ABSTRACT

ENNIS, JACKIE STRUM. Through The Lens of the Microscope: Examining the Addition of Traditional and Digital Microscopes to the Study of Cell Theory in a Rural Middle School Setting. (Under the direction of Dr. Ellen S. Vasu).

Situated in the classrooms of three middle school teachers in a rural school system in North Carolina, this study examined the variable of microscope use on three levels – no microscopes, analog microscopes, and digital microscopes – during the unit on cells. The study was designed to benefit from the use of two complementary parts – a quasi-experimental quantitative part and a qualitative component.

The quantitative component of the study utilized two instruments, the Scientific Attitude Inventory II (SAI II) (Moore & Foy, 1997) and a content test developed for this study. Each instrument was administered as a pretest and a posttest to each of the three groups of students. An analysis of covariance (ANCOVA) was conducted on the scores of each instrument. Results of the ANCOVA on the content test showed that when controlling for the pretest scores, there were no differences between the mean posttest scores of the students in the three learning environments. Results of the ANCOVA on the SAI II showed that when controlling for the pretest scores, there was a statistically significant difference ($p<.05$) among the mean posttest scores. However, Scheffe's Method of Multiple Comparisons revealed no significant differences among the scores of the three groups of students. Descriptive data provided the scores of the students in each classroom disaggregated by gender and by racial identity.

The qualitative component utilized classroom observation, teacher interviews, and student interviews as data sources in each of the three learning environments. Analysis of the data suggested that the students in all three classrooms were engaged in the learning activities

and benefited from the learning experiences provided. However, the students who used the digital microscopes were more engaged than the other two groups. These students used technology as a mindtool to help them bridge the concrete experiences to the abstract concepts associated with cell theory. However, the teacher who used the digital microscopes became so interested in having the students explore with these tools that she missed opportunities for them to use the devices for knowledge construction. Two types of digital microscopes were also compared, revealing a preference for the less expensive tool.

THROUGH THE LENS OF THE MICROSCOPE: EXAMINING THE ADDITION OF TRADITIONAL AND DIGITAL MICROSCOPES TO THE STUDY OF CELL THEORY IN A RURAL MIDDLE SCHOOL SETTING

by

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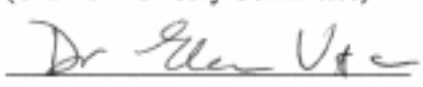

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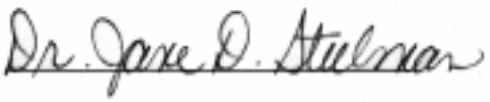

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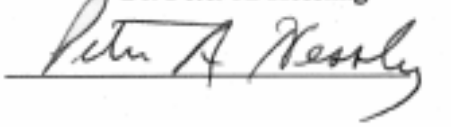

This work is dedicated to my family who

has supported me during this project,

including my Heavenly Father,

my husband, Jim,

our children, Logan and Margo,

my earthly parents and parents-in-law,

and Granny.

BIOGRAPHY

Jackie Strum Ennis was born in Red Oak, North Carolina in 1958. She grew up with her parents, Jack and Charlotte Strum, and her sister, Lottie, on a family farm. She married Jim Ennis in 1979. Their son, Logan, was born in 1983, and their daughter, Margo, was born in 1986. This family of four continues to live in the community of Red Oak.

Ennis graduated from Atlantic Christian College with a degree in Elementary Education in 1981. She taught mathematics, science, and technology courses to students at Parker Junior High in the Rocky Mount City Schools from 1981 – 1990. In 1981, she also began a program at Campbell University, earning a Master's degree in Middle School Education in mathematics and science in 1984.

From 1990 – 1995, Ennis taught mathematics, science, and technology courses at Benvenue Middle School in Nash County Schools (which merged with the Rocky Mount City School during this time frame, forming the Nash-Rocky Mount School System.) In 1995, Ennis was hired as an instructor in the School of Education at Barton College. She has remained in that department since 1995, and she is now an Associate Professor of Education. Ennis serves as the Middle School Education Coordinator and as the Instructional Technology Coordinator for the School of Education. In addition to these responsibilities, she teaches methods courses in the Elementary Education and the Middle School Education programs, teaches courses in instructional technology for all education majors, and supervises student teachers in the Elementary Education and the Middle School Education programs. During her tenure at Barton College, Ennis has served as a co-coordinator for a PT3 Grant focused on using technology to implement problem-based learning. She has also received a grant from Merck Pharmaceuticals, Inc., to help prepare majors in Elementary

Education and in Middle School Education to teach science and mathematics to their future students. The materials purchased by this grant are offered to area public school teachers, as well as to the preservice teachers at Barton College. Ennis oversees the implementation of this program. In addition to working with public school teachers through these grants, Ennis has provided numerous staff development workshops to public school teachers in surrounding school systems. In 1997, Ennis began the Ph.D. program in Curriculum and Instruction, with a concentration in Instructional Technology, at North Carolina State University. She was elected to the NCSU chapter of the Honor Society of Phi Kappa Phi.

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INTRODUCTION

Problem

National standards in science, and state standards based on them, have been developed (American Association for the Advancement of Science [AAAS], 1993; National Research Council, 1996; North Carolina Department of Public Instruction [NCDPI], 2004a). These standards call for changes in the content and skills that students are taught. Practices such as inquiry-based teaching, learning that is grounded in concrete activities, and active engagement in learning activities are encouraged. While progress has been made in implementing these standards, much work remains to be done in implementing the principles and reforms in science teaching that accompany these standards (Anderson & Helms, 2001; Edelson, 2001; Roseman, 1997; Sarason, 1996; Songer, Lee & Kam, 2002). Federal mandates have been issued that emphasize the need for improvement in science education. One particular mandate addressed the need for schools to capture students' interest in learning mathematical and scientific ideas (U.S. Department of Education, 2001, n.d.).

Data from the 1995 Third International Mathematics and Science Study (TIMSS) suggest that the longer the student stays in an American school, the worse his/her progress is, when compared to the test results of students in other nations. Research examining National Assessment of Educational Progress (NAEP) scores showed that during the middle school years, students' interest in learning about science declined (Simpson & Oliver, 1985; Yager & Penick, 1986). Simpson and Oliver (1990) found that student attitudes toward science are positively correlated with student motivation and achievement in science courses. They also noticed that the students' attitude toward science is a strong predictor of achievement in future science courses. Singh, Granville, Dika, and Johnson (2002) found that the success

students experience in science courses in middle school is related to whether they choose to take science electives in high school and whether they choose to pursue careers in the field of science.

Research studies on teaching and learning in middle schools have shown a need for the curriculum to be relevant, challenging, and exploratory. Studies also show a need for multiple approaches to teaching and learning, to which a diversity of students can respond, to be implemented in middle school classrooms (National Middle School Association [NMSA], 2003a). The need for improvement in middle school teaching methods that promote the success of a diversity of students in science courses is evidenced in the results of national testing scores. Data from the 1995, 1999, and 2003 TIMSS (U.S. Department of Education, National Center for Education Statistics, n.d.) administrations show a persistent gap between males and females in the eighth grade. While the gap between African American and White students in the eighth grade has narrowed from 122 score points in 1995 to 89 score points in 2003, a troubling difference remains (Gonzales, Guzmán, Partelow, Pahlke, Jocelyn, Kastberg & Williams, 2004).

Studies regarding the use of technology in the classroom have shown promise in improving some areas of education (Apple Computer, Inc., 1995, 2002, 2005; Christmann & Badgett, 1999; James, Lamb, Bailey & Householder, 2000; Kulik, 2002; Mann, Shakeshaft, Becker, Kottkamp & Lewis, 1999; Roschelle, Pea, Hoadley, Gordin, & Means, 2000; Sandholtz, Ringstaff & Dwyer, 1994; Sivin-Kachala & Bialo, 2000; Waxman, Connell & Gray, 2002), but more needs to be learned. A specific area of need is the use of technology to improve middle school students' attitudes and achievement in middle school science. One area of interest is the use of technology as a mindtool. Jonassen and Carr (2000) define a

mindtool as a device, such as computer, that can be used to help students build a bridge from a concrete experience to an abstract concept. Research into the use of computer technology specifically as a mindtool that can foster visualization is also needed (Linn, 2003). To complicate matters, a digital divide exists that affects the distribution of access to technology resources (Soloman, Allen & Resta, 2003). In addition, students attending schools in some rural areas, including North Carolina's rural counties, tend to perform less well on science achievement tests than their peers in other areas (Fan & Chen, 1999). The research referenced in this section will be discussed in more depth in the second chapter of this document.

Purpose of the Study

The purpose of this study was to investigate the use of microscopes in the study of cell theory at the middle grades level. Research based on the Apple Classrooms of Tomorrow (ACOT) (Apple Computer, Inc., 2005) found that the presence of computers seemed to serve as a catalyst for change in the classroom, facilitating a move to a more constructivist style classroom. This body of research also suggested that technology can help to provide students with multiple representations of ideas. A synthesis of research on this program (Apple Computer, Inc., 1995) concluded that skills that students need for the 21st century, including the ability to work and communicate with others, can be fostered by the use of the computer. Another conclusion from a body of research was that the use of technology might improve students' attitudes toward learning, which is an important goal in science education (Schiefele, 1991; Simpson & Oliver, 1985, 1990; Singh et al., 2002). In addition, a study examined the correlation between the Basic Skills/Computer Education (BS/CE) program implemented in West Virginia public schools and statewide assessment scores over an eight-

year period. The researchers concluded that as a whole, 11% of the students' achievement gains were considered to be accounted for by the BS/CE program. A review of over 80 studies conducted in grades K-12 on the effectiveness of computer-based technology concluded that computer-based technology can serve as tools that support effective educational environments, by promoting active engagement and collaborative learning (Roschelle et al., 2000). Kulik (2002) reviewed 36 evaluation studies on instructional technology in mathematics and science programs and concluded that instructional technology can benefit mathematics and science programs.

The purpose of this study was to examine the use of technology, in the form of digital microscopes connected to computers, in the teaching of cell theory at the middle school level. The researcher proposed that the presence of technology, in the form of microscopes – especially digital microscopes attached to computers – may foster constructivist learning and student engagement, facilitate understanding of content related to middle grades cell theory, and encourage positive attitudes toward the learning of science. Situated in the classrooms of three middle school teachers in a rural school system in North Carolina, this study examined the variable of microscope use on three levels – no microscopes, analog microscopes, and digital microscopes – during the middle school unit on cells. While the focus of the study was to examine the use of technology in teaching cell theory, this study also compared the use of digital microscopes to a more traditional type of technology – analog microscopes – and to a control situation where no microscopes were provided to the students.

Following the recommendations of Brewer and Hunter (1989), this study consisted of two complementary components – a quantitative part and a qualitative part. The quantitative part of this study examined changes in student attitudes toward science as measured by

pretests and posttests using the Scientific Attitude Inventory II (Moore & Foy, 1997). The study also investigated changes in the students' content attainment as measured by pretests and posttests using a content test developed for this unit of study.

The purpose of the qualitative part of this study was to provide insights into how the students and teachers viewed the teaching of this unit when no microscopes were used, and with the addition of the analog and digital microscopes into the unit on cell theory. The researcher proposed that when students used digital microscopes to observe cells and to capture images of them, they may become more engaged in their learning than when technology is not present. Thus she observed students to see how they responded to the addition of microscopes in the classroom. She was particularly interested in observing the students' engagement in learning in each of the three classroom situations. Student interviews provided insights into the students' attitudes toward the unit on cell theory in each of the three classroom environments. Interviews with the teachers provided additional data regarding how the teachers viewed the addition of analog and digital microscopes into the middle school unit on cell theory.

The Intervention as it Relates to the Problem

The intervention in this study was the addition of microscopes into the middle school unit on cell theory. This variable has three levels – no microscopes, analog microscopes, and digital microscopes that are connected to computers. As stated above, national standards for science education have been created. Benchmarks for Science Literacy, the goals established in Project 2061 (American Association for the Advancement of Science [AAAS], 1993), and the National Science Education Standards (National Research Council, 1996) provided national guidance regarding what students should know and should be able to do by the end

of certain grade levels. Both of these documents specify the goals that students should attain by the end of the eighth grade. The North Carolina Standard Course of Study (North Carolina Department of Public Instruction [NCDPI], 2004a) for science education is closely aligned to these national standards. The life science goal in the 2004 North Carolina eighth grade Standard Course of Study states that students will build an understanding of cell theory. Competency Goal 6 of this document specifically states, "The learner will conduct investigations, use models, simulations, and appropriate technologies and information systems to build an understanding of cell theory" (NCDPI, 2004b). Yet, much work remains to be done in implementing these standards and reforms in teaching that accompany these standards, including the use of technology to help build an understanding of cell theory (Roseman, 1997).

One type of technology that is available for learning about cell theory is the microscope. In recent years, a new type of microscope, a computer microscope that creates digital images, has become available. The Intel™ Play QX3™ Computer Microscope (Intel and Neo/SCIENCE Corporation, 2001) was introduced in 1998 (Bell & Bull, n.d.). This microscope has since been updated and has been purchased by another company. A more recent version of it is known as the Digital Blue™ QX3™ Plus Computer Microscope, and the most recent version is called the Digital Blue™ QX5™ Computer Microscope (Prime Entertainment, 2005). Other digital microscopes, such as the ProScope™ (Bodelin Technologies, 2004), have been developed. The microscopes connect to a computer and allow the user to view the images on a computer screen. This study included the use of traditional microscopes, the Digital Blue™ QX5™ Computer Microscope, and the ProScope™. The digital microscopes provided the opportunity for groups of students and the

teacher to view digital images on a screen. The students and teachers could discuss what they were seeing. These new tools also provided an opportunity for the students and teachers to take still digital pictures, time-lapse photographs, and digital video clips. The students and teachers could use then use these images in the software that accompanies the digital microscope and in other applications that incorporate the use of digital images. The images could also be posted on an Internet web site. Thus, this researcher proposed the introduction of microscopes, and particularly digital microscopes, into the study of cell theory as a means of helping students develop an understanding of cell theory. The students' content knowledge was assessed using a multiple choice content test before and after the unit of cells.

One of the recommendations from Science for all Americans (AAAS, 1989) is that students be actively engaged in their learning. Other suggestions from this publication include insisting on clear expression from the students as they communicate what they are learning, having students work as a team, encouraging curiosity, rewarding creativity, and promoting aesthetic responses to discoveries regarding the natural world and the implementation of science and technology. Research on middle schools has shown a particular need for students to be engaged in learning (NMSA, 2003a). This researcher postulated that the addition of microscopes, and in particular digital microscopes, might encourage the students' active engagement in learning about cell theory and foster their communication regarding what they are learning. This study included a qualitative component in which the researcher observed classes and interviewed selected students. Observations of students as they used the analog and digital microscopes provided data on whether their addition to a classroom was accompanied by high levels of student engagement

and whether students seemed more likely to work in teams and to communicate what they were learning.

A factor that is often considered to be related to engagement is the students' attitudes toward learning. Thus, some pertinent studies dealing with students' attitudes toward learning are reviewed in the second chapter of this paper. The review of these studies suggests that improving students' attitudes toward science and increasing the students' motivation to learn science content will have an effect on their academic achievement in this subject. As noted, this researcher proposed that the addition of microscopes, and especially digital microscopes, would foster student engagement and encourage improved attitudes toward science. Thus, the quantitative part of this study used the Scientific Attitude Inventory II (Moore & Foy, 1997) to measure students' attitudes toward science before and after the unit on cell theory.

An issue addressed in this study was that of using the computer and accompanying devices as a mindtool to help students construct knowledge. This goal is in alignment with the North Carolina Standard Course of Study (NCDPI, 2004b) goal, mentioned above, which states that eighth grade students should use appropriate technologies to construct knowledge related to cell theory. As noted in the review of the literature in the second chapter of this document, educational technology has shown some promise in helping students achieve educational goals. In addition, there is interest in using technology as a mindtool that helps students visualize the concepts (Jonassen & Carr, 2000; Linn, 2003), thus helping to build a bridge from a concrete experience to an abstract concept. This study examined two types of digital microscopes. Both require the use of a computer. The images from the microscopes can be displayed on the computer screen, on a television screen, or on a large screen via a

projector for a group of students to view. Both of these digital microscopes include software that allows the user to take still pictures, time lapse photographs, and video clips. This researcher was interested in investigating the use of these digital microscopes as mindtools to help the students construct knowledge of cell theory.

Another issue addressed in this paper is the Digital Divide, including the problem of providing resources to schools in rural areas. There is a large difference in the price of these two digital microscopes. (Details regarding price and technical requirements of these two types of microscopes are provided in a later section of this chapter.) Both types of microscopes were available in the classroom that used digital microscopes. This researcher obtained information regarding a comparison of these two types of microscopes from data collected through the student and teacher interviews and from the classroom observations of the room where the digital microscopes are used. This information may be valuable to school systems with limited technology budgets if they decide to purchase digital microscopes for middle school students' use. If an inexpensive device, such as the Digital Blue™ QX5™ microscope, could be used as a mindtool to help middle school students construct knowledge regarding cell theory, then that information could be especially valuable to school districts that have small budgets, such as schools in rural areas. If the less expensive product does not prove to be satisfactory for this purpose, but the more expensive microscope is able to serve as an effective tool, then school administrators and teachers would benefit from knowing the advantages of investing in these tools for their students.

A final issue of concern addressed in this study was the achievement of African American students and the achievement of girls in the area of middle grades science. Details in chapter 2 of this paper explain the science achievement test gap that continues to exist

between White and African American middle grades students and the gap between middle school girls and boys on science achievement tests. While this study has not been designed to examine techniques that are particularly created with the intention of boosting the achievement of female students or African American students, this issue is one that will not be overlooked in this study. If the analysis of data suggests that a larger gap existed between male and female students, or between White and African American students, among the students who participated in the intervention, then the researcher will note that discovery. While the sample of this study may not be large enough to support generalizations on this topic, and the study has not been designed to provide definitive data on this topic, the difference between the attitude survey scores and the content test scores of these groups has been noted. Ignoring the difference in the scores between the groups would be irresponsible.

In addition to disaggregating the scores according to gender and racial identity and noting the differences between groups of students in each treatment group, this study also ensured that the voices of the female, as well as male, students and the African American, as well as White, students was heard. Thus, the qualitative part of this study was designed to focus on a sample of students whose gender and racial identity reflected the population of the school. In the school system where this study occurred, approximately 86% of the middle grades students are African American and approximately 53% of the students are females. When the twelve students to be interviewed were selected, the researcher ensured that six students were females and that nine of the twelve students were African Americans. Thus, the racial groups that comprise the student population at this school and both genders were represented in the quantitative and the qualitative parts of this study.

Instructional Materials Used in All Three Teachers' Classrooms: FOSS Diversity of Life Course

The Full Option Science System (FOSS) kit is a research based science system, designed with support from the National Science Foundation, for grades K-8 and published by Delta Education. The program was developed by the Lawrence Hall of Science at the University of California at Berkeley. This material was designed to be in alignment with the national science standards (AAAS, 1993; National Research Council, 1996). The FOSS Diversity of Life Course (Lawrence Hall of Science, University of California at Berkeley [UC Berkeley], 2003a) was used in this study. This set of instructional materials is recommended by the North Carolina Department of Public Instruction for use in teaching the North Carolina Standard Course of Study middle grades objective on cell theory. The set of materials is provided in the format of a kit which contains a teacher's manual, 10 copies of a CD-ROM that contains interactive instructional materials and images, 2 drawers of materials that are shared by all the classes of students taught by the teacher, 5 drawers of materials that are intended to provide a set of additional materials for each of 5 classes, a lab notebook that can be reproduced for each student, and 15 copies of the student resource book (which has pictures, data, and reading materials for the students). This material is intended to be used to teach middle grades students about the diversity of life and about cell theory. This kit is designed to help students construct the following main concepts:

- Life happens in cells.
- Cells are aquatic, even in terrestrial organisms.
- Cells all have the same basic requirements for survival.
- Life is diverse.
- Most life is single-celled.
- All organisms are adapted to live where they live (UC Berkeley, 2003b, p. 7).

The FOSS Diversity of Life kit (Lawrence Hall of Science, UC Berkeley, 2003a) was constructed upon the principles of teaching science as inquiry. Thus, in accordance with national recommendations, the kit is focused on the deeper learning of less content, rather than a broad introduction to a larger number of topics. Activities are suggested that allow for instruction to take place in a variety of settings, allowing opportunities for students to work as a whole group, in small groups, in pairs, and by themselves. The materials are intended to provide concrete experiences for the students that they can use to build the symbolic understandings required by this topic. Pictures in the student resource book and images and video clips on the CD-ROM are intended to provide a means of visual representation for the students. In addition to the instructional materials, the kit provides formative and summative assessment activities.

Comparison of the Two Types of Digital USB Microscopes

The Digital Blue™ QX5™ microscope (Intel and Neo/SCIENCE Corporation, 2001), stand, and accompanying software can be purchased for less than $100.00. It has magnification powers of 10X, 60X, and 200X. In addition, the accompanying software provides a built-in paint program which can be used with images captured by the microscope. The program also allows the user to make a slide presentation and to include sound and special effects as elements in the presentation. The Digital Blue™ QX5™ microscope package includes the microscope, stand, USB cable, software and instructions on a CD, specimen jars, sample preserved slides, tweezers, eye dropper, and a slide clip. The resolution of the images from this microscope is 640x480 pixels. The computer requirements are listed below:

- Microsoft® Windows® XP, 2000, 98, 98SE, or Windows® ME
- Available USB port

- Intel® Pentium®, Celeron® 200MHz or processor that is comparable or faster
- 32MB of RAM
- Minimum 150MB hard drive space
- 4x CD-ROM Drive or faster
- SVGA 800 x 600 resolution video support (min. 16-bit color)
- Windows compatible sound device
- Video and sound compatible with DirectX® (Included on the CD-ROM)

The ProScope™ microscope (Bodelin Technologies, 2004) is a handheld digital USB microscope. A set that contains The ProScope™ USB 50X Imaging Kit (which includes the USB Shot imaging software on a CD-ROM,) the ProScope™ stand, 10X lens, 100X lens, 200X lens, the ProScope™ case, and a c-mount adapter (which allows the ProScope™ to be connected to a traditional microscope) can be purchased from http://www.comactivity.com for $745.00. The USB cable is built into the ProScope™ microscope. The resolution of the ProScope™ images is 640 X 480 at 72 dpi in millions of colors. This microscope comes with drivers for computers that run Microsoft® operating systems and those that use Macintosh® operating systems. One advantage of this microscope is that it comes with an adapter that allows it to be used in conjunction with an analog microscope. Thus, the ProScope can provide digital images from an analog microscope. The computer requirements are listed below for computers using Microsoft® operating systems:

- Microsoft® Windows® XP, 2000, 98, 98SE, or Windows® ME
- Available USB port
- Intel® Pentium®, Celeron® 200MHz or processor that is comparable or faster
- 32MB of RAM (64 MB recommended)
- 2GB hard drive space
- 4x CD-ROM Drive or faster
- SVGA 800 x 600 resolution video support (min. 16-bit color)
- Video compatible with DirectX® (Included on the accompanying CD-ROM)

Traditional Analog Student Microscope

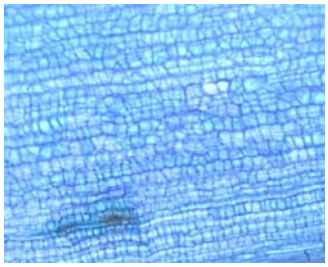
The analog microscope that was used was a student microscope made by Nasco™. It is a compound microscope with a wide-field 10X eyepiece and three objectives that are 4X,

10X, and 40X, thus providing magnification powers of 40X, 100X, and 400X. Illumination is provided by a 110V, 20 watt bulb. The microscope features course and fine focus controls and retails for about $125.00.

