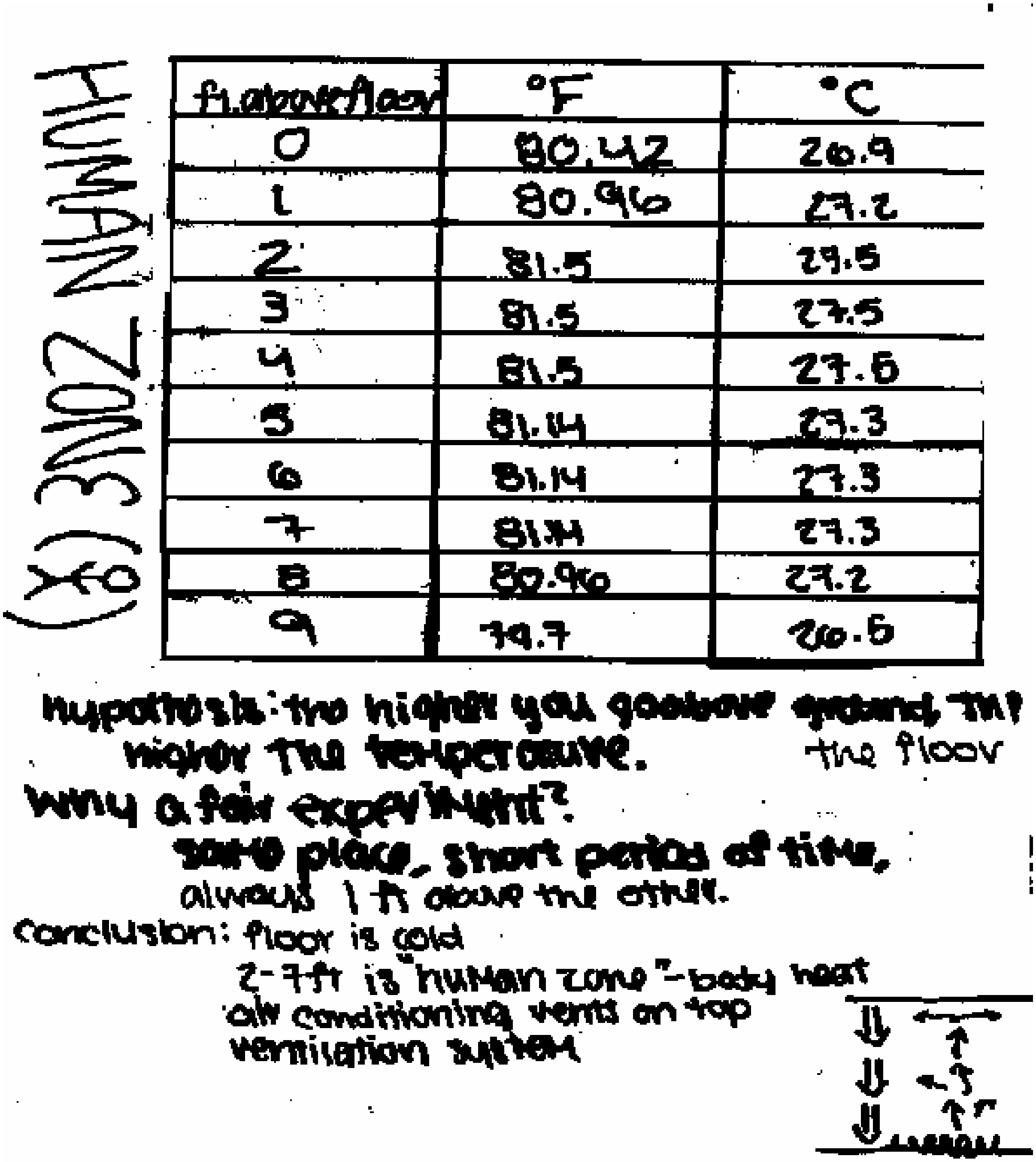

Figure 1. Overhead transparency prepared by Group 1 to illustrate their findings and conclusions.