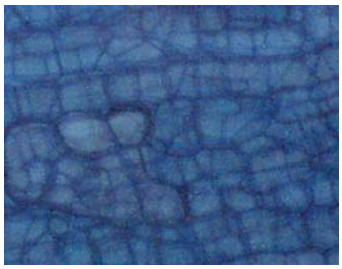
Pictures Taken with Digital Microscopes

Pictures captured with each of the two types of digital microscopes, at varying levels of magnification are displayed in Figure 1.

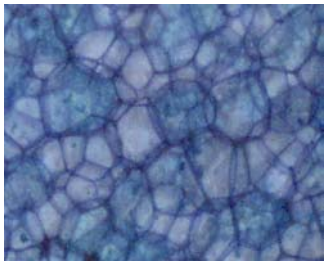
Pictures taken with the Digital Blue™ QX5™ microscope (purchased for less than $100):



Celery stem at 60X



Celery stem at 200X



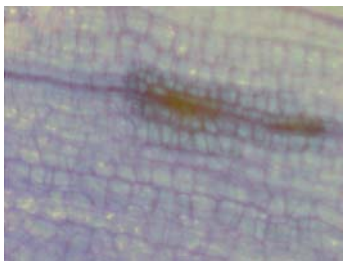
Potato at 200X

Euglena at 200X

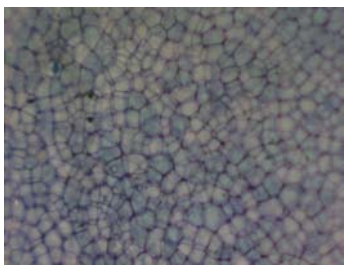
Paramecia at 200X

Paramecia at 200X

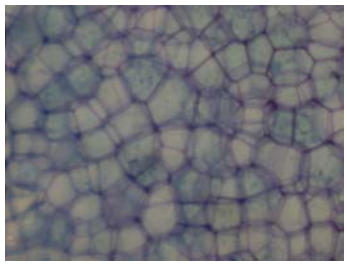
Pictures taken with the ProScope™ microscope (purchased for $745):



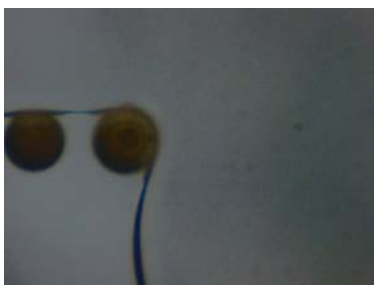
Celery stem at 200X



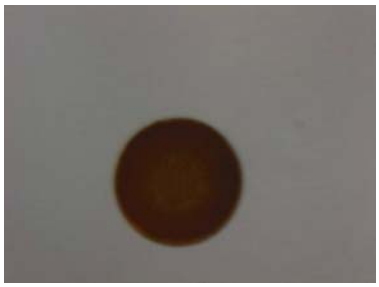
Potato at 100X



Potato at 200X

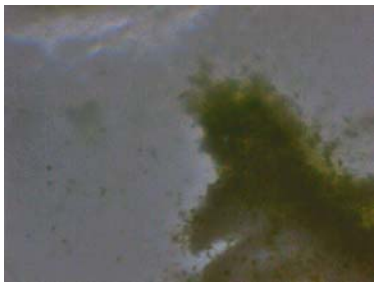


Brine shrimp eggs at 100X



Brine shrimp egg at 200X

Brine shrimp hatching at 100X



Euglena at 200X

Paramecium at 200X

Paramecium at 400X (ProScope used in conjunction with analog microscope)

Figure 1: Pictures captured with digital computer microscopes

Overview of the Review of the Literature

The review of the literature begins with the historical perspectives on science learning in the United States. A review of reforms and the need for systemic change in science education are discussed. The reform efforts resulted in the writing of benchmarks and national standards designed to help American students develop science literacy (AAAS, 1993; National Research Council, 1996). Recommendations from these standards and the development of the middle grades science North Carolina Standard Course of Study (NCDPI, 2004a), which is aligned with the national standards, are examined as part of the literature review.

Project 2061 was formed by the American Association for the Advancement of Science (AAAS) in 1986, the year that Halley's Comet could be seen from Earth. The comet will pass near Earth again in the year 2061. This year was chosen as the name of the project with the expectation that all Americans would achieve science literacy by that date. In 1989, the AAAS published *Science for All Americans*, which included their recommendations for achieving this goal. In this publication, they defined science literacy as follows:

> Science literacy—which encompasses mathematics and technology as well as the natural and social sciences—has many facets. These include being familiar with the natural world and respecting its unity; being aware of some of the important ways in which mathematics, technology, and the sciences depend upon one another; understanding some of the key concepts and principles of science; having a capacity for scientific ways of thinking; knowing that science, mathematics, and technology are human enterprises, and knowing what that implies about their strengths and limitations; and being able to use scientific knowledge and ways of thinking for personal and social purposes (AAAS, 1989).

As the AAAS (1989) posits, there are valid reasons for setting a goal of having all students obtain science literacy. Individual fulfillment, the good of the national economic state, the need to develop solutions for global problems such as acid rain, and the need for people to respect the desirability of wise and ethical uses of technology are a few reasons why science literacy for all is a worthy goal. The call for all students to achieve science literacy was echoed by the National Research Council, as it published *the National Science Education Standards* in 1995 (and reprinted the standards in 1996.)

Achieving a goal of science literacy for all Americans by the year 2061 is an ambitious, yet worthy, goal. In order to foster attainment of this goal, the AAAS (1993) published *Benchmarks for Science Literacy* to state goals. Teams of professionals, representing a cross-section of educators from across the country, developed the set of goals to guide the project's implementation. Their intent was for these goals to be evaluated and

changed as needed over time. The developers also sought to create standards that all students would be expected to reach. They thought that the best way to design the goals was to provide a common core of learning and to focus on less content, but more depth of content (AAAS, 1993). Thus, the instructional materials used in this study are intended to foster the national goals and recommendations.

The theoretical framework of this study, constructivism, is examined in the literature review. Constructivism proposes that individuals interacting with their environment construct knowledge or meaning, as opposed to the idea of students passively receiving knowledge from the teacher. The interaction takes place within a context that includes both the physical setting and the social engagement (Honebein, Duffy & Fishman, 1993). The constructivist view of learning is based on the works of educational theorists such as Bruner (1977), Dewey (1997), Papert (1993), Piaget (1963), and Vygotsky (1978). In general, a constructivist view of learning promotes learning that is focused on students' understanding of ideas and concepts, rather than the memorization of facts, definitions, and information. Social constructivist principles (Vygotsky) support the engagement of students in collaborative group projects in which knowledge and skills are taught in context, rather than as isolated sequential facts.

According to the constructivist view, learning is constructed in the student's own mind; therefore multiple representations of knowledge are possible (Jonassen & Carr, 2000). Jonassen (2000) encouraged educators to use computers as "mindtools," a term he used to refer to the use of a computer as tool that can help the user construct knowledge. Jonassen, Howland, Moore, and Marra (2003) suggested that technology is useful as a tool for knowledge construction because students can use technology to represent their ideas that they

are learning. These authors also stated that students might use technology as a tool to support learning by doing and as a social context to support learning by interacting with the environment and with other students. In other words, these authors viewed technology as an intellectual partner that allows students to learn with technology, rather than from it. Thus, in this dissertation, the idea of using technology as a constructivist mindtool was central to the investigation.

Science learning from a constructivist view fits with the national recommendations for reforming science education. The new standards are based on an inquiry learning model, where students are expected to form deep interconnected content knowledge, as well as to develop inquiry skills, as they work in an authentic setting (Edelson, 2001). Teachers have been making progress in moving toward this model, but there remains work to be done. Studies regarding the barriers that have prevented some teachers from the full implementation of science as inquiry and attempts to overcome those barriers (Edelson, Gordin & Pea, 1999; Krajcik, Blumenfeld, Marx, Bass, Fredericks & Soloway, 1998; Schauble, Glaser, Duschl, Schulze & John, 1995; Songer et al., 2002) are discussed in the review of the literature.

As noted above, Jonassen (2000) recommended the use of computers as mindtools for constructing knowledge. If the computer is to be used in this manner, then issues of equity have to be considered. Solomon et al. (2003) described a “digital divide” that exists among groups of people in the United States. The U.S. Department of Education, Office of Educational Technology (2004) provided statistical data regarding the availability of computers and the type of usage of computers by various groups of people in this country.

Wenglinsky (1998) provided further documentation of some aspects of this problem as it relates to middle school students.

One area in the middle grades science classroom that seems to be a particular problem is the lack of student engagement in learning. While research has suggested that students are more likely to learn when they are actively engaged in the lessons, there is a need to find ways to increase the students' engagement in middle school science learning (Waxman, Connell & Gray, 2002). A growing collection of research suggests that student engagement plays an essential role in the student learning process (Meece & McColskey, 2001; Voke, 2002). Studies have suggested that the lack of student motivation and engagement in the learning process are problems in American education (Anderman & Midgley, 1998; Meece & McColskey; Voke). This problem seems to be especially troublesome in the middle and secondary schools (Simpson & Oliver, 1985, 1990; Yager & Penick, 1986). In addition, it has been noted that the motivation students have to study science is very important because that characteristic is associated with the likelihood of students selecting science course electives in high school (Singh et al., 2002). The choice of science courses in high school will affect the student's ability to enroll in science courses on the post-secondary level and to seek a career in the field of science. Thus, increasing student motivation to learn and fostering student engagement seem to be worthy goals for middle school science classrooms.

The importance of the study of student attitudes toward science and student motivation and engagement is emphasized by research that shows that students' attitudes toward science tend to decline during the middle school years (Simpson & Oliver, 1985, 1990; Yager & Penick, 1986). In addition, Simpson and Oliver (1990) found a strong relationship between attitude and achievement in science education. Singh et al. (2002)

discovered that motivation, interest, and academic engagement are associated with academic success in the mathematics and science achievement of eighth grade students.

As motivation and engagement are reviewed, the unique needs of middle school students should also be considered. Early adolescents face changes in a multitude of developmental areas, including physical, cognitive, social, and emotional changes that occur as they encounter the transition from child to young adult. Accompanying these changes is a great potential for both positive and negative results (Knowles & Brown, 2000; Van Hoose, Strahan & L'Esperance, 2001). The school environment can have an impact on the choices made by middle school students, including their level of motivation to be successful in school. Providing a classroom environment that fits the needs of young adolescents tends to increase those students' motivational levels to succeed in learning (Eccles & Wigfield, 1997). Thus, the history of middle school education and current studies regarding recommendations for engaged student learning in middle school was reviewed in chapter 2 of this document.

The use of technology in the classroom has shown some promise in improving some areas of education (Apple Computer, Inc., 1995, 2002, 2005; Christmann & Badgett, 1999; James et al., 2000; Kulik, 2002; Mann et al., 1999; Roschelle et al., 2000; Sivin-Kachala & Bialo, 2000; Waxman et al., 2002). In particular, some studies (McGrath & Cumaranatunge, 1997; Sandholtz et al., 1994) reported positive changes in student attitude and a sustained level of enthusiasm for the learning projects when technology was used.

More information needs to be learned about the use of technology as a mindtool (Jonassen & Carr, 2000) and especially as a tool that can foster visualization (Linn, 2003). Edelson et al. (1999) conducted research on scientific visualization. One advantage they found that the computer could bring to the teaching of science was the multiple

representations that it could afford. Other studies conducted on visualization tools have suggested their importance in helping students visualize and understand abstract concepts (Crouch, Holen & Samet, 1996; Dodson, Levin, Reynolds & Souviney, 1999). A life science project in which students examined magnetic resonance images of fertilized eggs to monitor the development of unhatched chicks provided insights into how students can use a visualization mindtool to help them construct knowledge in life science (Bruce, Carragher, Damon, Dawson, Eurell, Gregory, Lauterbur, Marjanovi, Mason-Fossum, Morris, Potter & Thakkar, 1997; Hogan, 2000).

As mentioned earlier, there are inequities that affect the ability of the federal government, the state school systems, and the local school systems to be able to provide science learning for all. One factor affecting the students' availability of resources is whether the school system is located in a rural area. According to the National Center for Educational Statistics (2000), approximately 25% of public elementary and secondary schools in the United States are classified as rural schools. A report from The Rural School and Community Trust (2003) emphasized the need for attention to be paid to the plight of rural schools. This report listed 13 states which are in special need of attention. North Carolina was ranked sixth on this list, and it was noted that this state has the second largest rural population in the country and the eighth largest percentage of students who attend rural schools. Finally, there are gaps in science achievement test scores at the middle school level between males and females and between White students and African American students (Gonzales et al., 2004; Hoffman, Llagas & Snyder, 2003; O'Sullivan, Lauko, Grigg, Qian & Zhang, 2003; Tindal & Hamil, 2004; U.S. Department of Education, National Center for Education Statistics, 2003;

Von Secker, 2004). The research referenced in this section will be discussed in more depth in the second chapter of this document.

Overview of the Study

As noted in an earlier section of this chapter, the purpose of this study was to examine the use of technology, in the form of digital microscopes connected to computers, in the teaching of cell theory at the middle school level. Situated in the classrooms of three middle school teachers in a rural school system in North Carolina, this study examined the variable of microscope use on three levels – no microscopes, analog microscopes, and digital microscopes – during the middle school unit on cells. While the focus of the study was to examine the use of technology in teaching cell theory, this study also compared the use of digital microscopes to a more traditional type of technology – analog microscopes – and to a control situation where no microscopes were provided to the students. Brewer and Hunter (1989) stated that the use of quantitative or qualitative methods alone is insufficient for some research studies. This study was designed to benefit from the use of two complementary parts – a quasi-experimental quantitative part and a qualitative component.

The sample was a purposeful sample, based on criterion selection, as defined by Patton (2002). The school system was purposefully chosen, as is explained in detail in the third chapter of this document. The teachers from this system were also purposefully chosen, with the requirement that each be licensed in middle grades science and be willing to teaching a unit on cells to middle grades students in this rural school system during the 2004-2005 school year. There were three seventh and eighth grade teachers in the school system where the study took place who were licensed to teach middle grades science, and each was planning to teach the unit on cells in the spring of the 2004-2005 school year. Each of these

three teachers agreed to participate in this study. The students were selected in clusters, as defined by Gall, Borg, and Gall (1996), as all students of the three selected teachers were invited to participate in the study. All participating students were given the content test and the attitude inventory, and all were part of the classroom observations. Four students of each teacher were invited to participate in interviews. The process of how each student was selected is explained in detail in chapter 3.

All three teachers attended staff development on using the Diversity of Life materials. The day-long session was led by a science educator from a university not associated with the researcher. Each teacher was supplied a Diversity of Life kit (designed for use by five classes of students) and a computer and a video projector so that material from the CD-ROM in the kit could be viewed by the classes. All three teachers' classes used the materials in the kit, including the CD-ROM, a student notebook, a student book, videos, and hands-on materials in their study of cells.

Quantitative Component

There were three groups in this study. The set of all students taught by a teacher formed a group. There were three teachers participating, so the three sets of students were the three groups. The experimental variable was use of microscopes. There were three levels to this variable – no microscope use, use of analog microscopes, and use of digital microscopes. The seventh grade students taught by Ms. Nu had no access to microscopes. In their study of cell theory, those students used the Diversity of Life instructional materials, including the images provided in the paper materials and the pictures and video clips on the CD-ROM from the kit. Ms. Nu used the one computer and video projector to share the images on the CD-ROM with the students as a large group. The eighth grade students in Ms. Alpha's

classes formed the second group. The students in this group used the Diversity of Life instructional materials and used six analog microscopes in their study of cell theory. They also had access to a computer and a projector to share the images on the Diversity of Life CD-ROM. The eighth grade students in Ms. Delta's classes comprised the third group. These students used the Diversity of Life instructional materials six digital microscopes, connected to computers, as they studied cell theory. Three microscopes were Digital Blue™ QX5™ microscopes, and three microscopes were ProScope™ digital microscopes. Since the ProScope™ was designed to be used with traditional microscopes as well as a stand-alone microscope, the students in this group had access to an analog microscope that they could use in conjunction with a ProScope™ digital microscope if they desired. Table 1 shows the grade level and treatment type for each of the three teachers.

Table 1

Microscope Use

Digital	Analog	None
Ms. Delta	Ms. Alpha	Ms. Nu
Eighth grade students	Eighth grade students	Seventh grade students

Measurement Instruments

The quantitative part of the study utilized two instruments, the Scientific Attitude Inventory II and a content test. The Scientific Attitude Inventory II was developed and field tested by Moore and Sutman (1970), who also provided information on their findings regarding validity of the instrument. Moore and Foy (1997) revised the instrument to remove

gender-bias references, to improve comprehension, and to shorten the instrument. The authors have granted permission to use this instrument in this study (R. W. Moore, personal communication, April 12, 2004). More information regarding this instrument may be found in the third chapter of this document. A copy of the instrument is located in Appendix A and its scoring guide may be found in Appendix M of this document. The content test was developed by the researcher to provide an assessment of the content taught on cell theory at the middle grades level. Details regarding the development of this test are located in the third chapter of this document. A copy of the test may be found in Appendix B.

Analysis of Data

This study examined changes in student attitudes toward science as measured by pretests and posttests using the Scientific Attitude Inventory II (Moore & Foy, 1997). The study also examined changes in the students' content attainment as measured by pretests and posttests using a content test developed for this unit of study. For each instrument, an Analysis of Covariance (ANCOVA) was used to compare the population means of the three groups of students after adjusting for the pretest scores. (Each teacher's set of classes was considered to be a group.) If a statistically significant difference were found (at the $p<0.05$ level,) then post-hoc tests, using Fisher's least significant difference (LSD,) would be conducted to determine statistically significant differences between the groups.

Hypotheses

There will be a significant difference ($p<.05$) among the population mean posttest scores on the content test for the three groups (Digital, Analog, None) after adjusting for the effects of the pretest scores. The Digital group will be significantly higher than the Analog group and the None group.

There will be a significant difference ($p<.05$) among the population mean posttest scores on the Scientific Attitude Inventory II for the three groups (Digital, Analog, None) after adjusting for the effects of the pretest scores. The Digital group will be significantly higher than the Analog group and the None group.

Descriptive Statistics

In addition to the statistical tests of significance described above, the researcher used descriptive statistics to report the mean scores of the males and females in each group of students. She also reported the mean scores of the White and African American students in each group. Studies of national science achievement tests have shown a gap between the scores of males and females and a gap between the scores of White and African American students. While this proposed study was not intended to focus on specific ways to improve the science education of these groups, the researcher thinks that the scores for these groups of students should be provided. Net gains for the male and female students and for the African American and White students on each assessment instrument in each teacher's set of classes were reported.

Qualitative Component

The qualitative component can be described specifically as an instrumental case study, as defined by Stake (1995). He stated that the purpose of this type of case study is to help the reader understand an idea, rather than focusing only on learning about the particular case. In this study, the case provided data regarding the teaching of cells in a rural middle school. This case focused on three teachers and their students during the teaching of the middle school unit on cell theory. The teachers were selected because they were the three teachers in this system who were licensed to teach middle grades science and who were

teaching a unit on cell theory to middle grades students in the 2004 – 2005 school year. Participant observation, interviews, and video-taped classes provided data.

The purpose of the qualitative part of this study was to provide insights into how the selected classes of students and their teachers viewed the unit on cell theory. The researcher proposed that she would gain valuable information related to how the students respond to the teaching of this unit in each of the three classroom settings described above. The researcher observed students to see how they responded to the instructional activities in each of the three classroom settings. She was particularly interested in observing the students' engagement in learning in each of the three situations. Student interviews provided insights into the students' attitudes toward the unit on cell theory in each of the three classroom environments. Interviews with the teachers provided data regarding how the teachers viewed the learning environment, including the addition of analog or digital microscopes into the middle school unit on cell theory. Reviews of videotaped class sessions provided additional observational data. A review of the student-created multimedia products provided data on how the students used (or did not use) the multimedia options available on the digital microscopes.

Gagnon and Collay (2001) created a constructivist learning model, which they labeled as constructivist learning design (CLD.) Their CLD model consists of six parts, which they say flow back and forth into each other. The first part is labeled as "situation," and it is defined as the frame for student engagement. The situation provides the overall goals and tasks for the learning situation. The second element is "groupings," the social structures that will be employed during the learning experience. Third, "bridge" refers to the scaffolding that is provided to help the students connect the new learning to the knowledge they have

already formed in their minds. Fourth, “questions” are used to help inspire students to analyze, synthesize, extend, and integrate what they are learning. The fifth element, “exhibit,” refers to having the students share what they are learning with others. The authors also refer to the exhibits as “artifacts of learning” (p. xi.) “Reflections” allow students to think critically about what they are learning, to apply their learning to other areas of the curriculum and to their lives, and to think about future opportunities for learning. The CLD model provided a basis for observation of the classrooms in this study and supplied a common vocabulary for the researcher and the classroom teachers to employ as they discussed what was occurring in the classrooms.

Sample

As noted earlier in this chapter, a purposeful sample of three teachers and a cluster sample of students have been selected for participation in this study. The researcher observed the three teachers’ classrooms. The researcher also selected four students from each teacher’s set of students. These four students were invited to participate in an interview with the researcher. Details regarding the selection of the twelve students are provided in the third chapter of this document.

Overview of Procedures

The researcher observed the classrooms two or three times a week. Appendix C contains a detailed schedule of the lessons as they were originally planned. Appendix D provides a revised schedule which was the one actually used. (Adjustments to the original schedule were necessary to accommodate changes in the school schedule and the needs of the teachers and the students.) Observation days were noted on the revised schedule. The researcher also interviewed the twelve selected students and the three participating teachers.

More detailed information on these procedures is provided in the third chapter of this document.

Research Questions

The following research questions served as a guide for the qualitative part of this study.

- How might the selected middle grade students be engaged/disengaged in the study of cells when digital microscopes are available for their use compared with the availability of traditional microscopes or the lack of availability of any microscopes? (The Gagnon and Collay (2001) CLD model will serve as a guide for observing the students' classroom engagement.)
- How might the selected middle grade students in this rural school perceive the use of images (in text and on a CD-ROM), or the use of analog microscopes, or the use of digital computer microscopes (with corresponding multimedia applications) in their study of cells?
- When the selected middle grade students in this rural school are taught about cell theory, how do students perceive science instruction in classrooms that include the use of digital microscopes (and corresponding multimedia applications) and in classrooms that do not?
- How do selected middle grade students who have access to the use of digital computer microscopes, during the unit on cell theory, make use of the multimedia options that are available with these microscopes?
- How do selected middle grade students who have access to the use of digital computer microscopes, during the unit on cell theory, use digital microscopes as mindtools in their learning about cells?
- What comparison information can we learn from the selected middle grade students who have access to the use of digital computer microscopes, during the unit on cell theory, regarding the use of two types of digital microscopes, the Digital Blue™ QX5™ microscope and the ProScope™ digital microscope, in their study of cell theory?

Data Analysis

This researcher followed the advice of Creswell (1998) and Merriam (2001) and began to analyze the data while they were still being collected. As suggested by Creswell, she coded the data, expanding the categories as she worked, and then collapsing them during the final stages of the analysis. She also used Microsoft Word 2003 to help her search observation notes and interview transcripts for key words that helped her to locate details that

belonged in various categories. More information has been provided on the data analysis in chapter 3 of this document.

Significance of the Study

This research will likely contribute to the field of education by providing data on the use of analog and digital microscopes in rural middle school classrooms during the study of cell theory. While research has suggested that students are more likely to learn when they are actively engaged in the lessons, there is a need to find ways to increase the students' engagement in middle school science learning. This researcher proposed that if students were able to view cells with microscopes, especially with digital microscopes, they may become more engaged in learning about cell theory. The qualitative component of this study provided insights into the students' engagement in three types of learning environments (with no microscopes, with analog microscopes, and with digital microscopes) during the middle school study of cell theory. This information may be helpful to middle school science teachers in schools similar to the one in which the study is conducted as they plan a unit on cell theory.

The statistical analysis of the scores on the attitude inventory provided quantitative data on how students respond to the learning of cell theory with and without the use of microscopes in their classrooms. Students' attitudes in classrooms with digital microscopes were compared to those in classrooms with analog microscopes and to those in classrooms with no microscopes. If the use of digital microscopes is associated with a statistically significant greater positive change in students' attitudes toward science, then middle grades science teachers, especially those in schools similar to the one in this study, would likely be interested in learning about this correlation.

Analysis of scores on the pretest and posttest of the content test that were administered provided additional data regarding student learning with the inclusion of microscopes, including the use of digital microscopes, in the study of cells in the rural middle school classroom, as compared to the teaching of this unit with no microscopes. Middle grades science teachers in schools similar to the one studied would likely be interested in learning if there is a correlation between the students' gain on the science content test scores and the use of analog or digital microscopes during the study of cell theory.

Research suggests that students tend to become more interested in learning activities that involve the use of multimedia. The digital microscopes operate with software that allows students to create multimedia presentations of pictures, time-lapse photographs, and short video segments that they can capture with the digital microscopes. The researcher observed students as they used the digital microscopes to gain some insight into how they respond to their learning when they are allowed to work with these multimedia learning tools. She also be observed a classroom where students were using analog microscopes and a setting where were not be using microscopes so that she can observe how students in those settings responded to the same unit of instruction. The interviews with the teachers and selected students provided insights into what was learned from the quantitative data. Observing student reactions and hearing their comments provided insights that helped the researcher to understand the students' reactions to the learning environment and their interest in learning this content on cells. This information can be shared with other middle school teachers, especially those in schools similar to the one studied, who can consider the results as they think about teaching the unit on cells to their students.

Another important dimension of this study was the analysis of qualitative data comparing the two types of digital microscopes in the middle grades study of cell theory. Teachers and administrators will likely be interested in learning how an inexpensive digital microscope compares to one that is almost ten times its price. This study analyzed data on the use of both types of microscopes and offered information which will be helpful to teachers and administrators as they make decisions on how each type of digital microscope might contribute to their students' learning needs.

The researcher plans to share information learned from this study with the education community. As noted, no students or teachers will be personally identified. However, generalizations that are gleaned from the attitude inventory results, the content test results, the observations, and the interviews will likely offer insights to other middle school science teachers as they prepare a unit of study on cells. Teachers and administrators will be able to read the demographic data pertaining to the selected school system, the analysis of the quantitative and qualitative data developed in this study, and the rich descriptions provided in the qualitative component to determine how the information learned in this study might be applicable to their own situations. North Carolina teachers may be especially interested in the results of this study as they plan to prepare students for a new eighth grade science end-of-grade test that will be field tested in 2006.

Limitations of the Study

This study used a quasi-experimental design for the quantitative component. Since the sample was not a random sample selected from a population, then the reader must use caution when generalizing the results to other situations. Demographic data have been provided to aid the reader in comparing the sample used in this study to the population of

interest so that the reader can use caution and good judgment to decide if and how the information learned in this study might apply to the reader's population of interest. The qualitative part of this study was an instrumental case study. Stake (1995) emphasized that "the real business of case study is particularization, not generalization. We take a particular case and come to know it well" (p. 8). This case study was what Stake defined as an instrumental case study. He said that the purpose of this type of case study is to help the reader understand an idea. Therefore, rich descriptions and learning contexts have been provided to help the reader understand the case and the ideas that it presented related to the use of microscopes – including a lack of microscopes, analog microscopes, and digital microscopes during the unit on cell theory in a middle grade classroom in a rural school system.

REVIEW OF THE LITERATURE

Science Learning for All

Reform in science education has been an American concern for about a century. National events have played a role in refueling the interest in this area. The launching of the Soviet spacecraft Sputnik on October 5, 1957, was one of those defining moments. The national sense of fear that the United States was lagging behind the Soviet Union in the exploration of the space frontier led to a sense of urgency in improving science education. While reform efforts were already underway, this event accelerated their development. For approximately the next 15 years, there was a national emphasis on reforming science education (Bybee, 1997; Rutherford, 1997).

One contribution to science education that came from this era was the realization that scientists and educators could work together to make improvements in the areas of curriculum development and delivery. The National Science Foundation, already in the process of sponsoring curriculum development initiatives, continued that support with renewed interest. Funding from private sources, such as the Carnegie Corporation of New York and the Rockefeller Brothers Fund, were combined with the federal funds, particularly through the National Science Foundation (NSF), to provide support for development of science curriculum projects. Some of the secondary school science projects that were begun just before and after the launching of Sputnik included the Biological Sciences Curriculum Study (BSCS), the Physical Science Study Committee (PSSC), the Chemical Education Materials Study (Chem Study), and the Earth Science Curriculum Project (ESCP). Programs developed for elementary schools included the Elementary Science Study (ESS) and the Science Curriculum Improvement Study (SCIS). The elementary programs included an

emphasis on having young students actually do science, rather than just read about science (Bybee, 1997; Rutherford, 1997).

These reform efforts lacked the establishment of policies at the state and local levels needed to sustain the innovative process. Thus, momentum for these programs was lost. Rutherford (1997) blamed the diminished interest in science education reform on the fact that the United States became dominant in the area of space exploration, culminating with this nation being the first to place a man on the moon. He noted that 15 years of inaction followed the 15 years of reform efforts. Bybee (1997) agreed that the reform efforts may have been sustained for a longer period of time if the changes had occurred within the context of other changes to the educational system. He noted that the reform efforts were focused on replacing the traditional science programs with the new curriculum programs. For that level of change to have been sustained, Bybee argued, a concerted effort by teachers, administrators, and the community, as well as changes in policies at the local, state, and national levels, would have been required,. Rutherford noted that since the curriculum changes had not become institutionalized, educators tended to return to traditional practices. Thus, both Rutherford and Bybee became proponents for systemic change.

Rutherford (1997) proposed that the current national events that have rekindled American interest in science education reform are the rivalry for international trade and the competition for high scores in international education tests. Bybee (1997) and Rutherford agree that systemic change is important for lasting, effective educational reform in science education. Both also agree on the importance of this reform including an emphasis on improving science education for all students, not just for those labeled as the brightest students.

Project 2061 was begun by the American Association for the Advancement of Science (AAAS) in 1985. The goal of this project was to help all Americans attain science literacy. In 1989, this project published *Science for All Americans*. This publication outlined the need for all Americans to become literate in science, and it provided recommendations on how this goal might be achieved. The authors acknowledged that changing people, and changing a huge enterprise such as the American education system, is a very slow process. Thus, they recommended systemic change that would support long-term efforts at reform. First, the project coordinators agreed upon a definition of science literacy. "*Science for All Americans* is based on the belief that the science-literate person is one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes" (AAAS, 1989). The authors emphasized that teachers should teach less, but teach it more thoroughly and within a larger context that emphasizes meaning and connections to life and to other areas of science, mathematics, and technology. *Science for All Americans* (AAAS, 1989) did not contain content recommendations. However, this publication was followed in 1993 by *Benchmarks for Science Literacy*. This publication, from the AAAS, provided some basic content guidelines.

The benchmark development teams convened by the AAAS (1993) examined the content that was considered appropriate for students to learn in sets of grade levels. They categorized the topics into the following grade level groupings – K-2, 3-5, 6-8, and 9-12. As they examined the body of content, they decided that the number of subjects was too large.

Rather than proposing that students should learn more content, this group determined that students should learn less content, but learn it in more depth and within a context. This focused approach was also adopted by the National Committee on Science Education Standards and Assessment, of the National Research Council (1996), as they made similar recommendations for science education reform, published as *National Science Education Standards*. Thus, both groups sought an emphasis on a common core of content and skills that were determined to represent what a person should know and be able to do if he/she could be considered to have science literacy. In addition, both of these groups have promoted a focus of science as inquiry.

Benchmarks for Science Literacy (AAAS, 1993) recommended that by the end of the eighth grade, students should have developed basic concepts regarding cells, such as the understanding that all living things are composed of cells, the function of cells in living organisms, and properties of cells. In addition to the benchmarks outlined by the AAAS, the *National Science Education Standards* (National Research Council, 1996) also called for the study of cells as part of the middle school life science curriculum.

Many states, including North Carolina, have used these benchmarks formulated by *Benchmarks for Science Literacy* (AAAS, 1993) and the recommendations from the *National Science Education Standards* as a guide in developing their own set of goals and objectives for science education. The *North Carolina Science Standard Course of Study* (NCDPI) was revised in 1999 and in 2004. The 1999 version of this document was used in North Carolina public schools during the 2004 – 2005 school year. It stated that this curriculum was based on recommendations for the *National Science Education Standards* (National Research Council, 1996) and the *Benchmarks for Scientific Literacy* (AAAS, 1989). In accordance

with information taken from these documents, the *North Carolina Standard Science Course of Study* (NCDPI, 1999) included the following four major strands in each grade level: Nature of Science, Science as Inquiry, Science and Technology, and Science in Personal and Social Perspectives. The authors of the *North Carolina Standard Science Course of Study* (NCDPI, 1999) stated that these four goals reflected the "science as inquiry" approach that was inherent in this curriculum and in accordance with recommendations from the two national organizations cited. Also, in accordance with recommendations from these two organizations, the *North Carolina Science Standard Course of Study* (NCDPI, 1999) for middle school education stated that by the end of eighth grade, all students should have developed understanding of the diversity and adaptations of organisms and cell theory. Like the process skills, this content was in alignment with recommendations from the two noted national organizations.

The North Carolina Department of Public Instruction revised the *North Carolina Standard Course of Study* in 2004. This version is scheduled to be implemented in North Carolina public school classrooms in the 2004-2005 school year. The revision was made in an effort to reflect the *National Science Education Standards* (National Research Council, 1996) and the *Benchmarks for Scientific Literacy* (AAAS, 1989) better than the 1999 version. It was also intended to reflect recommendations from the 1996 *National Assessment of Educational Progress* (U.S. Department of Education) and the *Trends in International Mathematics and Science Study* (U.S. Department of Education, National Center for Education Statistics, n.d.). The 2004 version of the *North Carolina Standard Science Course of Study* was based on the same four strands as the 1999 version. Like the 1999 document,

the 2004 revision also included content on cells at the middle grade level, including understanding of the diversity and adaptations of organisms and basic cellular biology.

Researchers have been looking for ways to accomplish the task of effectively implementing these standards and benchmarks since the publication of the landmark publications *Science for All Americans* (Rutherford & Ahlgren, 1990) and *Benchmarks for Science Literacy* (AAAS, 1993). Yet, as Roseman (1997) stated, there is still much work to be done in implementing these reforms. She noted that goals-based reform is more difficult to implement than it might appear at first glance. Thus she articulated the need for research on understanding and implementing the benchmarks outlined by the AAAS and the similar national standards recommended by the NRC.

The benchmark selected for this study was taken from the middle school life science strand, and it was focused on the study of cells. Some of the issues that were explored in this literature review included the consideration of a Constructivist theoretical framework, equity issues in achieving science for all students, student motivation and engagement in the learning process, needs of middle school learners, and the role of visualization and digital literacy in the context of middle school life science.

Recommendations from Science for All Americans

The over-riding recommendation from the publication *Science for All Americans* (AAAS, 1989) was the emphasis on helping students to develop deep understanding of a few concepts, rather than a surface level knowledge of many topics. The authors promoted the idea of helping students to construct their own knowledge, and they emphasized the importance of starting with students' own conceptions and misconceptions. Students also need for their learning experiences to be grounded in concrete learning activities, which they

discuss with their peers and reflect on their learning, experiment with the ideas in other contexts, and move to a more abstract way of thinking about the learning, as they make connections to other concepts and to their real lives. Students need challenging but attainable learning tasks to build their self-confidence in their ability to be successful in developing science literacy. Thus, as will be discussed in this chapter, a constructivist framework was appropriate for this study.

There are other important recommendations found in *Science for All Americans* (AAAS, 1989). The authors suggested that students should be actively engaged in their learning. As part of the literature review for this study, some main ideas gained from research regarding ways to promote student motivation to learn, the importance of positive attitudes toward science, and ideas to foster engagement in student learning are examined. Other suggestions from this publication included insisting on clear expression from the students as they communicate what they are learning, having students work as a team, encouraging curiosity, rewarding creativity, and promoting aesthetic responses to discoveries regarding the natural world and the implementation of science and technology.

One method of encouraging active involvement in science learning that some school systems are trying involves the use of packaged kits designed to teach the content recommended by the American Association for the Advancement of Science (AAAS, 1993) and the National Committee on Science Education Standards and Assessment of the National Research Council (1996). Some states allow school systems to purchase pre-packaged science kits instead of textbooks. In February 2004, the North Carolina State Board of Education (NCDPI) decided to accept bids for science education kits that could be purchased with money allotted for textbook purchases. Kits have been constructed by educational

publishing companies who have attempted to create products that foster active learning and that promote the teaching of the content recommended by the AAAS and the NRC. Science education consultants at the North Carolina Department of Public Instruction have examined kits and have formed a list of those that they determined were most closely aligned with the North Carolina Standard Course of Study, which is based on the national recommendations. One of the kits recommended for middle grades life science is the Diversity of Life Kit (Lawrence Hall of Science, UC Berkeley, 2003a). Another recommendation from *Science for All Americans* (AAAS, 1989) was that science teaching should strive to counteract anxieties that students possess regarding the learning of science. Specifically, the authors recommended that teachers provide abundant experiences for the students in using the tools of science. They also suggested that the role of girls and minorities be supported. Finally, they suggested that an emphasis on group learning might help to reduce the learning anxieties associated with science education. A section of the literature review examined science education and the reaction of girls and students in minority groups to the study of science.

Houston, Fraser, and Ledbetter (2003) conducted a study comparing the use of traditional science textbooks to packaged science kits. Their sample consisted of 588 students in grades three through five. The students came from 28 classes in three schools in the Ft. Worth, Texas area. Six classes from School 1 used science kits, nine classes from School 2 used the textbook, and thirteen classes from School 3 used both the textbook and a science kit. Using both quantitative and qualitative methods, the researchers collected data over the course of a school year.

The quantitative instrument used was the My Class Inventory (MCI) (Fraser & Fisher, 1983). The students were given a pre-test and a post-test. An analysis of covariance

(ANCOVA) showed a significant difference for two variables: Cohesiveness and Satisfaction. The groups of students who used the kits showed considerably larger changes in scores from the other two groups, those who used only the textbook and those who used a combination of the textbook and a science kit.

The authors only briefly mentioned the qualitative part of this study, in which they interviewed the teachers. More in-depth interviews were conducted with one teacher from each grade level at each school. Also, each classroom was observed at least once, and one classroom from each grade level was observed an additional two times. The authors stated that a detailed report on the large amount of data collected from this part of the study was beyond the scope of that paper. However, they did provide a brief summary indicating that the overall pattern corroborated the results of the quantitative aspect of the study and showed that the students who were using the science kits exhibited a more positive attitude toward science instruction than those using the textbook. The authors concluded that this study could be useful to school personnel as they make decisions regarding the adoption of textbooks and/or science kits for students. More details regarding what the research literature says regarding student motivation, attitudes, and engagement, as well as the success of other attempts to have students work in teams, are covered in other sections of this literature review.

Theoretical Framework: Constructivism – Using Technology as a Mindtool and Learning with Technology

The use of constructivist principles can provide a framework for improving the way middle school students learn about cells. Constructivism proposes that individuals interacting with their environment construct knowledge or meaning. The interaction takes place within a context that includes both the physical setting and the social engagement (Honebein et al., 1993). In general, a constructivist view of learning promotes learning that is focused on students' understanding of ideas and concepts, rather than the memorization of facts, definitions, and information. Constructivists think that learning must be constructed in the student's mind, rather than being transmitted from the teacher to the student. Thus, the constructivist teacher operates more as a facilitator of learning, and less as a transmitter of knowledge. Social constructivist principles (Vygotsky, 1978) support the engagement of students in collaborative group projects in which knowledge and skills are taught in context, rather than as isolated sequential facts. In addition, students taught according to constructivist principles are usually asked to reflect upon their learning experiences (Becker & Ravitz, 1999). According to this view, learning is constructed in the student's own mind; therefore multiple representations of knowledge are possible (Jonassen & Carr, 2000).

The constructivist view of learning is based on the works of educational theorists such as Bruner (1977), Dewey (1997), Papert (1993), Piaget (1963), and Vygotsky (1978). Dewey was one of the first educational theorists to promote the idea that children should be immersed and active in their learning experiences. Piaget developed a theory of stages through which one progresses as part of normal development. According to Piaget's theory, students should be provided learning experiences that are appropriate for their developmental

levels. He stated that most middle school students are making the transition from concrete to formal learning. Therefore, developmentally appropriate activities for most middle school students would involve activities that allowed the students to be involved on the concrete level of learning and then encourage them to think about that learning from a formal, more abstract, perspective.

Piaget (1963) also contributed the idea of cognitive dissonance, a state in which one discovers facts that do not coincide with previously held conceptions. According to Piaget, when a person is faced with cognitive dissonance, he/she seeks to resolve the issue and reach a state of equilibrium. The dissonance is resolved through either the process of assimilation, which involves making the new information fit into one's existing mental structures, or through the process of accommodation, which involves changing one's mental structures to make them fit the newly acquired concepts. Constructivists think that learning is occurring when people are actively involved with their own thinking, re-arranging mental structures and creating new ones (Schulte, 1996).

Bruner (1966) wrote that there are three ways that people represent what they know: actions, icons, and symbols. He promoted these three ways as a method of instruction. Since humans develop these three forms of representation in the order of actions, icons, and symbols, Bruner theorized that this sequence is an appropriate one to use when teaching new material. However, he did recognize that prior knowledge and personal learning preference might influence whether the student really needed to move through each of the phases, or if he/she might find it appropriate to skip the first one or two steps (Presno, 1997). Bruner's theory is applicable to Constructivism in that he believed that first students needed to be actively involved in their learning, then they needed to be able to think of the concepts in

terms of pictorial representations, and finally they should be able to communicate with words and other symbols to express what they have learned. These ideas are used to guide this study in that students will be actively involved in the science class, they will be working with pictorial representations of what they are studying, and they will be expected to communicate their learning in words. Bruner (1977) was also a proponent of guided discovery learning, which is another facet of this study. The students will be provided opportunities to discover through active learning and through pictorial representations of what they discover as they explore with digital microscopes.

Vygotsky (1978) developed two main ideas that contributed to the constructivist view of learning. One was his social development theory. He thought that learning should be conducted in a social setting. He thought that learning had to occur first in a learning situation with other people (interpsychological.) Then, it could occur within the individual learner (intrapsychological.) Thus, his theories under gird the promotion of cooperative learning activities and other experiences where students interact with each other as they learn. Vygotsky also promoted the idea of scaffolding learning experiences. He developed the idea of the "Zone of Proximal Development," an area that theoretically exists between what the learner is able to do and what the learner has the potential to accomplish. Vygotsky thought that if "scaffolding" was provided, then the learner could progress from his/her current state to the next level of learning. Both of these ideas from Vygotsky are part of the constructivist framework. This theory holds that learners need to be actively engaged with other learners as they create knowledge. It also purports that teachers should provide scaffolding to help the learners progress in their knowledge construction.

Papert (1993) expounded upon the need for students to be engaged in concrete learning. In contrast to Piaget, Papert stated that sometimes students should learn "backwards" from an abstract view to the concrete level. However, the idea of learning grounded in concrete means was is important to Papert as it was to Piaget. Papert also viewed the computer as a tool that could provide a concrete means for students to learn abstract ideas.

Jonassen (2000) encouraged educators to use computers as "mindtools," a term he used to refer to the use of a computer as tool that can help the user construct knowledge. Jonassen provided suggestions to help teachers use technology to teach in a constructivist manner. He purported that computers could have more than one place in the classroom. He defined the areas of computer use in education as "Learning from Computers" (p. 4), in which the computer is used to provide tutorials and drill and practice to help students learn skills. The second use he noted was "Learning about Computers" (p. 7), which can also be referred to as computer literacy. While Jonassen agreed that some knowledge regarding computer literacy is important, he also purported the idea that computers are tools, and students do not have to understand how the tool operates in order to be able to use it effectively. He argued that the main emphasis of computers in school should be "Learning with Computers" (p. 8). He refers to this approach as a constructivist perspective. He said that when computers are used in this manner, they support the following components of constructivist learning: construction of knowledge, exploration, learning by doing, and learning by conversing. He also noted that computers can become "intellectual partners that support learning by reflection" (p. 9). Jonassen described several types of mindtools, one of which is "visualization tools" (p. 194). It is the use of computer technology as a mindtool to

help students construct knowledge, and particularly as a visualization tool, that comprise the focus of this study. More detail has been provided on the use of computers as visualization mindtools in a later section of this chapter that is devoted to this particular topic.