The next scenario describes the work of the second group, which was composed of 2 male students, Jesse and Adam. As in the case of the students in Group one, they had also worked collaboratively prior to this assignment and had learned to negotiate ideas with one another. Below is a brief description of how the students were able to extend their ideas about heat and temperature by investigating the heat capacities of various substances; water, syrup, orange juice, and ice water.

Scenario Two: Heat of Capacity

After the assignment had been made, Jesse and Adam skimmed the list of suggested topics. They agreed that the suggested investigation on rates of temperature increase was of interest to both of them. During the planning session they identified four liquids that were readily available to them and then conversed about how to control the variables in their experiment. In planning their investigation, they decided on the procedures and material, including who would bring in the substances to use in their experiment. They also spent approximately two days collecting temperature readings. As they began recording their initial readings, they recognized other variables that would need to be controlled, such as the distance of the temperature probe from the bottom of the beaker and the necessity of using a clean probe for each trial. This resulted in several retrials. In this case the temperature probes freed students from focusing on actual task of reading a thermometer and allowed them time to concentrate on controlling variables and interpreting data. After they were satisfied that their procedure had allowed them to collect the data needed, they compared the readings and noticed the water heated up more quickly than the other substances they had chosen. During their presentation to the whole class, the boys presented their findings. Jesse placed the transparency on the overhead (see Figure 2) and began to talk.

Jesse: We wanted to see what heats up the most, water, ice, syrup, or orange juice. And we found out that water heats up the most.

Adam: Yeah water heated up 51.355. The ice heated up 46.827, syrup heated up 30 degrees and orange juice heated up 26.0290.

The students went on to explain the variables they used to make sure the controlled experiment was "fair".

Jesse: And the way we controlled it is that we did it at the same temperature back there on those things with different 1,2,3,4,5,6 [temperature setting on burners]. So we kept it on 6 and we used 30ml of a substance, the same kind of beakers.

Adam: The same time.

The students had prepared a line graph showing the increase in the temperature of the substances over time. During the presentation one of the instructors noted to the class that one of the graphs the group had prepared was similar to the phase diagram for water, shown in high school chemistry textbooks. When asked about their diagram for ice the students were able to identify the area of the graph where the all the ice had melted and also noted that until the ice melted the temperature stayed the same.

Teacher: Okay, don't go away. Leave your overhead up here please. Okay you all did a great job on this. And I'm going to tell you how I know you did a great job. If you look at this, where it says ice water [pointing to graph], that graph looks like what a graph in a chemistry book would show. What does this graph tell you about what happens when you put ice on a hot plate? What's the graph telling you happened?

Pierce: Well that it…melts.

George: I agree with Pierce

Trent: It …pretty constant and then like I guess the ice melts quickly since it is on the burner. So you see less ice melting completely so you start going up really big.

Teacher: So what are you suggesting …at this point what happens?

Trent: That there is no more ice.

In this case, upon probing by the instructor the students used the graph to begin constructing a rudimentary notion of heat of fusion.