Jonassen et al. (2003) explained how technology is useful as a tool for knowledge construction. Students can use technology to represent their ideas and what they are learning. Technology can also be used as a context to support learning by doing and as a social context to support learning by interacting with the environment and with other students. In other words, these authors viewed technology as an intellectual partner that allows students to learn with technology, rather than from it. Thus, in this dissertation, the idea of using technology as a constructivist mindtool was central to the investigation.

Gagnon and Collay (2001) created a constructivist learning model, which they labeled as constructivist learning design (CLD.) They defined constructivism as the assumption that people participate in the "personal and social construction of knowledge" (p. x). They defined learning as "student development and improvement" (p. x), and design as "the overall structure and outline, sequence of the parts, and general forms through which educational activities flow" (p. x). Their CDL model consists of six parts, which they say flow back and forth into each other. The first part is labeled as "situation," and it is defined as the frame for student engagement. The situation provides the overall goals and tasks for the learning situation. The second element is "groupings," the social structures that will be employed during the learning experience. Third, "bridge" refers to the scaffolding that is provided to help the students connect the new learning to the knowledge they have already formed in their minds. Fourth, "questions" are used to help inspire students to analyze, synthesize, extend, and integrate what they are learning. The fifth element, "exhibit," refers

to having the students share what they are learning with others. The authors also refer to the exhibits as "artifacts of learning" (p. xi.) "Reflections" allow students to think critically about what they are learning, to apply their learning to other areas of the curriculum and to their lives, and to think about future opportunities for learning. The CDL model will provide a basis for observation of the classrooms in this study and will supply a common vocabulary for the researcher and the classroom teachers to employ as they discuss what is occurring in the classrooms.

Science Learning from a Constructivist View

Constructivist learning in the classroom generally begins with the identification of students' current conceptions and misconceptions regarding the science topic to be studied (Boethel & Dimock, 1999; Brooks & Brooks, 1993; Duit, 1995). Thus, this aspect of the constructivist framework fits with the call by national science education groups (AAAS, 1989, 1993; National Research Center, 1996) to begin science instruction with an identification of what students know. Brooks and Brooks suggest that teachers learn of students' conceptions and misconceptions by asking probing questions.

Dreyfus and Jungwirth (1989) conducted a study regarding students' misconceptions regarding cells. They noted that other studies, such as those conducted by Bell (1985), Brumby (1982), and Marek (1986), have shown that students hold misconceptions regarding biological processes. The students often continue to cling to these misconceptions, even after formal lessons in life science classes. Dreyfus and Jungwirth found some misconceptions that tenth-grade students held regarding cells. They used an open-ended questionnaire to examine the conceptions, misconceptions, and non-conceptions of 219 tenth-grade students who had taken a biology course the previous school year. One misconception that they found was that

some of the students misunderstood the concept of cell specialization and thought that cells could specialize in energy production or in protein production. Some students thought that the ingestion and enzymatic breakdown of molecules in microorganisms was the same as the process of digestion in animals. Another misconception was that cell membranes, which control the flow of molecules in and out of the cell, could actively decide which substances it would allow to enter and which would be denied entry. This study found data that agreed with previous studies and showed that students seem to construct answers that may be inaccurate but that are based on ideas they have learned out of school. Students might also form conceptions based on misunderstandings of what the teacher was attempting to teach. In either case, the teachers had not identified the students' misconceptions or helped them to clarify their understandings. The researchers noticed that some of these misconceptions arise as the result of trying to teach abstract concepts, such as those related to cells. Some of the concepts may be beyond the grasp of the students, so the teachers choose not to correct students' naïve knowledge regarding those concepts. However, the researchers posit that some concepts could be taught in more concrete ways, which might help the students to develop more accurate mental representations and concepts of cells. Yet, the authors do not provide specific suggestions regarding how the teachers might improve the learning experience and make it more concrete and more understandable for middle school students. Thus, one goal of this study was to examine whether the use of digital microscopes might help to make the learning of cells more concrete and understandable for the middle grade students participating in this study.

Attempts at Implementing Science Teaching Reforms

Anderson and Helms (2001) stated that goals and standards have been set for science education. As they examined research regarding implementing the standards, they concluded that implementation of the new science standards is now the major challenge facing science educators. They identified the following barriers that science teachers face as they attempt to implement the recommended reforms. One problem is the issue of time constraints. The new standards call for the addition and the deletion of content topics. Teachers find it a difficult transition to stop teaching content that they have valued and to teach other content instead. Also, the new reforms call for developing a deeper understanding of the concepts, a task which is time-consuming. The second dilemma that they identified was that of the ideal versus reality. As Sarason (1996) explained, change is complex and very difficult to achieve in long-lasting reform efforts. Thus, it is difficult for teachers to make the change from the reality of the classroom to the ideal of the standard. The third barrier noted by Anderson and Helms was that of changing roles and work. The current roles that students and teachers assume in a classroom are deeply rooted in traditional school culture. Teachers themselves were students for a number of years before becoming teachers. Making changes in the roles that they play and the type of work that students produce is a difficult transition. The fourth dilemma is the teachers' view of the preparation of the students for the next level of science study. While Anderson and Helms state that empirical research suggests that students who participate in programs following the new guidelines will be sufficiently prepared for the next level of study, that notion remains a barrier in teachers' minds. The final barrier that they identified was the teachers' concerns regarding what is meant by "science for all." There are ongoing debates regarding tracking and ability grouping. Many teachers are wondering

how they will teach students who seem uninterested in science and also provide challenging lessons for students who seem receptive to the challenge.

Edelson (2001) noted that the National Science Education Standards (National Research Council, 1996) call for changes to be made from the traditional ways of teaching science. He also stated that these standards call for a deeper understanding of concepts identified in the standards and that students should be able to discuss explanations and make predictions based on their conceptual understandings. In addition to conceptual knowledge, the standards call for students to develop procedural knowledge that is integrated with the conceptual knowledge. He said that students should have hands-on experience with the dynamic processes of questioning, collecting evidence, and analyzing data, working in ways that are similar to how real scientists operate. This model of science teaching is contrasted with the traditional model, where content and processes are usually taught through separate learning activities (Christensen, 1995; Roth, 1992). Thus, making the change to an integrated, dynamic, and more scientifically-authentic type of classroom can be a difficult challenge for a teacher.

Edelson (2001) explained that the ambitious objectives of the National Research Center (1996) are founded on an inquiry learning model. When this model is developed, students are expected to form deep, interconnected content knowledge, as well as to develop inquiry skills, as they work in an authentic setting. He noted that in spite of the calls for teachers to move to this model of teaching, the transition has been very slow. He proposed that technology might be a useful tool in helping teachers to make the transition from a traditional style of teaching to a style that is more aligned with a constructivist method of teaching. He thinks that putting technology as tools into the hands of students might add

authenticity to the students' learning environment and help them to develop the deep, interconnected knowledge and the process skills sought in the calls for reform in science education.

Call for Research on Implementing the Standards

After reviewing the literature related to implementing the science standards as outlined in *Project 2061* and the *National Science Education Standards*, Anderson and Helms (2001) proposed a call for needed research in this area. This study attempted to address five of the nine characteristics identified by Anderson and Helms. One of those characteristics was that the research be conducted in the "real world." The second identified characteristic was a focus on interventions into school practice. This study provided a simple intervention, the introduction of analog and digital microscopes, which could be used as mindtools for creating knowledge of cell theory. The third attribute outlined that was addressed in this study was that the researcher did not assume that change needs to be mandated from the top down. In this study, the teachers were provided tools that could be used with the students during their study of cells. However, only minimal directions will be provided to the teacher as to how this tool should be used. The fifth research characteristic that was identified and that was included in this study was a focus on student roles and student work. Classroom observations, student interviews, and teacher interviews were conducted. The results of the careful analysis of these qualitative data provided insight on the roles of these seventh grade teachers and their students during their study of cells. (These findings are presented in chapter 5.)

Federal Mandates Regarding Science Education

In March 1999, Richard W. Riley, who was Secretary of Education, established the National Commission on Mathematics and Science Teaching for the 21st Century. Former Senator John Glenn was named as chair of the commission, which was charged with creating an action strategy to improve the quality of mathematics and science teaching in grades kindergarten through high school in the United States. Thirty-two individuals – including business and education leaders, public officials, and mathematics and science teachers – joined Glenn to form this commission. They met five times to review what was known about quality mathematics and science teaching, to determine the current state of affairs in mathematics and science education, and to provide a set of recommendations designed to improve mathematics and science education in the United States (U.S. Department of Education, 2001).

The National Commission on Mathematics and Science Teaching for the 21st Century released its report, entitled *Before It's Too Late*, on September 27, 2000. This report noted the critical importance of improvement in mathematics and science education in the United States. The Commission specifically cited the demands of a changing global economy and workplace, the nation's need (as a democratic government) for a highly educated citizenry, the important connections between the nation's national security interests and mathematics and science, and the potential that mathematics and science have for helping humans understand the world and meet its myriad of challenges (U.S. Department of Education, 2001).

The Commission made four major points. First, the Commission stated that they were convinced that the future well-being of the United States depends on how well the nation

educates its children in general, and specifically in mathematics and science. Second, education in mathematics and science is not at the level it should be. They noted that schools are failing to prepare students for challenges already being presented the 21st century and noted in particular that the nation's education system is failing to acquire the students' interest in mathematics and scientific ideas, to teach students to reach the level of competence needed to perform their jobs productively and to live their lives in a fulfilling manner, and to challenge the students' imaginations satisfactorily. Third, the Commission concluded that the most powerful means of change lies in the actual teaching of math and science. They noted the importance of teachers who know their subjects well and who are enthusiastic about their content and teaching it effectively, and they cited the importance of sustained, high-quality professional development. Fourth, they outlined the three specific goals, including establishing an ongoing system to improve mathematics and science teaching, increasing the number of mathematics and science teachers while improving the quality of their preparation, and improving the working place to make the teaching profession a more attractive environment for K-12 mathematics and science teachers. Thus, this Commission emphasized to the nation the importance of improving mathematics and science education in grades K-12. They stated their case with urgency and requested that major changes be enacted immediately, as stated in the title of their report, *Before It's Too Late* (U.S. Department of Education, 2001).

Another important federal initiative is the *No Child Left Behind Act of 2001* signed into law on January 8, 2002, by President George W. Bush. This act reauthorized the *Elementary and Secondary Education Act* (*ESEA*) – the principal federal law governing education in grades kindergarten through high school. The *No Child Left Behind Act of 2001*,

which amended *ESEA*, represents major changes in federal support for elementary and secondary education in the United States. This mandate rests on four pillars: accountability for results; an emphasis on following guidelines based on scientific research; expanded options for parents; and additional local control and flexibility. The overall mandate is to close the achievement gap that exists between groups of students in the United States (U.S. Department of Education, n.d.).

One component of the *No Child Left Behind* legislation focuses on student achievement in science education. The U.S. Department of Education (n.d.) has stated that one challenge facing America's schools is that they are not producing the excellence in science education needed for global economic leadership and for homeland security in the twenty-first century. One supporting statistic cited is that eighty-two percent of America's twelfth grade students performed below the proficient level on the science test portion of the 2000 National Assessment of Educational Progress (NAEP). Another statistic reported seems to indicate that the longer the student stays in an American school, the worse his/her progress is, when compared to the test results of students in other nations in the 1995 Third International Mathematics and Science Study (TIMSS). It was noted that fourth graders ranked second on this test, but twelfth graders ranked sixteenth, as compared to students in other countries who took this assessment. The proposed solution is to have schools use research-based methods of teaching science and to monitor the progress of the students. In fact, the *No Child Left Behind* legislation requires that federal funding be granted only to the programs that are backed by scientific evidence. This law also states that beginning in 2007, every state will be required to conduct yearly testing in science. States must start measuring

the students' progress in science at least once in each of the following grade spans: grades 3-5, grades 6-9, and grades 10-12 (U.S. Department of Education, n.d.).

The Case for Scientific Inquiry

The American Association for the Advancement of Science (1989) described scientific inquiry as being a difficult concept to describe when attempting to define the process outside its specific context. Contrary to what has been taught in the past in some classroom settings, the AAAS proposes that there is no one scientific method, or set of specific steps that must be followed to conduct scientific inquiry. However, they outline a set of guiding principles that they purport are characteristic of work conducted by professional scientists. The first defining factor is that science demands evidence. Thus, observations of phenomena must be made and accurate data should be recorded. Often instruments that can measure characteristics more accurately than humans can ascertain are required, and sometimes instruments that can assess characteristics that humans cannot perceive without the assistance of such devices are needed for accurate observations to be conducted. Scientists often compare their observations with those of other scientists. A second principle of scientific inquiry, as outlined by AAAS (1989) is that science is a blend of logic and imagination. While logical reasoning forms the basis for deciding which path to pursue, often a scientist relies on imagination to generate options that are then checked with logical thinking. The third principle of scientific inquiry is that science explains and predicts. Scientists compare the theories they propose to data collected by other scientists to find connections and to see how their thinking might fit into the larger scheme of scientific theories. The fourth scientific inquiry principle outlined by AAAS (1989) is that scientists try to identify and avoid bias. This professional organization noted that one way to help prevent

bias is to have many different investigators working on the same problem. Thus a middle school classroom following constructivist principles provides an opportunity for students to compare their findings with other students. Perhaps this type of activity, as students compare the results of their investigations with others in the classroom, will provide them a glimpse of how real scientists work and show them the value of comparing data reported by many investigators. The final principle is that science is not authoritarian. Part of a scientist's job is to examine observed data and proposed theories with a critical eye. Edelson et al. (1999) postulate that when students participate in scientific inquiry using technological tools adapted for science instruction, they have the opportunity to achieve three important goals. They can achieve an understanding of scientific concepts, can acquire science process skills related to the context, and may develop general inquiry skills.

Songer et al. (2002) reviewed the literature on scientific inquiry and came to the same conclusions that Bransford, Brown, and Cocking (2000) had reached in favor of scientific inquiry. They gave four reasons of implementing science as inquiry, specifically when teaching middle school students who reside in areas of poverty. They noted that the use of scientific inquiry helps students to develop deep knowledge of content that can serve as a foundation for learning other concepts and relating them to this foundational knowledge. They also stated that inquiry-based learning allows students to build upon their own problem-solving skills. Third, they stated that programs fostering scientific inquiry can provide challenging learning opportunities in a way that does not feel threatening to students. Fourth, the use of scientific inquiry gives ownership to the students of their learning. As Songer et al. suggested, this characteristic is especially important when teaching children of poverty. This approach is in contrast to the traditional methods of teaching science where the teacher is

seen as owning and imparting the knowledge to students, who may not be motivated to learn when they do not sense that they own the learning experience.

Barriers to the Use of Scientific Inquiry

Researchers have noted that the implementation of scientific inquiry in classroom environments has been a slow process. Krajcik et al. (1998) stated that more needs to be known regarding students' experience with inquiry in science classrooms. The goal of their study was to examine case studies of eight middle school students who designed and implemented their own investigations. The researchers found value in collaboration among group members and in teacher support. Problems that they identified were the students' failure to focus on the scientific merit of the problems they pursued and students' difficulty in systematically collecting and analyzing data. Schauble et al. (1995) pointed out the difficulty of students' completing systematic scientific experiments. They listed tasks involved in scientific inquiry, such as data gathering, analysis, interpretation, and communication, as difficult undertakings for middle school students. Edelson et al. (1999) listed the following five challenges of implementing inquiry-based science learning: motivation, accessibility of investigation techniques, background knowledge of the science content, management of complex, extended activities, resources and work products, and the practical constraints of the learning environment, such as available resources, inflexible schedules, and access to resources, information, and experts in the field.

Haberman (1991) identified barriers to good teaching in urban schools. He described what he called a "pedagogy of poverty," a condition which he claims prevents the adoption of effective teaching strategies. Songer et al. (2002) concluded that the barriers identified by Haberman can also obstruct the transition to the use of scientific inquiry in middle school

classrooms where many of the students are classified as children of poverty. Barriers that Haberman identified included: lack of space and materials, inadequate time to prepare for the implementation of new strategies and programs, low levels of science content knowledge of the classroom teachers, and lack of administrative support and instructional freedom.

Overcoming Barriers to the Use of Scientific Inquiry

In a case study of urban middle school students (in an area of poverty), Songer et al. (2002) examined barriers that Haberman (1991) identified as obstructions and concluded that those barriers might also prevent teachers from implementing scientific inquiry in the classroom.

Songer et al. (2002) conducted a case study in the sixth-grade classrooms of five teachers in the Detroit Public Schools (DPS). In the year of the study, the DPS served a population of students that consisted of 95% minority students. Of these students, more than 70% were eligible for free or reduced-price lunches. The teachers in the study were five sixth-grade teachers from the Detroit Public Schools who were selected from approximately 240 teachers from 40 states who were participating in an eight-week implementation of the Kids as Global Scientists (KGS) weather program. The KGS: Weather curriculum is an 8-week middle school program that allows students to participate in inquiry science and to use technology as a tool. These five teachers were selected because they were from the same grade level and the same school system and because their students had made significant gains from the pre-test to the post-test that measured their mastery of weather content and of inquiry skills. The purpose of this study was to examine patterns in the classroom learning environments, to look at how the curriculum was enacted, and to assess student learning. Students were given a pre-test and post-test, and a repeated measures analysis of variance

(ANOVA) was used to compare the mean scores. In each of the five teachers' classrooms, there was a significant difference between the means of the pre-test and post-test scores of their students. A qualitative part of the study involved observations of the classrooms and teacher interviews. Each classroom was observed a minimum of two hours a week for each of the eight weeks of the program by a graduate student, using a classroom observation form developed by Emmer (1986). In addition, the five teachers were interviewed at the conclusion of the project. The observations and interviews were transcribed and analyzed. Patterns that were identified were checked for consistency with data, and discrepancies were discussed with the teachers until consensus was reached.

Songer et al. (2002) found that the five teachers faced varying levels of barriers to inquiry teaching, as identified by Haberman (1991). Some of those adverse conditions included large classes, inadequate time to plan for the instructional activities, low level of teacher comprehension of the science content, high levels of student mobility and teacher mobility, problems with access to computers, lack of computer and Internet reliability, and lack of administrative support. As might be expected, the teachers who indicated fewer adverse conditions found it easier to implement the KGS: Weather curriculum. However, in spite of the barriers in the classrooms, all classes showed a significant change in mean from the pre-test to the post-test (as noted above.)

From the qualitative data, the researchers identified six positive benefits of the KGS: Weather program. First, they noted that many students in poverty do not find the study of science interesting or relevant to their lives. According to the teacher interviews in this study, one of the greatest benefits of the KGS: Weather program was that students were able to see relevance in their study of science. Second, the teachers noted students learned science

content and inquiry skills. Third, the teachers stated that special populations of students benefited from this approach. One teacher noted that some of her lowest achieving students earned passing grades in science for the first time that year. The fourth benefit was the increase of teacher knowledge as the result of this program. All five teachers reported that the implementation of KGS: Weather had fostered their own learning of science content and of technology use. The fifth advantage of this technology-enriched science inquiry program that the teachers noted was student enthusiasm and strong self-esteem. The final benefit mentioned was an increase in the students' technology fluency, which transferred to their home use of computers. In conjunction with this increased fluency, the teachers also noted that the KGS: Weather program provided an opportunity for their students to use technology in ways that fostered higher levels of learning, rather than just to provide drill and practice.

Science for All Americans – Equity Issues

There are equity issues to consider when addressing the concept of science for all Americans. One issue is the accessibility of resources. Another important consideration is the equity of the availability of computer resources and the way that the resources are used with various groups of students. A third issue relates to the science achievement of African American students, and a fourth issue is the science achievement of students based on their gender.

Davidman and Davidman (1997) synthesized some of the various views on equity in schools. Their discussion of educational equity reminds the reader that this topic is complex and that various contrasting views exist on the definition of educational equity and on how best to achieve this goal. They noted that Sirotnick (1990) views educational equity as the equal distribution of resources to groups, which results in similar outcomes for each group.

He purports that these resources and outcomes can be measured quantitatively. In contrast, they discussed the emphasis that Eisner (1991) places on individuals, in addition to concerns regarding groups of students. Davidman and Davidman proposed that for educational equity to occur in a school district, certain conditions must be met. They listed those conditions as "physical and financial conditions, educational outcomes, and opportunity to learn" (p. 81).

Equity Issues in Implementing Technology as a Mindtool

The U.S. Department of Education, National Center for Education Statistics (2003) compiled statistics regarding the education of Black, non-Hispanic students. This report indicated that for the year 2001, the number of Black, non-Hispanic students using computers at school was slightly lower than the percentage of White, non-Hispanic students. (The actual percentages reported for ages 10 to 14 years old were 91.8% of the White, non-Hispanic students and 89.4% of the Black, non-Hispanic students.) Statistics that showed a larger discrepancy between the two groups were the data representing the students in this identified age group who use computers at home. In this category, 80.3% of the White, non-Hispanic population in 2001 reported using computers at home, while 44.5% of the Black, non-Hispanic students reported the use of computers at home. In addition, this report stated that 68.1% of the White, non-Hispanic students were using computers at home for school work, in contrast to 39.4% of the Black, non-Hispanic students in this age group. These figures provide a representation of what is referred to as the "digital divide" (Solomon et al., 2003).

Wenglinsky (1998) wrote a report based on data from the 1998 National Assessment of Educational Progress (NAEP) in mathematics. The data were obtained from national samples of 6,227 fourth grade students and 7,143 eighth grade students in the United States. Among other data, the NAEP collects information regarding educational technology. This

study was complex and multi-faceted. The first aim of the study was to compare the uses of educational technology among groups of students to investigate the equities and inequities of technology use. One area of equity that was found was that there was little difference in how often the different groups of fourth-graders and eighth-graders in this study used the computer at school. However, the analysis of the data revealed a difference in how the computers were used within the school setting. The researcher grouped educational activities, including learning games and drill and practice, into a category defined as those requiring lower-order thinking skills. He grouped the computer activities that included simulations and applications and the introduction of new topics as those that required higher-order thinking skills. The teachers reported the type of educational activity using the computer that was most often conducted in their classrooms. From the fourth grade data, 54.5% of the students' teachers reported that learning games were the primary use of educational computing resources; 35.9% stated that drill and practice was the primary use; 7.5% reported simulations and activities as the most frequent use; and 2.1% indicated that the use of the computer to introduce new topics was the primary use of computers in their classrooms. From the eighth grade data, 34.3% stated that drill and practice was the primary use; 29.2% of the students' teachers reported that learning games were the primary use of educational computing resources; 27.2% reported applications as the most frequent use; and 9.2% indicated that the use of the computer to introduce new topics was the primary use of computers in their classrooms. Wenglinsky concluded from these data that with fourth and eighth grade students, computers are often used for activities that require lower-order thinking skills, but they are also used frequently for higher-order activities in some of the teachers' classrooms.