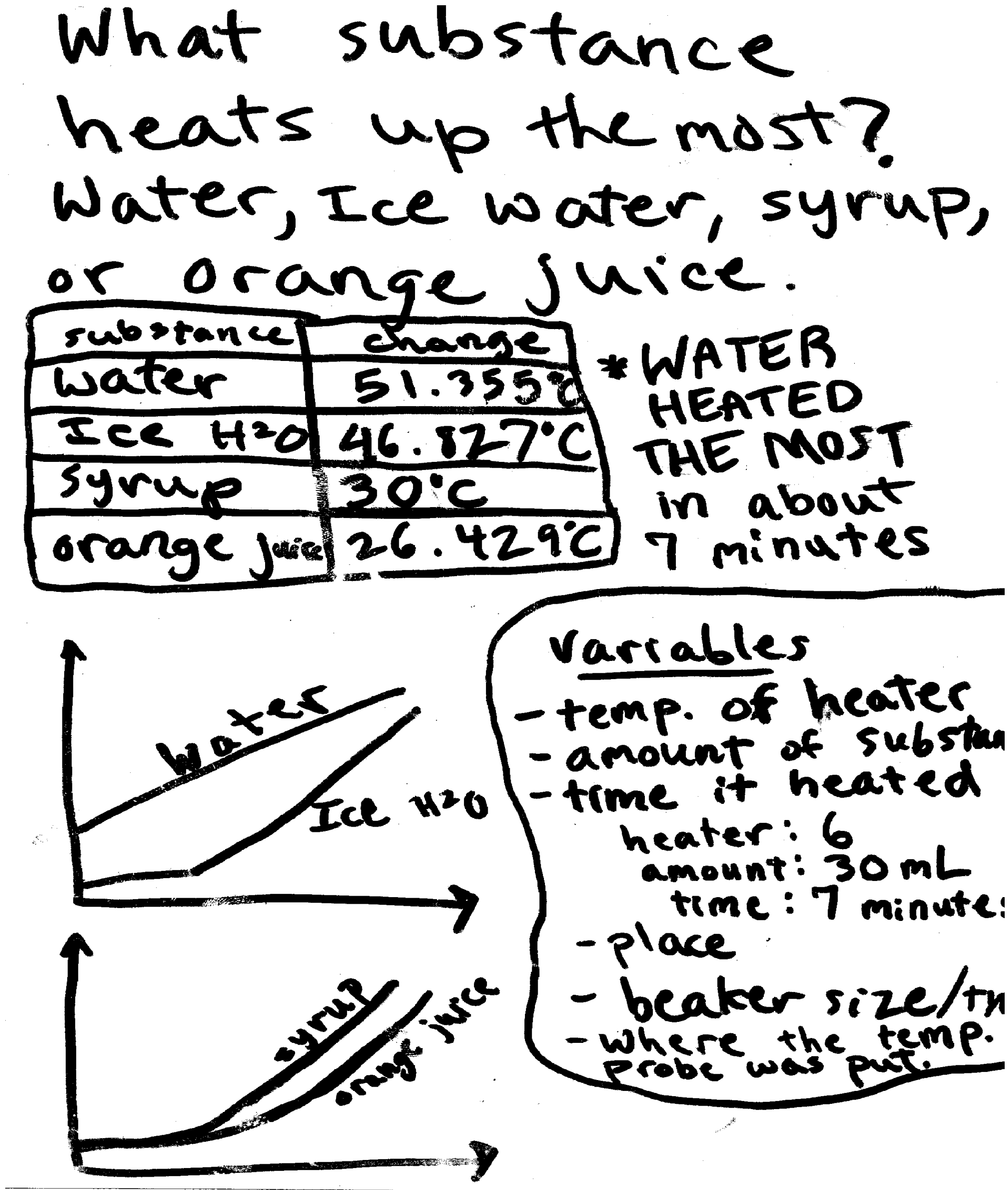

Figure 2. Overhead transparency prepared by Group 2 showing data collected and variables controlled.

Group 2 also explained how the tools improved their investigative skills. Below Jesse responds to the following question, “How might your experiment be different if you were in a non-technology classroom?”

Jesse: Oh it wouldn't have been as precise.

Teacher: Right

Jesse: Cause the EA100, it is really precise and if we had used a thermometer we would have to do it ourselves…and really big chance of human error.

Conclusions

Findings of this study indicate that middle school students were able to use the technologies provided to promote the qualitative and quantitative nature of their scientific investigations. The two examples described are remarkable in that students were able to carry out investigations in a brief amount of time but were able to construct initial understandings of scientific phenomena. In essence, the technologies enhanced students' learning of science concepts by providing them with the opportunity to collect high quality data. As the students themselves pointed out, if they had tried to collect data using a thermometer rather than a temperature probe there would have been a greater likelihood of human error. Additionally the data collection devices relieved enough tedium from the task of data collecting so that students were willing to recollect data when, in the process of their investigation, necessary corrections to their experimental designs were recognized. By examining high quality data, patterns emerged that enabled students to engage in the sense making process. From a Vygotskian perspective when technologies are used by students as described in this study technologies become mediators of the learning process by providing the raw material for the sense making process.

Educational and Research Implications

The science education community wants to enhance science learning of middle school students through the use of technologies (AAAS, 1993). The findings of this study indicate that technological tools are capable of serving as mediators of learning when used in the context of scientific investigations.

However, it is important to note that students were able to use the technologies for scientific investigations after several weeks of using the technologies in less complex contexts. If the scientific investigations had occurred early in the elective it is likely that procedural issues associated with using the technologies would have interfered with the sense making process and the potential of the technologies would not have been realized. If technology is to be effectively infused into the curriculum science educators must recognize their potential as mediation agents and must facilitate their use as such. A few guiding principles for readers to consider if they wish to achieve this goal involves carefully planning instruction for teaching students to use the tools within students' ZPD. Instruction should allow for scaffolding by a more capable other if the potential for learning is to be realized. Evaluating the use of technology is a beginning in forming a needed global framework from which a model of technology infusion can be developed.

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CONCLUSIONS

Instruction for teaching students to use technology as a tool must be carefully planned. From a Vygotskian perspective, the curriculum used in this study was planned within students' ZPD through the use of scaffolding. In this research study, a class of 23 middle school students participated in a structured set of activities, which resulted in their eventual use of technology as a tool to explore scientific ideas. The middle school students were able to carry out investigations and engage in the sense making process. The data collection devices relieved the tedious aspects of data collecting so that students were willing to recollect data when, in the process of their investigation, necessary corrections to their experimental designs were recognized (Brasell, 1997). Some of the students were able to construct initial understandings of scientific phenomena as a result of using the technologies to perform scientific experiments. In essence the learning environment created in the study afforded students' opportunities to process scientific and technological ideas and skills using technology as a tool.

Cazden's model of scaffolding was used in designing this viable strategy for changing the use of technology as a novelty, to a tool capable of mediating higher learning. The three instructional phases: <u>teacher directed</u>, <u>teacher/student directed</u>, and <u>student directed</u> were effective in providing students with the necessary knowledge and skills to use technologies as tools. Students were first taught fundamental skills in using the tools in data collection, and then provided with several experiences using technologies to conduct scientific inquiry and engage in scientific discourse. The gradual release of responsibility by the teacher afforded students' opportunities for higher learning. Students were able to make mistakes, learn to diagnose and correct errors while becoming independent learners, capable of advanced problem solving. The Exploring Technologies elective class provided evidence that the three-tiered structure of scaffolding could be used in teaching students to use new technologies as well as allow them to construct understandings of scientific ideas.

Findings of this study indicate that middle school students were able to use the technologies provided to improve the quality of their scientific investigations. The technologies enhanced students' learning of science concepts by providing them opportunities to collect high quality data. As the students themselves pointed out, if they had tried to collect data using a thermometer rather than a temperature probe there would have been a greater likelihood of human error. By examining high quality data, students were able to engage in the sense making process.

Some may read the findings as evidence that technology can effectively be infused in the context of a middle school science classroom. The length of the course, small class size, and the lack of racial and ethnic diversity in the class are some of the limitations of the study. The author acknowledges the limitations and confronts readers to understand findings based on the context of the study. These findings should be viewed as a basis for seeking additional research on how to implement instruction for teaching students to use technology as a tool for learning.

Suggestions for Further Study

If an instructional approach is used in presenting technologies in the context of general science classroom perhaps technology as a tool will no longer be considered an end unto itself, rather as a means to improving science teaching and learning (Bush, 2001;

Mergendoller, 1996; U.S. Department of Education, 1995). Evaluating the use of technology is a beginning in forming a needed global framework from which a model of technology infusion can be developed. Further research is needed to define the proper role of technology and in determining how this instructional model can affect students' use of technology as a tool to process, manipulate, and analyze data.