As Wenglinsky (1998) disaggregated these data for sub-groups of students at each grade level, he discovered that there was variation of the type of use according to the sub-group of students. From the fourth-grade data, he noticed differences based on the factors of school governance (public or private institution,) region of the country, and community status. For example, students in the southeastern United States are more likely to use computers for drill and practice than for other applications. He stated that there seemed to be little difference in how computers were used with advantaged and disadvantaged students in the fourth grade. From the data on the eighth-grade students, he found some similar patterns and some different patterns from the fourth-grade data. He did not find any differences based on gender for either grade level. Also, as with the fourth-grade data, students in the southeastern United States are more likely to use computers for drill and practice than for other applications. However, in the eighth-grade data, he identified patterns that were associated with ethnicity and economic status. He found that the Black students in the eighth-grade sample were less likely than White students to be assigned tasks on the computer that required higher levels of thinking. Also students who were labeled as poor, urban, or rural were less likely to be provided educational technology activities that required higher-order thinking.

Wenglinsky (1998) created a model that included the following variables: access to home computers and frequency of their use, frequency of use of school computers for mathematical tasks, professional development of teachers in instructional technology use, higher order and lower order uses of computers by mathematics teachers and their students, and mathematics achievement test scores. He used multivariate analyses of the variables to help determine the effect size of the various factors related to student achievement. From his

analyses, he concluded that fourth grade students who used the computers to play educational games were 0.15 of a grade level (or five weeks of a 36-week school year) ahead of the students who were not using the computer primarily for learning games. At the eighth grade level, he discovered that students who were engaged in higher-order thinking skills while using the computer were 0.42 of a grade level (or 15 weeks of a 36-week school year) ahead of the students who were not using the computer primarily for higher-order thinking activities. Thus, he concluded that for eighth-grade students, the type of use of the computer seemed to be related to the achievement of the students.

From his study, Wenglinsky (1998) concluded that while frequency of computer use was unrelated, or even slightly negatively related, to eighth-grade student achievement, the type of use of the computer was related to achievement. The computer activity that was associated negatively with student achievement in mathematics was the use of the computer for drill and practice. He reminded readers that the data used in this study suggested that Black students in the eighth-grade sample were less likely than White students to be assigned tasks on the computer that required higher levels of thinking and more likely to be given drill and practice on the computer. Also students who were labeled as poor, urban, or rural were less likely to be provided educational technology activities that required higher-order thinking. He posited that Black students were less likely than White students to be asked to use the computer in ways that were associated with student achievement. Thus, his research exposed inequities that occur not only in the frequency of computer use, but more importantly in how the computers are used.

Other studies have suggested discrepancies in computer use based on the socio-economic status of the students and the perceived ability level of the students. Becker (2000)

analyzed data collected from the Teaching, Learning, and Computing (TLC) national survey of more than 4,000 teachers from grades four through twelve. This survey was conducted in the spring of 1998, using funding from a grant from the National Science Foundation. The sample was comprised of a probability sample taken from 655 schools and a purposeful sample taken from 378 schools participating from 52 major reform programs and 182 schools that had high-end technology. The researcher found that teachers in high poverty middle schools were more likely to state that their primary use of the computers was for skill remediation and mastery. Teachers who taught students in the higher socio-economic groups were less likely to state that their primary use of computers in the classroom was for remediation and skill mastery. Instead, they noted more constructivist uses, such as using computers to analyze information, to allow students to present their ideas and learning, to communicate, and to collaborate. These findings are similar to those of Wenglinsky (1998) in that students in higher socio-economic status were more likely to be using the computer for higher-order thinking, and those in lower socio-economic status were more likely to be asked to use the computer for skills that only require lower levels of thinking.

Motivation, Attitudes, and Engagement

Much of the literature on motivation fits with the "expectancy X value" theory (Feather, 1982). This theory is based on the idea that the effort people are willing to devote to a task is the product of the degree to which they believe they will be able to succeed at the task if they apply themselves (including the degree to which they expect to receive the rewards associated with successful completion of the task) and the degree to which they value the associated rewards. In other words, people are willing to invest their efforts only if they think the task is achievable and if they value the task and its expected outcome. Until

about the early 1980s, research on student motivation focused on the first half of this equation, providing suggestions for teachers on developing the expectation of success within the student. Since about the mid-1980s, research has also been examining issues related to the value issues of this equation. In other words, recent research has looked at the issues associated with how students come to value a task, as well as the issues involved in helping students to develop the expectancy of success (Good & Brophy, 2000).

Good and Brophy (2000) state that four conditions must exist in order for students to be motivated. First, there must be a supportive environment. Second, an appropriate level of challenge or difficulty must be provided. In other words, the student must see the task as a challenge that he/she can achieve if he/she applies him/herself. Third, there must be valuable learning objectives. That is, the student must see value in accomplishing the task. Fourth, there must be moderation and variation in the motivational strategies used. The authors recommend a combination of external and intrinsic motivational strategies, with the intrinsic strategies playing a very important role. Two recommended intrinsic motivational strategies include providing an opportunity for students to create finished products, such as a multimedia production that shows others what one has learned, and providing the opportunity for students to interact with their peers in meaningful learning activities.

Why Study Attitudes?

Interest in student attitudes and their relation to achievement began with a 1978 education report written by Paul deHurd and a 1976 book by Benjamin S. Bloom in which he postulated that approximately 25% of the variance in school achievement could be accounted for by the students' attitudes toward the area of study (Simpson & Oliver, 1990). Since those two publications, numerous studies have been conducted to examine attitudes as they relate

to school achievement. Simpson and Oliver (1990) reported on a 10-year longitudinal study that specifically investigated attitudes toward science and achievement in science among adolescent students. In this study, the three main categories of independent variables included those related to school, to home, and to the individual student. Two independent variables, attitude toward science and achievement in science, were used.

Simpson and Oliver (1985) were interested in looking at attitudes toward science and science achievement motivation of students in grades six through ten. One of their goals was to examine how student attitudes toward science and science achievement motivation change over the grade levels. While this study was not a longitudinal study, it did involve a large sample of students in the same school system from each of the grade levels in grades six through ten. The sample consisted of 178 science classes, 57 teachers, and about 4,000 students from twelve schools, which were randomly selected from the 55 schools that comprise a large school system in central North Carolina. All sixth graders from four elementary schools, all of the seventh, eighth, and ninth graders at four middle schools, and all of the tenth-grade biology students in four senior high schools were selected to participate in this study. The students were given an attitude toward science scale, which they determined had a reliability of .94 using Cronbach's Alpha, and an achievement motivation scale, which had a reliability figured at .88 using Cronbach's Alpha. Mean scores for each grade were compared using ANOVA and Duncan's Multiple Range test. Mean scores were also compared by gender and race.

Simpson and Oliver (1985) noted some interesting patterns. They found that for this sample of students, attitudes toward science declined steadily from grade six to grade eight. The steepest decline was from the seventh grade to the eighth grade. They also noted that at

each grade level, the male students had more positive attitudes toward science than the female students did. However, it is interesting to note that at each grade level, the female students were significantly more motivated to achieve in science than the male students at the same grade level. The authors noted that this particular finding was contrary to what some prior studies had indicated related to gender and the motivation of students to succeed in science.

In addition to comparing the attitude changes across grade levels, Simpson and Oliver (1985) also examined the attitude changes that occurred within each grade level. Attitudes were assessed at the beginning, middle, and end of the year for each grade level. In each grade level, the attitudes declined sharply from the beginning of the year to the middle of the year. They also declined somewhat from the middle to the end of the year, but this change was not statistically different. Like the attitude scores, achievement motivation scores declined steadily from the sixth grade to through the tenth grade. Also at each grade level, there was a significant decrease in achievement motivation from the beginning of the year to the middle of the year. There was also a significant decrease from the middle of the year to the end of the year in two of the grades, the seventh and tenth grades.

Yager and Penick (1986) examined data collected from the National Assessments of Educational Progress (NAEP) for three separate studies in three different years – 1977, 1982, and 1984. In 1977, data from a stratified random sample of 2,500 participants in each of four age levels – 9-year olds, 13-year-olds, 17-olds, and a sample of young adults. In 1982, a sample of 600 participants in each of the identified age groups, except the young adult group, was used. There were 400 participants selected for the young adult group. In 1984, the sample was chosen by selecting a sample of teachers who were members of the National

Science Teachers Association. From this group of students taught by these teachers, a random sample of 750 students and 310 young adults was selected for this study.

Yager and Penick (1986) found a pattern similar to the one identified by Simpson and Oliver (1985). In their study, Yager and Penick found that as the students got older, they were less likely to describe science classes as fun, interesting, or exciting. These researchers also found that as the students aged, the percentage of students who thought that science learning would be useful in the future dropped from about 92% for 9-year-olds to about 75% for 13-year-olds to approximately 68% for 17-year-olds and down to 23% for young adults. The authors argued that these data, collected from three different studies over a seven year period of time, show students' attitudes toward learning science become less favorable as they take more science courses. The authors also postulated that perhaps as the method of teaching science becomes less hands-on and more lecture-oriented, students' interest in learning science declines. They advocated teaching science in a way that involves the students and helps them to see the usefulness of learning and doing science.

In 1990, Simpson and Oliver (1990) reported on a follow-up study to the earlier research. They conducted a 10-year longitudinal study that investigated attitudes toward science and achievement in science among adolescent students. The researchers maintained a close contact with the cooperating schools. The sample of students who participated in the 1985 study and who were in grades eight through twelve at the time of that study comprised the sample for the longitudinal study. In this study, the three main categories of independent variables included those related to school, to home, and to the individual student. Two independent variables, attitude toward science and achievement in science, were used.

Simpson and Oliver (1990) were interested in examining whether earlier measures of attitude and achievement could be used to predict the students' participation and achievement in science. Records of students from the 1983 and 1985 classes were used, and every other student's name on an alphabetized list of those students was selected for this study. The researchers found that declines in student motivation were correlated with achievement motivation. Interestingly, they also noted that adolescents' attitudes toward science are positively correlated to their friends' attitudes, and this relationship is at its peak when the students are in the ninth grade. They also found that school factors are stronger influences on students' attitudes toward science than either home or individual influences. In addition, they learned that for the adolescents in this sample, family and school influences were mediated by the student's sense of self. They also suggested that the students' sense of science self-concept, achievement motivation, and anxiety toward science are the major factors that affect the students' development of this sense of being able to achieve in the study of science. How the student feels in the tenth grade about science and his/her ability to be successful in its study is a strong predictor of achievement in future high school courses. In fact, this study found a stronger relationship between attitude and achievement than previous studies did. This study helps to show the importance of schools developing positive attitudes toward science in middle school students.

Fredricks, Blumenfield, and Paris (2004) conducted a review of the literature on student engagement. They noted a growing interest in engagement and referenced studies that suggest students today often see school as boring or as a game to get good grades. From their literature review, they concluded that engagement is presumed to be malleable. Student engagement, they proposed, is best defined as a meta-construct, consisting of three

interactive components – behavioral, emotional, and cognitive engagement. As they synthesized research on behavioral engagement, these authors noted that behavioral engagement may be defined in three ways, which include the adherence to classroom and school rules, involvement in learning tasks (which included behaviors such as effort, persistence, attention, participation,) and participation in school-related activities (which show a commitment to the institution.) Also, based on their literature review, Fredricks et al. (2004) defined emotional engagement as the students' affective responses in the classroom, including happiness, discontent, interest, and boredom. These authors posit that research on emotional engagement is related to research regarding attitudes of students. As they examined the literature on cognitive engagement, the authors found that cognitive engagement seems to involve student investment in learning, a construct which includes self-regulation and psychological investment. They noted that the definitions of cognitive engagement are similar to those used when discussing motivation to learn. They also distinguished between effort that is aimed at completing the work and effort that is focused on learning the content. The former type of effort is viewed as pertaining to behavioral engagement, while the latter form is seen as the type associated with cognitive engagement.

Fredricks et al. (2004) noted studies that have documented a correlation between behavioral engagement and achievement. Yet, they found only a few studies that addressed achievement and motivation in specific contexts, such as the middle school science classroom. They called for more qualitative research regarding engagement in specific contexts. They noted a particular need to learn more about the engagement of minority students in learning contexts.

Singh et al. (2002) investigated the effects of motivation, interest, and academic engagement in the mathematics and science achievement of eighth grade students. The authors noted that there are factors associated with academic success. Some of these are not easily changed in the school setting. Rather, they are related to home life and other factors that are not easily altered in a classroom context. Three constructs which might be malleable in the classroom context include motivation, interest, and academic achievement. One reason to study factors associated with success in mathematics and science courses is that the success students experience in these courses in middle school is related to whether they choose to take course in these subjects as electives in high school, the level of science and mathematics courses that they choose to pursue, and the jobs that are associated with successfully completing the higher levels of these courses.

This study used the nationally representative data of eighth grade students taken from the National Educational Longitudinal Study in1988 (NELS: 88) to investigate those factors in eighth grade mathematics and science classes. The sample for the NELS: 88 consisted of 24,599 eighth grade students from 1,057 schools across the United States. The researchers examined attitude, two motivation factors, and achievement. The two factors that they used to indicate motivation did not seem to be as context-related as it could have been. One of the factors they used to indicate motivation was based on the number of days the student had been absent from school and the number of times that the student had skipped the math or science class. The other motivation factor was based on whether the student came to class with the appropriate materials and completed homework. Perhaps the construct of motivation could have been better evaluated in terms of how willing the students were to participate in learning activities and the interest that they showed in learning about the science content.

Yet, these data were taken from quantitative data collected on a large sample of students. Therefore, the researchers needed to find concrete behaviors that could be reasonably associated with the concept of motivation and that were recorded by this assessment instrument. In light of those limitations, the factors that they identified as “Motivation 1” and “Motivation 2” could be reasonably associated with behaviors exhibited by students who are motivated to succeed in the classroom, even if they are not as aligned with the behaviors exhibited by students who are motivated to learn, as compared to behaviors associated with those who are motivated to earn good grades. The value gained by analyzing the data on a large number of students could compensate for the use of these particular behaviors as representatives of behaviors exhibited by students who are motivated to learn.

Schiefele (1991) proposed that motivation is not just a predictor of academic achievement, but it is also a construct that has merit of its own. A positive learning experience is a desired outcome in its own right. He reviewed studies suggesting that topic interest was significantly correlated with involvement, enjoyment, concentration, and activation.

Singh et al. (2002) reviewed other studies and noted that attitudes toward mathematics and science were shown to be predictive of academic performance in mathematics and science. They also noted that the accumulated research evidence suggests that motivation, attitudes and interest, and academic engagement seem to be critical constructs related to learning. From their review of the literature and from the results of their own study, the authors concluded that affective and motivational factors have the potential of being enhanced and modified by innovative curricular and instructional approaches.

In this study, Singh et al. (2002) examined eighth graders' school performance in mathematics and science and developed a conceptual model of behaviors and attitudes that seemed to influence performance in these subjects. Mathematics and science achievement were measured by course grades and by standardized test scores. The model developed for science achievement involved four factors - Motivation 1, Motivation 2, attitude, and academic time. These four factors explained 38% variance in the science learning. As noted above, Motivation 1 was defined by class attendance, and Motivation 2 was based on how often the student brought the appropriate materials to class. Academic time was defined as the amount of time that the student reported he/she spent on science homework. Attitude was measured by survey questions regarding the usefulness of science study, boredom at school, and whether the student looked forward to science class. The strongest effect on science learning was that of academic time. Attitude toward science had the next largest effect on science learning, and the strongest total effects were that of Motivation 1, Motivation 2, and the attitude toward science. The results of this study suggested that science achievement among eighth graders is influenced by motivation, attitude, and academic engagement.

Middle School Education

The history of middle school education is traced to the concept of the junior high school movement (National Middle School Association, 2003b). Gruhn and Douglass (1947) published a list of the six functions of a junior high school: integration, exploration, socialization, differentiation, guidance, and articulation (Lounsbury, 1996). After this publication, there continued to be numerous models for the junior high concept, and most of them were more reflective of the senior high school concept than of the model that Gruhn and Douglas had proposed. In the 1960s, William Alexander introduced the concept of the

middle school for a configuration of grades from 5-8 that was an alternative to the junior high school model, which usually incorporated a grades 7-9 configuration. In 1980, John Swaim, who was president of the National Middle School Association (NMSA), saw a need to provide clarity and direction for the middle school movement. He appointed a committee to write a position paper outlining the middle school concept and a rationale for this concept. This committee met over a period of months to develop this concept and to reach a consensus on the components of the middle school model. In 1982, the NMSA approved and published *This We Believe*. This publication was reissued in 1992 and was then revised in 1995 as *This We Believe: Developmentally Responsive Middle Level Schools.* It was again revised in 2003, entitled *This We Believe: Successful Schools for Young Adolescents* (Lounsbury, 1996; National Middle School Association, 1982, 1992, 2003b).

The original NMSA position paper, *This We Believe* (National Middle School Association, 1982, pp. 10-15), included the following characteristics of middle school program: educators are knowledgeable about and committed to young adolescents; a balanced curriculum based on student needs; a range of organizational arrangements; varied instructional strategies; a full exploratory program; comprehensive advising and counseling; expected continuous progress for students; evaluation procedures that are compatible with the nature of young adolescents; cooperative planning; and a positive school climate. This publication provided a framework for the middle school concept.

Another monumental publication was released by Carnegie Corporation of New York (CCNY) in June, 1989. It was based on the two years of work by the Task Force on the Education of Young Adolescents. This report, *Turning Points: Preparing American Youth for the 21st Century* (Carnegie Council on Adolescent Development, 1989), stated that young

adolescents make choices that have consequences affecting their lives. The authors recognized that schools alone could not accomplish all that needed to be done to provide the type of middle school education that the commission envisioned. They called upon people in various sectors of the United States' population to join together to improve the educational experiences of adolescents. This report (pp. 9-10) made the following recommendations: create small communities for learning; teach a core academic program; ensure success for all students; empower teachers and administrators to make decisions about eh experiences of middle grade students; staff middle grade schools with teachers who are expert at teaching young adolescents; improve academic performance through fostering the health and fitness of young adolescents; re-engage families in the education of young adolescents; connect schools with communities.

As noted, in 1995 the NMSA released *This We Believe: Developmentally Responsive Middle Level Schools*. The authors stated that society had changed greatly in the second half of the twentieth century. They noted changes in the roles of males and females, the structures and traditions of families, changes brought by the advent of electronic media, and the fact that communities were becoming increasingly diverse. The NMSA thought that in light of the changes in our society, and because of their continuing desire to help young adolescents develop as "scholars, democratic citizens, and increasingly competent, self-sufficient young people who are optimistic about their future" (p. 10), the concept of middle level schools should be clarified. This revision made the following statement as its central belief.

National Middle School Association believes:

Developmentally responsive middle level schools are characterized by:

Educators committed to young adolescents
A shared vision

High expectations for all
An adult advocate for every student
Family and community partnerships
A positive school climate

Therefore, developmentally responsive middle level schools provide:

Curriculum that is challenging, integrative, and exploratory
Varied teaching and learning approaches
Assessment and evaluation that promote learning
Flexible organizational structures
Program and policies that foster health, wellness, and safety
Comprehensive guidance and support services (p. 11)

In 2000, another report was released by Carnegie Corporation of New York. This report, entitled *Turning Points 2000: Educating Adolescents in the 21st Century* (Jackson & Davis, 2000), was based on the decade long efforts of those who were attempting to implement the suggestions from the original *Turning Points* report (Carnegie Council on Adolescent Development, 1989). The latter report was based on research that occurred during the 10-year period between the two reports, and it was intended to serve as a means to help bridge the gap between research and practice. *Turning Points 2000* emphasized that the recommended organizational structures in middle schools, such as teams and inter-disciplinary instruction, are vital components, but they alone are not sufficient for creating appropriate middle school educational experiences. This second report emphasized the need for a strong curriculum, appropriate student assessment, and effective instruction.

Turning Points 2000: Educating Adolescents in the 21st Century (Jackson & Davis, 2000) reminded the readers of the importance of reflecting upon the fact that important knowledge is currently expanding at a rapid pace. Teachers should also consider the recent research on how students learn best and use that knowledge to inform their practice and to meet the changing needs of developing adolescents. The authors emphasized the need to have

students engaged in their learning and to help the students to make connections between what is occurring in the classrooms and in their own lives.

In 2001, the National Middle School Association published *This We Believe . . . And Now We Must Act* in an effort to develop further the ideas advocated in the previous publications. The NMSA decided to keep the same twelve components identified in *This We Believe: Developmentally Responsive Middle Level Schools* (National Middle School Association, 1995). The authors note that there is much overlap between the important ideas of this publication and those outlined and explained in *Turning Points 2000* (Jackson & Davis, 2000). Both of these publications emphasized the need for reformers to consider the recommendations as an interactive whole, rather than just as a series of disconnected parts.

The latest publication of this sort from the National Middle School Association was published in 2003. This report, titled *This We Believe: Successful Schools for Young Adolescents,* provides an updated model of middle school education. The recommendations can be summarized as follows:

Successful schools for young adolescents are characterized by a culture that includes:

- Educators who value working with this age group and are prepared to do so
- Courageous, collaborative leadership
- A shared vision that guides decisions
- An inviting, supportive, and safe environment
- High expectations for every member of the learning community
- Students and teachers engaged in active learning
- An adult advocate for every student
- School-initiated family and community partnerships

Successful schools for young adolescents provide:

- Curriculum that is relevant, challenging, integrative, and exploratory
- Multiple learning and teaching approaches that respond to their diversity
- Assessment and evaluation programs that promote quality learning
- Organizational structures that support meaningful relationships and learning
- School-wide efforts and policies that foster health, wellness, and safety

- Multifaceted guidance and support services (National Middle School Association, 2003b, p. vii).

These latest recommendations are based on research on middle level education that was published from 1991 to 2002. Thus, the National Middle School Association was able to use the results of these studies to create their most recent suggestions for effective middle level schools. A summary of this research was reported in 2003 by the National Middle School Association in the publication *Research and Resources In Support Of This We Believe.* It is interesting to note that 67% of the studies they referenced were qualitative in nature, only about 15% were quantitative studies, and none of the studies were replications of earlier research. The authors noted an urgency for more research and for validation of the research in this field.

The 2003 research publication of the National Middle School Association reviewed research that supports each component they suggested for successful schools. In this review of literature, the two areas that are most related to this study will be considered. These are the two recommendations that apply specifically to the middle school classroom setting. One of those recommendations is the curriculum be integrative, challenging, and relevant to the students' lives. The other recommendation is the implementation of multiple teaching and learning approaches that are responsive to a culturally diverse body of students.