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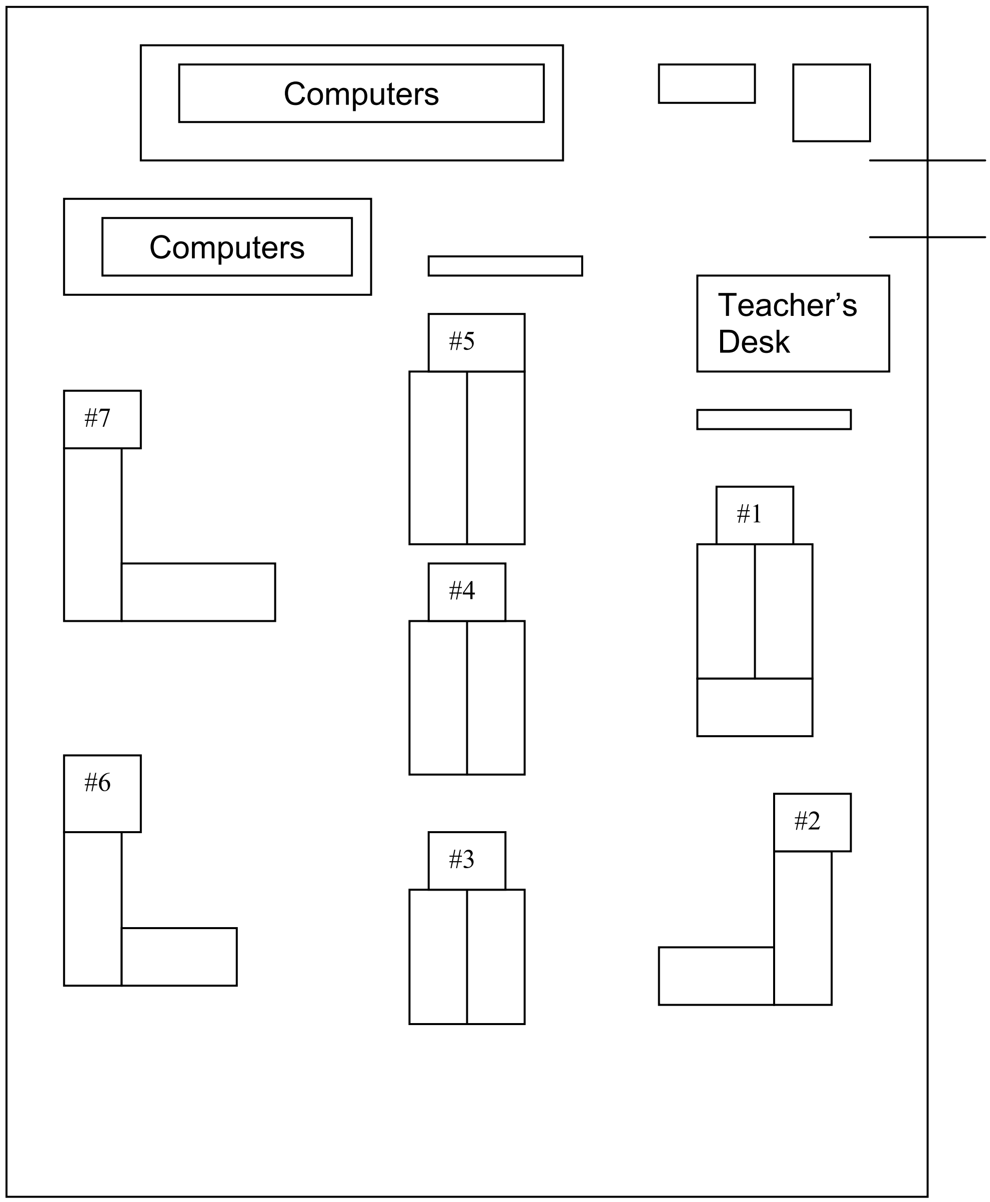
Appendices

Appendix A
Schedule of Activities
(January- March, 2001)

Monday	Tuesday	Wednesday	Thursday	Friday
8 End of 2nd nine weeks	9 Intro. Calculator Activities	10 Mystery #'s & Mystery draw Activities	11 Leaf Drawing Activity	12 Teacher Workday
15 Holiday	16 Intro. Mystery Voltage & Temperature Activities	17 Motion & Temperature Activities	18 Motion & Temperature Activities	19 Motion & Temperature Activities
22 Temperature "cool down", Match motion, & Light intensity activities	23 Temperature "cool down & Light intensity activites	24 Mystery Powders	25 Introduction to Mystery Activity	26 Chromatography, Mystery Powders
29 Match motion, Mystery powders, Mystery case	30 Mystery Case	31 Logic Activity Mystery Case	1 Mystery Case	2 Mystery Case
5 Mystery	6 Mystery	7 Mystery	8 Mystery	9 Mystery
12 Teacher Workday	13 Spinners Activity Probability Lessons	14 Assessment Probability Lessons	15 Probability Lessons	16 Intro to Carnival Activity
19 Carnival Planning	20 Carnival Planning	21 Carnival Planning	22 Carnival Planning	23 Carnival Planning
26 Carnival Presentations	27 Carnival Presentations	28 Carnival Presentations	1 Carnival Extension	2 Carnival Presentation & Intro to Inquiry Activities
5 Inquiry Projects	6 Carnival Presentation	7 Inquiry Projects	8 Inquiry Project Presentations	9 All About Us Activity
12 Inquiry Presentations Mr. Circuit Activity	13 Mr. Circuit Activity Post- Interviews	14 Ice Cream Activity Assessments, Technology Skills Survey	15 Teacher Workday	16 Teacher Workday

Appendix B

Layout of Educational Setting



Appendix C
Interview Guide

Introduction:

Greetings/ Small Talk

Explain the purpose of the study

Background:

Have you ever used tools prior to attending class?

Probes: What type of tools are you familiar with?

How have you used technologies?

Research Information:

Which instruments do you feel comfortable about using?

Probe: Showing others how to use? How do you feel about using technology in this class? Which activities do you feel you gained the most?

Probe: How has working with others affected your feelings about the class? Fun? Difficult?

How has using tools in this class affected your attitude towards learning science and math?

Overall, how do you feel about the class and using the tools?

Closing information:

Thank you for your time

Do you have any question?

Leave

Follow up Interview/Post- Interview

Appendix D

Initial Technology Skill Survey

I. Directions: Indicate how you feel about each of the following statements by circling one of the numbers.

Circle **5** if you **strongly agree**
Circle **4** if you **agree**
Circle **3** if you are **not sure**
Circle **2** if you **disagree**
Circle **1** if you **strongly disagree**

	Strongly Agree	**Agree**	**Not Sure**	**Disagree**	**Strongly Disagree**
1. The graphing calculator activities have increased my enjoyment in learning math and science.	5	4	3	2	1
2. The graphing calculator activities make science and math more interesting.	5	4	3	2	1
3. I know how to enter and delete a list using the graphing calculator.	5	4	3	2	1
4. I know how to use the main menu of the graphing calculator to perform several tasks.	5	4	3	2	1
5. I can create pictures using the graphing calculator.	5	4	3	2	1
6. I know how to write my own program using the graphing calculator.	5	4	3	2	1
7. I can transfer programs from one graphing calculator to another.	5	4	3	2	1
8. I know how to use the graphing calculator and data analyzer to determine the voltage of some foods.	5	4	3	2	1

Overall:

9. Which activity(s) using the graphing calculator did you most enjoy? Please explain your answer.

10. Which activity(s) using the graphing calculator did you learn the most? Please explain your answer.

Appendix E

Final Technology Skill Survey

I. Directions: Indicate how you feel about each of the following statements by circling one of the numbers.

Circle **5** if you **strongly agree**
Circle **4** if you **agree**
Circle **3** if you are **not sure**
Circle **2** if you **disagree**
Circle **1** if you **strongly disagree**

	Strongly Agree	**Agree**	**Not Sure**	**Disagree**	**Strongly Disagree**
1. The data collection activities using the probes and motion detectors increased my enjoyment in learning math and science.	5	4	3	2	1
2. The data collection activities make science and math more interesting.	5	4	3	2	1
3. By using the data analyzer, probes (voltage and temperature) and motion detector, I can easily collect and analyze data.	5	4	3	2	1
4. I know how to use the graphing calculator to show data collected using the data analyzer, probes, and motion detector.	5	4	3	2	1
5. I can create graphs using the data collected on the graphing calculator.	5	4	3	2	1
6. I know how to use the motion detector to determine bounce of a ball.	5	4	3	2	1
7. I can determine changes in temperature using temperature probes.	5	4	3	2	1
8. I am able to solve problems using the graphing calculator, data analyzer, probes (voltage & temperature) and motion detector.	5	4	3	2	1

Overall:

9. Which activity(s) using the graphing calculator did you most enjoy? Please explain your answer.

10. Which activity(s) using the graphing calculator did you learn the most? Please explain your answer.

Appendix F

Initial Technology Skill Survey Results

		Criteria*				
No.	Question	SA	A	NS	D	SD
1.	The graphing calculator activities have increased my enjoyment in learning math and science.	5	13	4	1	0
2.	The graphing calculator activities make science and math more interesting.	15	7	1	0	0
3.	I know how to enter and delete a list using the graphing calculator.	20	2	1	0	0
4.	I know how to use the main menu of the graphing calculator to perform several jobs.	18	2	3	0	0
5.	I can create pictures using the graphing calculator.	16	4	1	2	0
6.	I know how to write my own program using the graphing calculator.	4	4	8	2	5
7.	I can transfer programs from one graphing calculator to another.	10	5	5	0	3
8.	I know how to use the graphing calculator and data analyzer to determine the voltage of some foods.	14	7	2	0	0

Note. Criteria: SA=Strongly Agree; A=Agree; NS=Not Sure; D=Disagree; SD=Strongly disagree. Total number of students surveyed = 23.

Appendix G

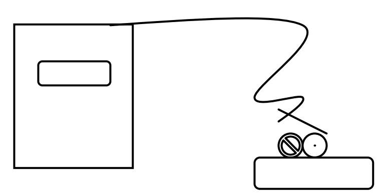
Final Technology Skill Survey Results

No.	Question	SA	A	NS	D	SD
		Criteria*				
1.	The data collection activities using the probes and motion detectors increased my enjoyment in learning math and science.	7	12	0	0	0
2.	The data collection activities make science and math more interesting.	9	9	1	0	0
3.	By using the data analyzer, probes (voltage & temp.) and motion detector, I can easily collect and analyze data.	12	7	0	0	0
4.	I know how to use the graphing calculator to show data collected using the data analyzer, probes, and motion detector.	16	2	1	0	0
5.	I can create graphs using the data collected on the graphing calculator.	18	1	0	0	0
6.	I know how to use the motion detector to determine bounce of a ball.	12	7	0	0	0
7.	I can determine changes in temperature and using temperature probes.	14	4	1	0	0
8.	I am able to solve problems using the graphing calculator, data analyzer, probes (voltage & temp.) and motion detector.	10	8	1	0	0

Note. Criteria: SA=Strongly Agree; A=Agree; NS=Not Sure; D=Disagree; SD=Strongly disagree. Total number of students surveyed = 19.

Appendix H

Samples of Assessment Questions

Question	Student Responses
Temperature:	
Erma wants to design an experiment to see which liquid, coffee or tea, cools down more quickly. Write a set of directions that would tell Erma how to design a "fair" experiment.	Students describe setup of experiment using a step by step approach. They note the importance of using the same amount of liquids and using the same temperature. Jo- Heat coffee & tea to the same temperature; setup EA100, probes (thermometer), and calculator accordingly; place, say, 250 ml of each in a bowl, and stick the probes in; hit the trigger button on the EA100, then wait; when done, open your calculator's list feature & subtract the ending temp. from the highest temp.
Voltage:	
Using picture & diagrams explain the proper way to set up an experiment testing for voltage of a fruit or vegetable.	All of the students provided the same drawings for setting up this experiment. Few of the students failed to describe the voltage setup. Example: Jane- EA100 

Appendix I

Additional Samples of Assessment Questions

Question	Student Responses
Technological Tools: Explain in your own words how data collection devices such as the EA100 can help students learn science.	Students provide brief explanations on how the technologies have been used in class. Jo- EA100s help you collect data. Using that data you can do a plethora of things; make laws, theories, rules, inferences, and interpret data to form a conclusion about something. Ex. Ball bounce heights-soccer ball always bounces the highest. Jane- The EA100 can be used to help students learn science because they can see what would happen if you drop a ball or leave soup and hot chocolate out for a while. It is interactive learning & hands on.
For each of the following identify any science, math or technology you learned as a result of doing the activity. (cooling liquids, inquiry projects, etc.)	Students list the activities they conducted in class during the nine-week period. Student: Jo wrote: Activity: Cooling liquids- Fun Science: hypothesis Math: Cooling liquids- Celsius Technology: Cooling liquids- Probes, EA100, calculator Activity: Inquiry Pjt- Fun Science: "human zone" hypothesis Math: Temperature, graphs Technology: Temperature probes