The first component to be examined is that the curriculum should be relevant, challenging, and integrative. A major work addressed in this area was a publication from the National Research Council in 2000. This publication reviewed hundreds of research studies on learning and concluded that learning is more than the memorization of isolated facts. Rather, learning occurs within a context, and students should be using that context to help

form larger concepts of inter-related facts and understandings. The importance of helping students to create meaningful patterns of information was emphasized. The authors also emphasized that teachers must design classroom activities that help students to foster attitudes toward learning that construct a sense of a community of learners. Their reviews of studies suggested that students who sense that they belong to a community of learners are more likely to become engaged in challenging learning than those who are working independently without a sense of support from the other learners.

The National Middle School Association (2003a, p. 14) also based their recommendation for a curriculum that is "relevant, challenging, integrative, and exploratory" on a publication by Daniels and Bizar (1998). This work presents six practices that the authors state are "best practices" based on the research they present. The six best practices they identified included "representing-to-learn, small-group activities, classroom workshop, authentic experiences, reflective assessment, and integrative units" (p. v-vi). Each of these practices was selected based on research. Since the publication of this book, Daniels and Bizar (2004) have published an updated version that presents further research for these practices and that adds a seventh best practice – Reading as Thinking.

Another important work that was used as a basis for the National Middle School Association's proposing a curriculum that is curriculum is relevant, challenging, and integrative is *The Eight-Year Study Revisited* (Lipka, Lounsbury, Toeper, Vars, Alessi & Kridel, 1998). This volume re-examined a study that was conducted from 1933 – 1941, with the findings released in 1942. The 28-member Commission of the Relation of School and College (CRSC) was appointed by the Progressive Education Association in the fall of 1930. This commission analyzed secondary education in the United States and found 18 areas that

were inadequate. (As noted by the authors of this study re-visitation, the list sounds like one that might be made regarding schools today.) The commission worked with 30 schools to make changes in curriculum, instruction, and organization of the school. They gave the experimental schools freedom to make changes and support in implementing the changes they devised. One goal of this study was to follow students through four years of high school and four years of college; thus, the study became dubbed "The Eight Year Study."

One concern of the CRSC was that secondary education provide more socially responsive curriculum. Three concerns they identified that work against this type of curriculum are a lack of unity in the work of the school, the lack of continuity in the high school education, and the lack of knowledge and skills needed to perpetuate our cultural heritage. Lipka et al. (1998) noted that all three of these concerns persist in secondary (including middle school) education today and that the third concern is more critical now than ever due to the increasing cultural, ethnic, and racial diversity present in our country. They noted that the failure of schools to address these concerns over the last 60 years highlights a perplexing problem. They also noted that there were successes experienced in the 30 schools participating in this study, as detailed in descriptions of changes that occurred in these schools. However, Lipka et al. noted that modern schools have much that can be learned from this experiment and recommended that educators pay more attention to the recommendations from this study. They also noted that the Middle School Education movement was born about the same time that this study was released and that recommendations from it have been applied to developing the philosophy of the middle school concept.

One of those recommendations that Lipka et al. (1998) made for middle schools was that the curriculum become more closely related to the lives of the students. The authors noted that in traditional subjects increased their vitality in the 30 schools participating in the eight year study. The courses became more exploratory in nature, and a more investigative, as well as interdisciplinary, approach was used in teaching the traditional subjects. Teachers examined the content of the traditional courses to see which parts they deemed worth keeping, and they focused on a deeper meaning of these concepts. Lipka et al. recommended that middle schools today learn these lessons from this earlier research study.

As noted earlier, the 2003 research publication of the National Middle School Association reviewed research that supports each component they suggested for successful schools. Also, as noted earlier, this literature review will examine the research basis of their recommendations that specifically apply to this particular research study. A second recommendation that is applicable is that multiple teaching and learning approaches that respond to diversity be employed. One work they referenced was by Tomlinson (1999), in which she made extensive recommendations on how classroom learning could provide for a diversity of students. Based on a synthesis of research, she recommended that teachers answer the following three questions as they plan a differentiated classroom: “Differentiate what? Differentiate how? Differentiate why?” (p. 62). From her research synthesis, Tomlinson surmises that education should accommodate and enhance the diverse abilities, skills, and interests of the students. The National Middle School Association also used the work of Eggen and Kauchak (2001) to support the recommendation of having students engage in hands-on learning that is set in meaningful contexts. In addition, the National Middle School Association referenced the work of Gay (2000) in promoting methods of

teaching a diversity of students. Gay acknowledged that the school achievement of minorities often lags behind students of the majority population. As she synthesized the research on teaching students who are culturally diverse, she developed a proposal, which she referred to as "power pedagogy through cultural responsiveness" (p. xiv). Based on the work of theorists and researchers, she developed a model of teaching that is based on culturally responsive teaching and that she proposes will benefit students who are ethnically diverse. Components of her proposal include fostering an atmosphere of caring, fostering communication that is respectful of the cultural context, promoting cultural and ethnic diversity within the content of the curriculum, and having teachers understand how ethnically diverse students learn and incorporating teaching and learning strategies that are congruent with those ways. She recommends that teachers and students should be partners in the learning process. Thus her work is used to support the proposal by the National Middle School Association (2003a) for "multiple learning and teaching approaches that respond to diversity" (p. 20).

Another study cited by the National Middle School Association (2003a) as part of its research base was conducted by Russell (1997). This study examined the implementation of several middle school education program components at ten middle schools in an urban school district. The middle school components that she examined were those identified by Alexander and George (1993). The list includes: interdisciplinary teaming/block scheduling, guidance services (such as the advisor/advisee model,) an exploratory curriculum, developmentally appropriate teaching strategies, transition/articulation strategies, and appropriate required curriculum/learning skills.

Russell (1997) noted a need for research on the relationship between implementation of the middle school components and student achievement. In this study, she invited all

certified teachers in this school district to participate. She then sent surveys to each of them, and those who chose to participate completed the survey and returned it anonymously. She received completed surveys from 381 teachers, about 73% of the certified teachers in the district. Through the survey information, the teachers provided data regarding the stage of implementation of each of the listed middle school components in his/her school. The independent variable in this study was the perceived level of implementation of each component. Data on student scores were obtained from all departing eighth grade students for whom data from the sixth and eighth grade achievement tests were available. Data from 2,373 students, about 75% of the eighth grade students, were analyzed.

Russell (1997) found that there was a wide range of implementation levels at the various middle schools within this school district. Through regression analyses of the data, she discovered that there was at least one significant relationship that occurred between each middle level program component and at least one achievement test score. Interdisciplinary teaming had a positive relationship with the reading and mathematics scores. Developmentally appropriate teaching strategies corresponded positively to the mathematics scores and to composite battery achievement test scores. There was one small negative correlation, which was the relationship between the guidance (advisor/advisee) program and the language arts and composite battery scores. Russell wondered if perhaps the time allocated to the advisor/advisee program detracted from the time that had previously been spent on the language arts program. Even though there were several positive correlations between the implementation of middle level program components and achievement test scores, Russell noted that the largest predictor of eighth grade scores was past performance (as based on the sixth grade scores.) She also found that three of the middle school

components were related positively with two or more student achievement test scores. Those three concepts were appropriate required core curriculum, developmentally appropriate teaching strategies, and interdisciplinary teaming. Another interesting correlation was that mathematics was the subject area that had a positive, statistically significant relationship with more of the middle level components than the other subjects.

McEwin, Dickinson, and Jenkins (2003) referenced studies that were conducted on middle school education. They referred to these studies as the 1968, 1988, and the 1993 studies. They also reported on their most recent study, which they call the 2001 study. The 1968 study, conducted by William M. Alexander, was the first national comprehensive study of middle schools. This study gathered data which became benchmark data for future studies of the middle school concept and its implementation. William M. Alexander and C. Kenneth McEwin conducted the study referred to as the 1988 study as a follow-up to the 1968 study. In this second study, many items from the original survey were used, and some new items were added. The 1993 study, conducted by C. Kenneth McEwin, S. Thomas Dickinson, and Doris M. Jenkins provided a comprehensive study of middle school education about 25 years after the first study of this nature. These same three authors conducted the 2001 study. The purpose of the 2001 study was to provide a snapshot of current programs and practices in the United States' public middle schools. In the spring of 2001, the researchers sent surveys to 1,436 middle schools (about 12% of the middle schools in the nation,) and they received 745 completed surveys with an overall return rate of 52%.

As noted, the data from the 2001 study (McEwin et al., 2003) provided a snapshot of middle schools in the United States. Of those respondents who returned the surveys, 41% were from rural school districts, 21% were from urban districts, and 38% were from

suburban communities. The authors learned that the number of middle schools have increased significantly since the 1968 study and the most common grade level pattern in the 2001 study was that of grades six through eight. The most common student enrollment was between 601 and 300 students, and almost half (49%) of the middle schools reported enrollments between 401 and 800 students. The smallest school enrollment in this study was 28, and the largest was 4000. The median was 656.

McEwin et al. (2003) observed that research findings are noting the importance of a team organization and common planning time for middle school teachers. They stated in the 2001 study that the use of team organization has increased significantly since the 1988 and the 1993 studies. In the 1993 study, 52% of the respondents used a team organization, while 77% of the respondents in the 2001 study reported that the team organization was used at their schools.

When asked about the time allocated for core subjects, respondents to the 2001 survey indicated that, on the average, the most time is devoted to the study of language arts, and the second most time to the study of mathematics. The respondents also indicated that the study of science and social studies had fewer minutes than language arts or mathematics, but that the amount of time for science and social studies was not drastically different from the time allocated to the other two core subjects. Another statistic that helped to provide this snapshot of American middle schools was the number of schools that implemented a teacher guidance (advisor/advisee) type of program. While this aspect is generally considered to be an important part of the middle school concept, the statistics from these studies show that the majority of middle schools have not implemented this component. The percentage of schools

reporting an advising program in the 1988 study was 39%. That statistic increased to 47% in the 1993 study and only to 48% in the 2001 study.

The 1993 and the 2001 studies collected data on instructional strategies used by the teachers who responded to the surveys. The most frequently used strategy was direct instruction. Comparisons of the data from the surveys showed an increase of 10% in the use of cooperative learning from the 1993 to the 2001 study. Schools also reported an increased use of independent studies. The strategy that was most frequently selected as "occasional use" was inquiry teaching.

McEwin et al. (2003) collected and analyzed data concerning the percentage of teachers at each school who had specialized training in middle level education preparation. They asked each teacher to indicate whether less than 25%, 25-50%, 51-75%, or 76-100% of the teachers in his/her school had received specialized middle level teaching preparation. Respondents at 24% of the schools indicated that 76% or greater of the teachers had received this type of training. This statistic was a 15% increase from the 1993 study. Also, respondents to the 2001 study indicated that 15% of the schools had 51-75% of the teachers with specialized middle level education preparation. The data showed that 17% of the responding schools had 25-50% of the teachers with this type of preparation, and that 45% of the schools indicated that less than 25% of the teachers had received special training in middle level education. Thus, the data from the 2001 study provided a snapshot of the current state of American middle schools, and it provided data that could be compared with previous studies on the middle school concept.

Educational Technology

In the last couple of decades, educators have begun experimenting with technology in classrooms. One of the first studies regarding technology in education was conducted by Apple Computer, Inc, (1995). The project entitled Apple Classrooms of Tomorrow (ACOT) was launched in 1985 in one classroom in Eugene, Oregon and in one classroom in Blue Earth, Minnesota. The next year, five more sites were added to the project, and a two-year longitudinal study was begun. The study continued to grow, as the researchers gathered and analyzed data on the use of technology in education. Eventually, over 100 elementary, middle, and secondary classes throughout the United States participated in this study. The ACOT project was completed in 1998 (Apple Computer, Inc., 2002).

From this thirteen-year study (Apple Computer, Inc., 2002), there are some findings that are highlighted in this review of literature. One main idea that researchers discovered was that the presence of computers seemed to serve as a catalyst for change. Some of the changes that were observed were that the ACOT classrooms moved from being teacher-centered and didactic to becoming more learner-centered and interactive. The teacher's role became less of a "fact-teller" and more a collaborator. The students became more collaborative and even sometimes served as experts in the classroom. The concept of knowledge changed from valuing accumulation of knowledge to appreciating a transformation of knowledge. Technology use moved from the role of seat work to a role that provided communication, information access, and expression of knowledge. The researchers also noted that technology helped to provide multiple representations of ideas for the students.

One particular ACOT study focused on student engagement. Sandholtz et al. (1994) examined student engagement when technology is available in the classroom. The authors noted that it is difficult to define student engagement operationally. Yet, they thought that teachers, who work with the students on a regular basis, could recognize it. Therefore, they decided to have teachers report on the student engagement. The researchers decided not to define engagement in traditional terms, such as an observation of time on task. Instead, they asked the teachers to think of student engagement in terms of such variables as student initiative, self-motivation, collaboration, voluntarily acting as a peer coach, and levels of enthusiasm and frustration. They also asked the teachers to consider the amount of time that students put into projects outside of class time, as well as the effort and time they gave in the classroom. This qualitative study included 32 teachers in five elementary and secondary schools. Seven of the teachers (and their 180 students) were located in a rural middle school. The classrooms were equipped with Apple® computers and were also designed to be multimedia environments where students and teachers had access to textbooks, workbooks, other traditional materials, televisions, and computers. Data collected from 1985 – 1991 included bimonthly audiotapes from the teachers, weekly reports sent by electronic mail, and electronic correspondence that occurred between the teachers at the various sites.

From the analysis of these data, the researchers found some trends. They reported positive changes in student attitude. In fact, they documented a sustained level of enthusiasm from both the teachers and the students. When given a choice, students chose to complete their work using the computer rather than more traditional methods, and teachers reported that the students were more likely to edit their work when using the computer. Another trend noted was changes in the use of time. Teachers found that the students tended to work longer

on a project if they used the computer. Students also frequently chose to use the computers during their free time, and in some classrooms, the students even chose to come in early and stay late to be able to work on the computers. Interestingly, the teachers also found that the students would stay after school to discuss instructional activities, rather than participating in some of the more typical extra-curricular activities that were offered after school. A third trend that the researchers noted was that the teachers reported that the students were enthusiastic about learning and as a whole were spending more time on task than they had in the past. One high school teacher noted that his students were interested and involved in the class, even right before Christmas break. An elementary ACOT coordinator noted that while most teachers were involved in activities typical of an ending school year, the students in the ACOT classroom were still enthusiastically involved in the lessons. A fourth trend was the increase in student initiative. Teachers noted that many students not only completed the assignments, but they exceeded the expectations. Teachers also noted that some students independently sought to learn about new applications and developed skills that were not part of the regular lesson. A fifth trend was that of increased student experimentation and risk-taking. The teachers and researchers noticed that the students' desire to experiment on their own often led to increased interest and engagement in learning.

While the researchers reported five trends that were positive, they also noted some challenges that the teachers and students involved in this study faced. One problem they found was student frustration. Some computer projects were too hard, and others were too easy or became boring with repeated use. Another problem was that of time management. Teachers had problems balancing the time that was spent using the computers with other learning activities. They were sometimes perplexed as to whether they should allow the

students to continue working on a project of interest or stop them to work on another area of the curriculum. A third challenge was the increased student distractibility. Some students were distracted by the noise of printers and of students communicating with each other. Some did not easily adjust to a new type of educational environment. Teachers were also surprised that even though students were interested in the projects in the classroom and asked to work on them outside of class, they often did not complete the homework assignments. A fourth challenge was learning how to set boundaries. With students willing to go beyond requirements, teachers had to figure out what the new boundaries might be. A fifth challenge was the disruption of the teachers' plans. Some of the students wanted to continue an activity until it was complete or until they had solved the challenge or problem. While the teachers were pleased to see that many students were interested in completing the work, they also found that it brought a new challenge to them as they had to determine how to deal with this new situation.

In conclusion, the researchers noted that student engagement was most likely to be a continuing trait in classrooms where technology was used as one tool among many. They found the most benefit when the computer was offered as a tool that was helpful in a situation, rather than just a tool that was used because it was available. The researchers also found that the teachers who used the computers in a meaningful context reported the highest levels of sustained student engagement. Third, the researchers learned that an over-reliance on drill-and-practice software was associated with student boredom, frustration, and off-task behavior. Finally, the teachers who adjusted the use of technology for individual needs had more instances of sustained student engagement than the other teachers did.

Apple Computer, Inc. (2002) presented a synthesis of the research findings from the thirteen years of study in the ACOT program. The researchers concluded that when students have routine access to computers and the opportunity to practice fundamental skills using the computer, they learn the basic skills needed for reading, writing, and mathematics more quickly than they do when they do not have that access. However, Schacter (1999) noted that students in the ACOT schools did not perform any higher on nationally norm-referenced achievement tests than did students in other groups. The researchers from Apple Computer, Inc. (2002) also reported that the computer could be a good tool for individualizing instruction for students who are below grade level in their performance. A third conclusion was that students tend to develop proficiency quickly in the use of technology. A fourth conclusion was that the skills that students need for the 21st century are quickly changing and that the use of computers can help students develop those skills. In addition to learning skills needed to use technology efficiently, the necessary skills include being able to work and communicate with others. The ACOT researchers found that the use of computers tended to foster collaboration in the classroom. A fifth conclusion was that use of technology might improve students' attitudes toward learning. One fact that supported this claim was that in the ACOT classrooms, fewer students were absent. Also, in a five-year study at one of the high schools, no students involved in the ACOT program dropped out of school, as compared to the 30% rate of students in the remaining student body of the school. Schacter agreed with the ACOT researchers that students in the ACOT program seemed to develop better attitudes toward learning and that the program seemed to foster collaborative student-centered classrooms.

An interesting study that focused on the use of technology in a middle school setting was the GTECH project (James et al., 2000). This project was funded by the GTE foundation to help middle school teachers integrate mathematics, science, and technology education. The sample for this study consisted of 36 participants from nine school districts in east-central and southern Texas. A team comprised of a middle school mathematics teacher, a science teacher, a technology teacher, and an administrator represented each selected school district. The participants were given the Stages of Concerns Questionnaire (Hall, George & Rutherford, 1997) at the beginning of the two-year project and again at its completion. The second administration indicated that some of the information, personal, and management concerns of the teachers had been resolved. The profile in general was still that of new users, but the researchers were not discouraged with those results. They were satisfied to see that some concerns were being resolved and that more teachers were now technology users than before the project began. The researchers observed the teachers' classrooms during the latter part of the project and noted that in many cases only one of the team's three teachers was using the ideas developed in the project. Usually, this teacher was the science teacher. The authors suggested that future staff development should be focused on increasing the use by all participants and by helping them to remember the potential impact that these strategies can have on all of their students.

James et al. (2000) noted many accomplishments of the GTECH project. Among them were the 16 integrated units developed by the seven teams of teachers. The units included the use of HyperStudio 3.0, Microsoft PowerPoint software, and the Internet. The units were aligned to the state of Texas standards. The authors also noted other achievements, such as instructional technology use by teachers who, prior to the project, did not know how

to turn on a computer. One accomplishment mentioned was that in one school a group of students was taught how to use HyperStudio so that they could teach the teachers and other students. The authors emphasized that this approach was successful. The teachers stated that as a result of this project, students had developed problem-solving skills, the ability to work in teams, technology expertise, and an increased level of creativity. These accomplishments are associated with constructivist teaching principles and technology integration.

McGrath and Cumaranatunge (1997) conducted a qualitative study that was intended to focus on the following three areas: science understanding and attitudes, gender and attitudes, and responsibility for learning. The sample consisted of 10 teachers from grades three through eleven in rural schools in Kansas and their science students. These teachers were selected for the study because they participated in a one and a half year staff development project. The number of students in the classes ranged from 6 to 24. Six teachers joined together in three pairs, so there were only seven case studies. Students collected data from near-by sites and used a hypermedia program to organize and present their findings.

Each teacher decided on his/her own plan to evaluate student attitudes toward science. McGrath and Cumaranatunge (1997) reported improved attitudes toward the science content and toward the multimedia project. This study, which was qualitative in nature, showed patterns of improved attitudes toward the content and the multimedia project. There was no discernable change in attitude toward science. The middle and high school students reported that they learned important processes associated with other areas of the curriculum as well, such as writing, finding information, organizing information, and communicating the findings. Gender did not appear to be a factor affecting attitudes toward the technology-related components of the project. The researchers did not find changes in attitude toward

science, so they did not compare this attitude by gender. In general, the teachers did find that the students seemed to follow a sequence as they learned to take responsibility for their learning. At first, the students resisted the changes in the type of work that was expected of them. Then, they began to feel a sense of responsibility to their groups. Finally, they realized that they had to sustain the hard work if they were to be successful. A finding that was not expected was that students seemed to have higher self-esteem when their work was to have a real audience.

This study covers a wide grade range and lacks some conformity in evaluating attitudes. However, it does seem to lend some credibility to the idea that multimedia projects might foster good attitudes in students enrolled in science courses. If the students' attitudes improve, then perhaps students will be more motivated to learn and to understand and be able to apply the scientific concepts being taught in the class.

One technology study of interest involved a large-scale implementation of technology initiatives. In this program, the technology was used as a means of instruction, rather than as a separate entity of study. The study involved collaboration between the West Virginia Department of Education and the Milken Family Foundation. Mann et al. (1999) examined the correlation between the Basic Skills/Computer Education (BS/CE) program implemented in West Virginia public schools and statewide assessment scores. The BS/CE program was implemented in 1990-1991 with the kindergarten class. Each year, this program was available to that cohort of students and those entering in the grade(s) below that group. When this study was published, the BS/CE program had been in place for eight years. The BS/CE program contained the following three main parts: software that provided instruction and practice on objectives aligned with the state's instructional goals for basic skills, sufficient

numbers of computers to provide easy access to computers that contained the skill-building software, and staff development for the teachers on how to use the technology.

Data were collected from all 1996-1997 fifth-grade students in the 18 elementary schools that were chosen to represent the state. The researchers also collected survey data from 290 teachers in the 18 selected schools. Both quantitative and qualitative data were collected and analyzed. The data were analyzed using the access/attitude/training model. This model assumed that increases in the students' achievement test scores could be predicted by the following three factors: access to computers and the amount of time spent using software that was related to the basic skills in the state curriculum, teachers' and students' attitudes toward computers, and training provided to teachers on using the computers and the software. Factor analysis was done to create reliability and validity figures for these three components. Then, they used multiple regression analysis to analyze the relationship of these identified factors with the student achievement test scores. The researchers concluded that as a whole, 11% of the students' achievement gains were considered to be accounted for by the BS/CE program. They also noted other factors that may have contributed to the students' gains on the achievement tests, including the renovation of 470 schools and the construction of 68 new buildings, as well as a substantial increase in teachers' salaries. In spite of these other factors, 48% of the teachers said that technology was the best explanation for the students' test score improvements (Mann et al., 1999).

A report released by the U.S. Department of Education, Office of Educational Technology (2004) cites the increasing competition that the United States will face in the global economy over the next ten years and calls for students to be ready to face these challenges. Building upon the changes being implemented with the *No Child Left Behind Act*

of 2001, this newly released report states that the digital age is changing how teaching and learning take place. Dramatic improvements in education are being predicted for the next decade. For students today, the use of technology is part of their everyday lives. They are demanding that technology be integrated into classes. This report suggests that students are pushing teachers to use more technology in their classes. Seven major action steps were recommended. First, technology-savvy leaders should be developed. Second, educational budgets should be examined to determine where funds can be moved to provide more funding for technology in the schools. Third, teachers should receive more training in the effective use of technology. Fourth, they recommended that support be provided for electronic learning and for virtual schools. Fifth, broadband access in schools should be encouraged. Sixth, a move toward digital content should be fostered. Seventh, schools should make better use of data systems for tracking assessment data.

Syntheses of Research on Technology

Some recent studies have synthesized the research on technology and provided educators with generalizations gleaned from a large number of studies. Since reviewing each of these individual studies is impossible within the scope of this work, a review of some recent synthesized studies adds some insights to those gained from a more careful examination of particular studies.

The Software & Information Industry Association (Sivin-Kachala & Bialo, 2000) issued a report on the effectiveness of technology in schools. This report examined 311 research studies. In general the authors reported that there is a positive correlation between the use of educational technology and student achievement. Positive effects could be found for all major subjects and for the span of grades from kindergarten through higher education.

In particular, in the area of science, studies suggested that students could benefit from participating in simulations, using microcomputer-based laboratories, watching video that was used to anchor instruction dealing with real world problems, and by using software that focused on clarifying students' misconceptions. In addition, the authors noted that there was a positive effect on student attitudes. The three core subject areas where this positive correlation was the strongest were in language arts and writing, mathematics, and science. It was also noted that graphics (both still pictures and animated ones) could help improve student learning and were associated with positive student attitudes and motivation, specifically in the areas of mathematics and science instruction. The research also suggested that students benefit from the use of multiple representations of concepts and of visualization of abstract ideas. There were interesting findings related to the use of computers and student group work. Students who worked in groups performed better with their peers if they received instruction on how to function in groups. Also students who were in groups were more likely to interact with their peers and participate in both cognitive and social exchanges. Thus, this study corroborated other reports that student collaboration is associated with group work on the computer. Students working in groups also tended to use better instructional strategies and persisted longer at instructional tasks than those who worked independently. The students who worked independently while using the computer tended to complete their tasks more quickly, but they required more help and interaction from their teachers (Sivin-Kachala & Bialo).

In 2002, the North Central Regional Educational Laboratory commissioned a meta-analysis of research on technology and education. The focus of this study was the effect of technology on student outcomes. The authors of this study noted that several meta-analyses

have been conducted that consistently show a small but significant positive effect on student outcomes when educational technology is employed. They noted that the fact that technology is rapidly changing is the reason that this more recent study was conducted to investigate the latest findings on this topic. They also noted the need for a meta-analysis that addresses specifically the impact on student outcomes in relation to teaching and learning with technology. This study consisted of a meta-analysis of 20 studies published from 1997 to 2002. The studies selected for this meta-analysis were quantitative in nature and used either an experimental or quasi-experimental design. The studies focused on teaching and learning in grades K-12 in the United States, used a technology group and a non-technology comparison group or used a pre-test/post-test design, and reported statistical data. Of the selected studies, 14 were published studies in refereed technology journals, three were published in refereed education journals, and three were published in refereed conference proceedings. The mean of the weighted effect sizes was .30 ($p<.05$) with a 95-percent confidence interval. Thus, similar to the findings of previous meta-analyses, the authors found a small, positive significant effect of educational technology on students' outcomes when compared to traditional instruction. The authors noted that one limitation of their study was that they were able to use only those studies that provided sufficient statistical information for figuring the effect size. Thus, the results of many studies were not figured into the effect sizes that they reported (Waxman et al., 2002).

Christmann and Badgett (1999) conducted an analysis of studies on computer-assisted instruction in science education. This study analyzed the results of eleven studies. To be selected, the studies had to be quantitative in nature, conducted in educational settings, used experimental, quasi-experimental, or correlational research designs, had at least 20 students

in the combined control and experimental groups, and used computer-assisted instruction as the independent variable and student outcomes as the dependent variable. A total of 2,343 students participated in these 20 studies. The authors calculated 24 size effects. The mean effect size was 0.266, which the authors characterize as a small, positive overall effect. Effect sizes were also calculated for groups of studies. The groups were determined by the branch of science. The mean effect sizes were 0.707 for general science, 0.280 for physics, 0.085 for chemistry, and 0.042 for biology. The authors suggested that there might be greater effects for physics than the other branches because of the use of computer simulations and visualizations of concepts such as force and velocity that would be very difficult for students to visualize without the computer.

Kulik (2002) reviewed 36 evaluation studies published since 1990 on instructional technology in mathematics and science programs. After determining and comparing effect sizes for the studies, he concluded that instructional technology can benefit mathematics and science programs. He found the most favorable results from integrated learning systems, noting that the effect size was not only significant, but large enough to be meaningful for education. This finding contradicted the study conducted by Wenglinsky (1998) who found that drill and practice were not statically significant factors in mathematics achievement, and that sometimes they were even negatively associated with achievement in mathematics. Kulik found that computer tutorials were the second category of instructional technology that was associated with achievement in mathematics and science. He also found an additional benefit in that students' attitudes often rose dramatically when part of their instruction was from computer tutorials. He found that effects from computer simulations and microcomputer based laboratories were not as large as the other two categories of computer-

based instruction. As he noted, this effect may be due to the fact that the two methods that had the largest effect are aimed more at helping students learn skills. Also, the six studies that he reviewed on computer simulations in science education investigated a simulation that was presented for a short duration, usually only one class period. Therefore, the results of these studies might have more to do with the short duration of the simulation rather than the true effect of the program. Kulik also acknowledged that the latter two methods are designed to help students achieve higher order thinking skills, rather than just learn skills and facts. That distinction could account for the fact that these types of programs did not produce as large as an effect on mathematics and science achievement in the studies that he evaluated.

Roschelle et al. (2000) reviewed over 80 studies conducted in grades K-12 on the effectiveness of computer-based technology. They found that computer-based technology can serve as tools that support effective educational environments, by promoting active engagement and collaborative learning. These tools can also provide immediate feedback and real-world contexts, which are two components that have been associated with effective classroom environments. The authors noted that computer-based technology was most effective when it was viewed as an integral part of a larger educational program. Finally, they call for more longitudinal studies to be conducted regarding educational technology.

The National Middle School Association (2001) published a research report in the impact of technology on middle level education. This report reviewed studies of technology and education and noted some implications for practice in American middle schools. They noted that the use of educational technology is congruent with the components proposed for an effective middle level program. For example, there is an exploratory nature inherent in

computer use, computers can be used to foster higher level thinking skills, and technology can foster curriculum integration.

The New Digital Literacy

Labbo and Reinking (1999) examined the relationship between literacy research and practice in light of new digital technologies. For them, a beginning point was the consideration of multiple realities. They focused on the consideration of technology not as a topic itself, but as a tool that can be used in multiple ways to foster literacy. The authors suggested that educators should consider multiple realities as they propose research in this area. One reality they offered is that digital technologies should be available, but the goal of making the technologies available should not erect barriers to providing literacy instruction to students. The second reality they proposed is that the new digital technologies should be utilized to foster conventional literacy instruction. An important distinction that they call for educators to make is the difference between learning from a computer and learning with a computer. They proposed that educators should focus more on the value of having students learn with a computer, when that tool is available and useful, rather than focusing on having students learn from a computer. The third reality they proposed was that the new technologies should be used to transform literacy instruction in positive ways. They called for researchers to look for ways that technology can foster this transformation, offering a variety of contexts for reading and writing for students. They also encouraged researchers to look for barriers to this transformation and for ways that are conducive to this positive transformation. The fourth reality was that the new technologies should be used to prepare students for the literacy of the future. They proposed that the new technologies are changing the way communication will occur in the future. The uncertainty of what the future will hold

provides a challenge to researchers to examine how the new literacy is developing and to help students be ready for the future challenges. The fifth reality was that the new technologies should be used to give students power. The authors cautioned that one should not assume that technology is neutral. One hope they offered is that technology might empower students who are currently disenfranchised. In conclusion, the authors called for researchers to frame their studies in the reality to which it applies. They proposed that this practice will bring more insights into the value of the new technologies being examined. They also anticipated that this practice will encourage researchers to look for the complex interactions between cognitive processes, socio-cultural factors, learning, and the goals of instruction.

The Computer as a Mindtool for Visualization

Jonassen and Carr (2000) promoted the idea that computers can serve as mindtools, helping students to construct knowledge. One type of mindtool for which they think the computer is suited is a visualization tool. Wollsey and Bellamy (1997) also promoted the idea of the computer as a visualization tool and noted its capability of bringing still pictures and video images to students, who can analyze the images using digital technology. Mathewson (1999) examined various studies regarding visualization and concluded that although visual-spatial thinking can be a valuable tool in helping students learn in a variety of science content areas, it is often under-used by teachers. Linn (2003) considered 25 years of the utilization of technology in science education and recommended five areas that should continued to be examined and pursued. One of those areas is science visualization.

Linn (2003) noted that science visualization needs to be tailored to the specific topic of study, and she suggested that technology can help to accomplish this goal. She noted

examples reported by other researchers of students using imagery to study weather, to visualize molecular structures, to visualize the flow of heat, and to visualize geological structures. Jonassen (2000) also noted that research has been conducted on the use of visualization in the areas of weather imagery and with the use of chemical visualization tools. None of these sources mentioned the use of technology as a visualization tool in the life sciences, which suggests a need for studies to be conducted in this area.

Overview of Visualization Studies

Edelson et al. (1999) conducted research on scientific visualization. One advantage that they thought that the computer could bring to the teaching of science was the multiple representations that it could afford. Their study focused on the use of colored maps to represent geographic data in the study of weather and climatology. They created the "Climate Visualizer" and distributed it to teachers through the CoVis project. They later created the "Radiation-Budget Visualizer," which included a set of climatology data from areas across the world. Later, they developed the Greenhouse Effect Visualizer. One improvement in this model was the addition of explanatory materials to the visualization tool. The most recent tool, World Watcher, was designed to be used with the LeTUS Global Warming Curriculum, which was developed in 1998 through the CoVis Project. Through case study research, the researchers evaluated the product in each of its forms and made revisions for its successors based on what they learned from its use in the classroom. The researchers noted that by observing students as they used these tools, they learned that students could use the images for both interpreting data that were presented in the visual images and that they could create images which allowed them to express data in a visual format (Edelson, 2001; Gordin et al., 1996).

Crouch et al. (1996) described a visualization tool used in teaching some undergraduate chemistry concepts. The tool is in the form of a software package that permits molecular modeling. The authors noted success in using this tool with their students because the students were able to visualize the atoms of a molecule individually and to study the reactivity through a visual representation of the process.

The Visualizing Earth Project (VisEarth) studied teaching and learning activities based on images of the Earth taken through ISS EarthKAM, a project which allowed middle school students to take pictures of the Earth from the International Space Station and the space shuttle. ISS EarthKam also allows students and teachers to access via the Internet thousands of digital images taken of the Earth from space. VisEarth was launched to study how teachers and students use the pictures in the classroom. The researchers spent three years observing teachers and students. They also interviewed teachers and compared the results of pre-tests and post-tests given to students involved in the project. In this report, the authors described the first-year of implementation of the VisEarth activities in one teacher's six eighth-grade classrooms, with a total of 190 students, and the second year as he used it with those six classes, which included 160 students. The teacher and students spent about 3 weeks completing the 10 geology activities from VisEarth. Results of the differences between the pre-test and the post-test were statistically significant, but there was no control group against which to compare the findings. The teacher, who worked on this project and who used it with his eighth-grade students, reported that the VisEarth activities were effective in helping his students to understand complex geological processes. He credited the use of images as a way to help his students understand the interaction of plate tectonics (Dodson et al., 1999).

An interesting project that involves students in grades K-12 and that uses technology and scientific visualization in the study of life science is known as Chickscope. This project, begun in 1996 by a group of scientists at the University of Illinois, provided remote control of Magnetic Resonance Imaging (MRI) equipment viewing images of chicken embryos to a group of students and teachers. The researchers sought to study the impact of this system on students and to field test the system they created which allowed the remote operation of the MRI device. Nine teachers, each from different schools, and including four high school teachers, one middle school teacher, two elementary teachers, and one primary school teacher, participated. In addition, one home school parent also took part in this project. A total of 210 students were involved. For each of the 21 days of the embryonic stage of a chicken, a fertilized egg was placed into the MRI system so that students and teachers could view the development of the chicken. Each class also had their own set of fertilized eggs and an incubator so that the children were incubating eggs at the same time that they were viewing the MRI results. Some problems that the researchers encountered were related to synchronization of the equipment when its use was in demand in ten different classrooms. They also noted that obviously this experiment required unusual resources, and they found that the technology was not easy to implement in the classrooms. However, they noted that the students were more involved in the science lessons during this project than during regular science lessons. They also found that MRI visualizations gave students the opportunity to develop spatial skills, and from the interviews with students and observations of the classrooms, the researchers determined that students benefited from participating in this project (Bruce et al., 1997).

As a follow-up to the Chickscope project, the researchers at the University of Illinois made a database containing MRI visualizations of chicken embryos take at each of the 21 days of development available to a group of thirty-two K-12 teachers from 15 schools in Illinois. A case study of two middle school classrooms who participated in this project was reported. The two teachers used MRI images of baby chicks to augment their classroom incubator project. They found it easier to use the database of images when compared to the experiences of the first group of teachers who used the remote-controlled equipment. The database was also a less expensive option that could be made available to more teachers and students than the original method used in the Chickscope project. As in the original project, the two teachers had incubated eggs in the classrooms. They could help the students access the database images that were provided for each day of development. The teachers noted that this project provided a time of intense engagement in their classrooms. They noted the students' excitement about the project and their enthusiasm for this unit of study. Some of the particular student behaviors that were observed were "using new vocabulary (e.g., 'germ spot'), participating without solicitation, staying late to complete tasks, self-directing their activities, transferring learned concepts to new situations, and expressing positive affect (e.g., smiling, laughing, and cuddling the chicks)" (Hogan, 2000). During the project, the two teachers and their 60 students shared one computer. In spite of this limited access to technology, they were able to provide an engaging experience for their students (Hogan). As a follow-up note, the database of MRI visualizations from the Chickscope project are now available online for anyone to access at http://chickscope.beckman.uiuc.edu/.

The Digital Divide

If instructional technology is to be effective in the classrooms, students and teachers must have adequate access to technology resources. Solomon et al. (2003) developed a definition of digital equity which includes the following: "Digital equity in education means ensuring that every student, regardless of socioeconomic status, language, race, geography, physical restrictions, cultural background, gender, or other attribute historically associated with inequities, has equitable access to advanced technologies, communication and information resources, and the learning experiences they provide" (p. xiii). The authors note that the opposite of digital equity is the digital divide. Koss (2001) states, "Lacking access to technology and computer skills, an entire generation will be disempowered from realizing its full potential to contribute to society" (p. 18).

One study that showed promise in helping to bridge the digital divide was conducted in West Virginia. This study, described in an earlier section of this chapter in more detail, found that the Basic Skills/Computer Education (BS/CE) program was especially effective with low income students and students who live in rural areas. They noted that the 62% of their student body who did not have computers at home made the largest gains in achievement scores in several areas, including basic skills, language, and reading, when computers were used in their schools as part of the BS/CE program (Mann et al., 1999).

Rural Education

According to the National Center for Educational Statistics (2000), approximately 25% of public elementary and secondary schools in the United States are classified as rural schools. One problem facing rural schools is poverty. While characteristics of the student body vary widely among rural school districts, approximately 2.5 million of the children who

live in rural areas are considered to live in poverty. One reason for this poverty is the lack of job creation in rural areas (Save the Children, 2003). Another problem for school funding is that most districts rely on county taxes to support the school system. In a rural area, there is a small basis of people to pay the costs. There are some costs that exist whether the school system is located in a rural or a non-rural area, but in a rural area, there are fewer people to share the burden of the costs (Parker, 2000).

A report from The Rural School and Community Trust (2003) emphasized the need for attention to be paid to the plight of rural schools. They listed 13 states which they determined are in special need of attention. North Carolina was ranked sixth on this list, and it was noted that this state has the second largest rural population in the country and the eighth largest percentage of students who attend rural schools.

While students in rural schools have some problems in common, there are differences in achievement levels found in varying rural areas. As a whole, students in rural districts perform as well as their peers in metropolitan schools on achievement tests in mathematics and science (Fan & Chen, 1999). However, when scores are compared by state, there is a large variation in the scores of students in rural areas. Data from 14 states with a large percentage of students in rural schools were compared. Rural eighth grade students had a higher test score average than non-rural students on the 1996 NAEP mathematics scores in seven states, while rural eighth grade students had a lower test score average than non-rural students on the 1996 NAEP mathematics scores in the other seven states. North Carolina was one of the seven states in the latter category. Three factors were associated with rural school systems that had higher levels of achievement: instructional resources, a safe and orderly climate, and collective support for student learning. The National Science Foundation (NSF)

has recognized the important need of providing science education for all students and has launched a program, Systemic Initiatives, to help achieve this goal. They also published a document intended to provide guidance on ensuring equity in science education for all students. One of the programs funded by this grant is the Rural Systemic Initiatives, intended to promote improvement in mathematics and science education in rural schools, especially for those in areas that are economically disadvantaged (National Science Foundation, 2003).

At a conference sponsored by the National Science Foundation (NSF) and conducted by the Appalachian Rural Systemic Initiative, a research agenda was established for examining factors that have an impact on learning and achievement in science and mathematics among students in rural schools. Seven categories of needed research were identified. One of those categories was instructional resources. Two researchable questions that they proposed should be addressed are the following:

> What is the accessibility, availability, use, and effectiveness of advanced digital technology to teach mathematics and science in rural schools?
> How can the teaching and learning of science and mathematics in rural schools be improved with the effective integration of technology? (Harmon, Henderson & Royster, 2003, p. 54)

These questions have relevance for the proposed study.

Science Achievement, Technology, and Middle School Students

The National Center for Education Statistics of the U. S. Department of Education (2003) released a report card on science education in the United States. A summary of the 2000 National Assessment of Educational Progress (NAEP) and a comparison to this assessment in 1996 are provided in this report. In 2000, nationally representative samples, consisting of 47,000 students in grades four, eight, and twelve from 2,100 schools, were assessed on their science knowledge and skills. They were rated as “basic, proficient, or

advanced." The National Assessment Governing Board (NAGB) recommended that students should perform at the proficient level or higher. In 2000, 32% of the eighth grade students were ranked at this level. This ranking was higher than the percentage of students designated as proficient in 1996 study. However, there was no statistically significant difference in the average eighth-grade score from 1996 to 2000. This report also noted that there was a gender gap shown in the scores. In the eighth grade, the average score of the male students in 2000 was seven points higher than the average score of the female students. There was also a gap in scores when scores were disaggregated by race. Among the eighth grade students, the average scale score was 162 for White students, compared to an average scale score of 122 for Black students. The report also noted that eighth-grade students whose science teachers reported that their students used the computer data analysis, simulations, modeling, and other applications had a higher average score than those students whose teachers did not report these types of activities. In addition, it was noted that the percentage of eighth-grade teachers who reported that their students use the computers for these types of applications increased from 1996 to 2000. Thus, this report highlights some important data regarding science achievement of eighth-grade students as a whole and by sub-groups.

Science Achievement, Technology, and Middle School Students – Focus on Gender

As noted earlier, the report released by The National Center for Education Statistics of the U. S. Department of Education (2003), provided a summary of the 2000 National Assessment of Educational Progress (NAEP) and a comparison to these assessment data in 1996. These data showed that among eighth grade students, the average scores of the male students was significantly higher than the average scores of the eighth grade students, with an average scale score of 154 for males and for 147 females.

An analysis of the TIMSS data from 1995, 1999, and 2003 also show a persistent gap between males and females in the eighth grade. While both groups made progress, the gap between their average scores has remained fairly steady, as shown in Tables 2.1 and 2.2. In the last three administrations of this study, the males scored an average of 15 points higher than the females in 1995, 19 points higher in 1999, and 17 points higher in 2003.

Table 2.1

TIMSS Data – Average Science Scale Score of Eighth-Grade Students in the United States by Gender; 1995, 1999, 2003

Year	Scale Score in 1995	Scale Score in 1999	Scale Score in 2003
Males	544	547	552
Females	422	438	463

**Note*. (Gonzales et al., 2004).

Table 2.2

TIMSS Data – Difference in the Average Science Scale Scores of Eighth-Grade Students by Gender; 1995, 1999, 2003

	1995	1999	2003
Difference between the average science scale scores of male students and female students in the eighth grade.	15	19	17

**Note*. (Gonzales et al., 2004).

Literature reviews on the achievement of girls in science provide additional documentation that a gap continues to exist between the science achievement of males and females (Tindal & Hamil, 2004; Von Secker, 2004). Finson (2002) examined the research that has been conducted on the "draw-a-scientist" approach and concluded that the

stereotypical image of a scientist as a male persists. Thus, the analysis of the achievement of females, as compared to their male counterparts, in science courses continues to be a need in the study of science education.

Reports have also documented a gender gap in the area of technology (American Association of University Women [AAUW], 1998, 2000; Gehring, 2001). Statistics showed that girls use computers less at home and that they consistently rate themselves lower on computer skills than boys rate themselves (AAUW, 1998). Girls are under-represented in computer science courses in both high school and higher education settings (AAUW, 2000). Christie (2004) conducted a year-long qualitative study on how seventh and eighth grade students, by gender, view and use the computer. She found that the girls used much more precise terms to express what computers do than the boys used. Interestingly, the boys were more likely to refer to a computer as a machine; while girls used other words to describe specific uses, such as "a gateway to information" (p. 8). She also found that each gender tended to use computers differently. While females were likely to use computers to connect with others, males were more apt to use computers to compete with others. Mann et al. (1999) found that in the West Virginia Basic Skills/Computer Education technology program, girls and boys were given the same amount of access to computers and were asked to use the computers in the same ways. Yet, girls tended to think of computers as tools for accomplishing specific jobs, and boys tended to think of computers as toys. In this study, boys were more likely than girls to report that computers were fun to use. One encouraging note from this study was that the more the females used the computers, they more they said that they knew about them. In general, concerns have been expressed that many females may be less prepared for the top-paying computer careers if they do not develop the new standard

of computer fluency, which involves applying information technology in more sophisticated, analytical, and interpretive ways than were considered important in the past (AAUW, 2000). Thus, examining and analyzing females' uses of computers continues to be viewed as a needed area of research.

Science Achievement, Technology, and Middle School Students – Focus on Racial Groups

As noted earlier in this chapter, there are differences in science achievement test scores for groups of students based on their racial/ethnic identities. This study focused on the two groups that comprised the population of interest in this study – White and African American students. Comparisons of scores on the National Assessment of Educational Progress (NAEP) from its latest administrations in 1996 and 2000 provide data on the gap that exists in the average science achievement test scores for these two groups of students. The average scale score in science for White eighth-grade students in 1996 was 159, and the average score for this group in 2000 was 162. In contrast, the average scale score in science for African American eighth-grade students in 1996 was 121, and the average score for this group in 2000 was 122. Thus, there was a difference of 38 points in 1996 and 40 points in 2000. These data are shown in Table 2.3 (U.S. Department of Education, National Center for Education Statistics, 2003).

Table 2.3

Average NAEP Science Scale Scores by Race for Grade 8; 1996 and 2000

	1996	2000
White	159	162
African American	121	122

**Note*. (U.S. Department of Education, National Center for Education Statistics, 2003).

The NAEP data also provided information on the percentage of students whose scores are considered to be at the basic, proficient, or advanced levels. Students whose scores fall into the *Basic* range are said to have partial mastery of the knowledge and skills tested at that grade level. A rating in the *Proficient* level is considered to be an indication that the students in this category have solid mastery of those concepts and skills. A third level, designated as the *Advanced* level, represents superior performance. A comparison of the percentage of students in each racial group who are considered to have reached the basic level or higher and the percentage of students who are considered to have reached the proficient level or higher provide further evidence of the gap on science achievement test scores. In 1996, 73% of the White students were designated in the basic or higher category, and 37% were designated in the proficient or higher category. Similar results were reported from the 2000 administration with 74% classified as basic or higher and 41% designated as at least at the proficient level. In contrast, in 1996, 24% of the African American students were designated in the basic or higher category, and only 5% were designated in the proficient or higher category. Similar results were reported from the 2000 administration with 26% classified as basic or higher and 7% designated as at least at the proficient level. These data are shown in Table 2.4.

Table 2.4

Percent of Students At or Above the Basic and Proficiency Level on the NAEP by Race for Grade 8; 1996 and 2000

	White		African American	
	1996	2000	1996	2000
Proficient or higher	37%	41%	5%	7%
Basic or higher	73%	74%	24%	26%

**Note*. (U.S. Department of Education, National Center for Education Statistics, 2003).

Data reported from the latest three administrations of the Trends in International Mathematics and Science Study (TIMSS) show that a gap continues to exist between these two groups of students, but the gap on the science achievement tests in this study has narrowed from the 1995 administration to the 2003 test administration. The average science scale score of White eighth-grade students in the United States was 544 in the 1995 administration, 547 in 1999, and 552 in 2003. In contrast, the average science scale score of African American eighth-grade students in the United States was 422 in the 1995 administration, 438 in 1999, and 463 in 2003. Thus, the difference in the average scores of these two groups of students was reduced from 122 points in 1995 to 109 points in 1999 and to 89 points in 2003. These data are shown in Tables 2.5 and 2.6.

Table 2.5

TIMSS Data - Average Science Scale Score of Eighth-Grade Students in the United States by Race for White and African American Students; 1995, 1999, 2003

Year	Scale Score in 1995	Scale Score in 1999	Scale Score in 2003
White	544	547	552
African American	422	438	463

**Note*. (Gonzales et al., 2004).

Table 2.6

TIMSS Data - Difference in the Average Science Scale Scores of White Students and African America Students – Eighth-Grade; 1995, 1999, 2003

	1995	1999	2003
Difference between the average science scale scores of the White students and African American students each year	122	109	89

**Note*. (Gonzales et al., 2004).

In an effort to address the achievement gaps that exist between racial/ethnic identity groups, the Multicultural Education Consensus Panel, which was sponsored by the Center for Multicultural Education at the University of Washington and by the Common Destiny Alliance at the University of Maryland and which also received support from the Carnegie Corporation of New York, was convened to review and synthesize research related to teaching diverse groups of students. This panel, consisting of eight experts in this field, worked on this project for four years. They concluded that schools can make a difference in students' lives and that schools are crucial for maintaining a democratic society.

The members of this panel generated 12 essential principles, which they grouped into five categories. Two of those categories are pertinent to this study: 1) student learning, and 2)

school governance, organization, and equity. Under the category of student learning, these experts recommended that students be engaged in the learning. They also suggested that learning resources, including information technology, be sophisticated, current, and available to all students. A third recommendation was that students not be rigidly tracked into groups that are formed on the basis of the students' past performance. Under the category of school governance, organization, and equity, the panel recommended that equitable resources for learning be available to all school districts and schools (Banks, Cookson, Gay, Hawley, Irvine, Nieto, Schofield & Stephan, 2001).

Kahle, Meece, and Scantlebury (2000) found that urban African American middle school science students in Ohio scored higher on science achievement tests when their teachers incorporated standards-based teaching methods, such as the use of inquiry, into their classes than students in a control group whose teachers had not received training on using standards-based teaching methods. Teel, Debruin-Pareck and Covington (1998) found that inner-city African American middle school students showed improvement when their teachers incorporated strategies that including providing multiple ways for students to show what they are learning, including expressing themselves orally, through acting, and by artistic renderings. A synthesis of research conducted by SciMath and the Minnesota Department of Children, Families, and Learning (1998) suggested that students in minority groups performed better on science achievement tests when their teachers held high expectations for all groups of students. They also called for more research to be conducted which helps students of all groups increase their success in the learning of science.

Earlier in this chapter, details were provided on a study in which Wenglinsky (1998) wrote a report based on data from the 1998 National Assessment of Educational Progress

(NAEP) in mathematics. He concluded that African American students were less likely than White students to be asked to use the computer in ways that were associated with student achievement. Hoffman et al. (2003) reported that in 2001 African American students were less likely to use computers at school than White students. However, this difference for students in the 10 to 14 year-old age group was only two percent. A much larger gap, of 36 percentage points, was found in the difference between these two groups of students in this age group for use of the computer at home. O'Sullivan et al. (2003) analyzed the NAEP 2000 data and found that students in the eighth grade who had access to computers in laboratories at school, had a higher average score than students who did not have access to computers at school. Other studies dealing with technology in learning were outlined in detail in an earlier section of this chapter. Finally, as was noted in more detail earlier, Krajcik et al. (1998) found technology to be a useful tool in supporting inquiry based science with urban middle school students.

METHODOLOGY

Purpose of the Study

The purpose of this study was to investigate the use of microscopes in the study of cell theory at the middle grades level. The researcher proposed that the presence of technology, in the form of microscopes – especially digital microscopes attached to computers – may foster constructivist learning and student engagement, facilitate understanding of content related to middle grades cell theory, and encourage positive attitudes toward the learning of science. Situated in the classrooms of three middle school teachers in a rural school system in North Carolina, this study examined the variable of microscope use on three levels – digital microscopes, analog microscopes, and no microscopes – during the middle school unit on cells. The quantitative part of this study examined changes in student attitudes toward science as measured by pretests and posttests using the Scientific Attitude Inventory II (Moore & Foy, 1997). The study also investigated changes in the students' content attainment as measured by pretests and posttests using a content test developed for this unit of study.

The purpose of the qualitative part of this study was to provide insights into how the students and teachers viewed the study of cell theory without the use of microscopes, as well as with the addition of the analog and digital microscopes into the unit on cell theory. The researcher observed students to see how they responded to the addition of microscopes in the classroom. She was particularly interested in observing the students' engagement in learning in each of the three situations. Student interviews provided insights into the students' attitudes toward the unit on cell theory in each of the three classroom environments.

Interviews with the teachers provided additional data regarding how the teachers view the addition of analog and digital microscopes into the middle school unit on cell theory.

Research Design Overview

This study employed both a quantitative and a qualitative component. Brewer and Hunter (1989) state that the use of quantitative or qualitative methods alone is insufficient for some research studies. They contend that each of these two methods have strengths and weaknesses. The strengths of each can help to compensate for the weakness of the other. Brewer and Hunter see these two forms of research as complementary because the area of weakness for each is different from the other. In this study, both quantitative and qualitative methods were used. The intention was for each to provide complementary information for the other. The quantitative data provided information regarding a larger sample of the population than the qualitative data alone could furnish. They also provided some measurable data on how well students in the three classrooms had learned the content that was taught during the time of the study, and they gave quantifiable data regarding the students' attitudes toward science. The qualitative data added depth and insight to the analysis of the quantitative data. The classroom observations allowed the researcher to watch how the students responded to the learning situation in each of the three environments. As the students were interviewed, they talked about their thoughts and feelings toward the learning situations. Their interviews provided insights into their reactions toward the unit on cell theory in each of the three classroom environments. Interviews with the teachers provided additional data regarding how the teachers viewed the addition of analog and digital microscopes into the middle school unit on cell theory and how one teacher compared the use of two types of digital microscopes in her classroom. As Brewer & Hunter note, data from each of these methods

can lend validity to data collected from the other method. The quantitative data analyzed from the students' scores on the Scientific Attitude Inventory II were made more meaningful with the addition of the qualitative data in which 12 students were interviewed regarding their attitudes toward the specific science unit that was the focus of this research study.

This study used the method that Tashakkori and Teddlie (1998) referred to as an equivalent status design. The specific title they defined that applied to this study was the Parallel/Simultaneous design, in which quantitative and qualitative data are collected and analyzed from parallel situations during the same time frame. This study gathered quantitative data in the form of content pretests and attitude inventory pretests. Then, qualitative data were collected as the researcher observed the classes and interviewed the selected students. The three teachers provided informal qualitative data as they commented to the researcher on how they viewed the lessons and the learning environments as the study was in progress. Quantitative data were collected at the end of the unit of study when the students were given the content posttest and the attitude inventory posttest. Finally, more qualitative data were gathered as the three teachers were formally interviewed at the end of the study. Each set of data was analyzed. Then, results of each type of data were used to help form a complete picture, as presented in chapter 6 of this document.

The quantitative part of this study employed a quasi-experimental pretest-posttest comparison-group design. The qualitative section was an instrumental case study (Stake, 1995), which was designed to illuminate the results of the statistical findings and to provide additional data that may be helpful to those involved in middle school life science instruction, particularly in the study of cell theory. Descriptive research was the "glue" that bonded the two components of this project. Gall et al. (1996) note that description is essential

to quantitative research and is also a very important goal of qualitative research. Descriptive statistics, as well as inferential statistics, were employed to summarize the results of the two assessment instruments used in the quantitative part and were used to report test results of sub-groups of students. The qualitative section of this study employed thick description to provide a picture of what happened when no microscopes were used and when analog or digital microscopes are added to the study of cells in middle grades classrooms in rural schools. The research methods for the quantitative and qualitative components are discussed separately. First, the methods for quantitative part are outlined. Then, the methods for the qualitative component are explained.

Quantitative Research Design

The quantitative component of this study employed a quasi-experimental pretest-posttest comparison-group design. The design is considered to be quasi-experimental because the students were not assigned at random. Rather, existing classrooms of students were used to form the groups. The pretest-posttest comparison-group design was helpful in controlling for threats to internal validity, such as maturation, history, instrumentation, experimental mortality, selection-maturation, statistical regression, and testing (Gall et al., 1996). Table 3.1 illustrates the research design.

Table 3.1

Research Design

		Pretest		Treatment	Posttest	
Experimental Group 1	(E_1)	O_{11}	O_{21}	X_1	O_{12}	O_{22}
Experimental Group 2	(E_2)	O_{11}	O_{21}	X_2	O_{12}	O_{22}
Comparison Group	(C)	O_{11}	O_{21}		O_{12}	O_{22}

Note. E_1, E_2, and C represent a cluster sample of research participants which was formed from a naturally-occurring group of students taught by the same science teacher. All three groups used the Diversity of Life kit of materials during the unit on cell theory. O_{11} = Scientific Attitude Inventory II pretest. O_{12} = Scientific Attitude Inventory II posttest. O_{21} = Science content pretest. O_{22} = Science content posttest. X_1 = Addition of six analog microscopes. X_2 = Addition of six digital microscopes.

Target Population

The target population is the large group to whom the researcher wishes to generalize the results of the study (Gall et al., 1996). The target population of this study is middle school classrooms, particularly those in rural school districts and with demographics similar to the sample group, engaged in the study of cell theory. Some demographic data from the school system are provided so that the reader can make the comparison to another group of interest and decide whether data from the sample might generalize to this group.

The school system in which this study was situated is a rural school district in North Carolina. According to The Rural School and Community Trust (2003), North Carolina has the second largest rural population in the United States and the eighth largest percentage of students in rural schools. In North Carolina, 39.8% of the state's population reside in rural areas, and 42.1% of the public schools are located in rural areas. For rural schools in this state, spending on school administration is usually high, which dilutes the amount of per pupil spending that is spent at the classroom level (The Rural School and Community Trust). According to the U.S. Census Bureau (2004), the county in which this school system is

situated is considered to be a rural county. There are no metropolitan areas within the county. The average number of persons per square mile in this county is 28.3.

In the selected school system, there are six elementary schools, two middle schools, one high school, and one alternative school (that serves middle and high school students.) In the 2002-2003 school year, there were a total of 3,592 students enrolled in this school system. Of these students, 256 were enrolled in the sixth grade, 285 in the seventh grade, and 316 in the eighth grade for a total of 857 students enrolled in the two middle grades schools (NCDPI, 2004c). Of those students, approximately 583 students attended the larger middle school, and 271 attended the smaller middle school (National Center for Education Statistics, n.d.). Table 3.2 provides data regarding the ethnic composition and the subsidized lunch eligibility of the students attending each of the two middle schools.

Table 3.2

Eligibility of Middle School Students by Ethnicity for Subsidized Lunch

	Percentage of Eligibility	African American	White	Hispanic	Other
Larger Middle School	83%	83%	15%	1%	<1%
Smaller Middle School	85%	89%	11%	0%	0%

**Note.* (National Center for Education Statistics, n.d.). CCD Public school data 2002-2003 school year.

As noted, the school system that was chosen for this study has a total student population of 3,592. County school system populations in North Carolina range from 710 to 113,865 students. There are 35 systems in this state with a total student population less than 5,000 students and 29 systems with a student population of less than 4,000 students (NCDPI,

2004c). Thus, this system could be considered typical in the number of students attending public schools in rural areas of North Carolina.

The number of middle schools in the selected school system is two. This number is also consistent with the other school systems of similar public school student populations. Each of the 35 systems with a total student population less than 5,000 students has one or two middle schools in the system, except for five systems which have one to three schools that are combinations of elementary and middle schools or middle and high schools, rather than distinct middle schools (NCDPI, 2004c). These figures show that the selected school system is similar in the number of middle schools to other systems with similar numbers of students in this state. This information is intended to help the reader make an informed decision in determining how to generalize the information from this study to other situations. Although the sample is not a random sample, it would also seem reasonable that the results from this sample might be generalized, with some caution, to systems of similar size and demographics in other states. Tables 3.3 and 3.4 provide some additional data that may be useful to the reader.

Table 3.3

Financial Information for this County and School System – 2002-2003 School Year

	Amount	Rank in the State
Per capita personal income of the county	$21,293.00	79/100 counties
State per pupil spending, child nutrition included	$ 5,376.02	21/117 school systems
Local (county funds) per pupil spending, child nutrition included	$ 942.84	104/117 school systems
State per pupil spending, child nutrition excluded	$ 7,046.63	21/117 school systems
Local (county funds) per pupil spending, child nutrition excluded	$ 843.07	102/117 school systems

**Note*. (NCDPI, 2004c).

Table 3.4

Population Information for this County

	Population
County population, 2003 estimate	19,544
County population, 2000	19,773

**Note*. (U.S. Census Bureau, 2004).

Sampling Technique

The school system where the study occurred was purposefully chosen as an appropriate match for a study designed to address the problems identified in this document. A brief explanation of the problem is restated here to help the reader understand why the

system that was chosen was a suitable match. National standards in science, and state standards based on them, have been developed (AAAS, 1993; National Research Council, 1996; NCDPI, 2004a). These standards call for changes in the content and skills that students are taught. Practices such as inquiry-based teaching, learning that is grounded in concrete activities, and active engagement in learning activities are encouraged. While progress has been made in implementing these standards, much work remains to be done in implementing the principles and reforms in science teaching that accompany these standards (Anderson & Helms, 2001; Edelson, 2001; Roseman, 1997; Sarason, 1996; Songer et al., 2002). Federal mandates have been issued that call for improvement in science education (U. S. Department of Education, 2001, n.d.). The administration and the middle school teachers in this system have expressed interest in learning about teaching science as inquiry and in providing for their students more science learning experiences that are grounded in concrete activities and that encourage active engagement. Before this study was planned, the teachers and the administrators had already decided to buy the science kit, Diversity of Life (Lawrence Hall of Science, UC Berkeley, 2003a), for use with their middle school students in learning about cell theory. This kit was recommended by the North Carolina Department of Public Instruction for use in teaching this unit of study. When the administrators and teachers were approached about the possibility of a study occurring in their classrooms while the unit on cell theory was taught, they welcomed the opportunity to participate in this study, noting that they were interested in participating in a research study that would help middle grades teachers learn more about teaching this unit on cells to their students.

Research on teaching and learning in middle schools has indicated a need for the curriculum to be relevant, challenging, and exploratory. The need for multiple approaches to

teaching and learning, to which a diversity of students can respond, has also been identified (National Middle School Association, 2003a). While studies regarding the use of technology in the classroom have shown some promise in improving some areas of education, (Apple Computer, 1995, 2002, 2005; Christmann & Badgett, 1999; Sandholtz et al., 1994; James et al., 2000; Kulik, 2002; Mann et al., 1999; Roschelle et al., 2000; Sivin-Kachala & Bialo 2000; Waxman et al., 2002), more needs to be learned about the use of technology as a mindtool that helps students construct meaning (Jonassen & Carr, 2000) and especially as a tool that can foster visualization (Linn, 2003). Thus, the middle school would provide a setting where the researcher could study the use of instructional technology in a way that is intended to help make the science curriculum on cells more relevant and interesting for students. The unit on cell theory was selected because that topic provides a middle school science unit of study that is an abstract concept that students need to visualize.

The researcher wanted to provide a way to help bridge the abstract ideas of cell theory to concrete experiences. At the same time, the researcher was interested in the possibility of using instructional technology in the form of digital microscopes as mindtools. She proposed that the digital microscopes would allow the students to have a concrete experience with cells and would help them to visualize concepts that usually are only presented in an abstract manner. The researcher has 15 years of experience of teaching mathematics, science, and/or technology to middle school students. During that time, she taught about cells by using pictures and texts. It was difficult for her students to connect the pictures they viewed to the concepts she was trying to teach. For example, students might see a picture of a paramecium, but they were not able to comprehend that those single-celled organisms could live in an ordinary-looking drop of water.

In this study, the researcher asked one of the middle school teachers to use digital microscopes in her classroom. She proposed that if students were able to see cells on a computer screen, where they could view the slides as a collaborative group, discussing what they were seeing in real-time and could take still pictures and movies of the cells, that they may be able to make a better connection between the concrete experience of viewing the cells and the abstract idea of the cell as a part of a living organism or as a single-celled organism living in the ordinary looking drops of water on their slides. Thus, the researcher proposed that the students in this classroom might use the computers and digital microscopes as mindtools that help them to connect their concrete activities to abstract learning about cell theory.

The researcher planned three classroom settings, one that used handheld magnifiers, but no microscopes, one that used traditional analog microscopes, and one that used digital microscopes. The digital microscopes offered the advantage of students' being able to view the slide as a collaborative group, as well as the advantage of students being able to capture their own still pictures and movies of the cells that they were actually viewing. The analog microscopes provided an opportunity for students to view cells, but students could not view the slides in collaborative groups or take pictures of what they were viewing. The third classroom provided only handheld magnifiers. In addition to the magnification devices, each classroom was provided pictures from textbooks and pictures and videos taken from microscopes and presented on the computer via the CD-ROM materials provided with the FOSS Diversity of Life Course kit (Lawrence Hall of Science, UC Berkeley, 2003a).

The administration and the teachers in the selected middle school were agreeable to having this study occur in their classrooms. The school system volunteered to purchase some

of the digital microscopes to be used in this study. Additional microscopes were loaned to the school system by a university that is not associated with the researcher.

Another facet of the stated problem was the existence of a digital divide that affects the distribution of access to technology resources. One factor contributing to the digital divide is household income (Soloman et al., 2003). As noted in Table 3.4, the county in which this school system is situated is ranked 79th in North Carolina's 100 counties in personal per capita income (NCDPI, 2004c). This figure is a good indicator that this system is a low wealth system. Also, as shown in Table 3.4, when child nutrition figures are excluded, this system ranks 102nd out of 117 North Carolina school systems in the per pupil spending of local (county) money (NCDPI, 2004c). This figure is another indication that the selected system does not have much local money to spend to enhance the presence of technology in the classroom. Thus, that fact provided another reason that made this system a good selection for this study. The researcher was interested in learning how low income counties might spend their precious technology funds in ways that would improve the students' attitudes toward science and their learning of the middle grades content on cell theory. Having information that helps teachers and administrators in these school systems make wise choices on technology purchases could be helpful in overcoming a digital divide.

A fourth issue of this problem is that students attending schools in some rural areas, including North Carolina's rural counties, tend to perform less well on science achievement tests than their peers in other areas (Fan & Chen, 1999). According to the U.S. Census Bureau (2004), the county in which this school system is situated is considered to be a rural county. There are no metropolitan areas within the county. The average number of persons per square mile in this county is 28.3. Also, there are gaps in national science achievement

test scores at the middle school level between males and females and between White students and African American students (Gonzales et al., 2004; Hoffman et al., 2003; O'Sullivan et al., 2003; U.S. Department of Education, National Center for Education Statistics, 2003; Tindal & Hamil, 2004; Von Secker, 2004). As noted in Table 3.1, the student population of the two middle schools in this system is composed of about 85% African American students and about 15% White students. Thus, this school system provided an appropriate population for the voice of African American students to be heard in this research study. Based on the problem outlined in this study, the selected rural North Carolina school system was an appropriate match.

Once the school system was selected, the teachers and students were chosen. The sample of teachers and students was a purposeful sample, as defined by Patton (2002). He noted that this type of sample involved the selection of cases that were purposefully chosen to provide the specific type of information needed for the study. Of the 16 types of purposeful samples that he defined, the method that was used in this study was criterion sampling. Patton defined criterion sampling as "picking all cases that meet some criterion" (p. 243). In this study, the criteria were that the teachers be licensed in middle grades science and be teaching a unit on cell theory to middle grades students in a particular rural school system during the 2004-2005 school year. The criteria for selecting this particular school system included the fact that it was a rural school system in North Carolina and the fact that the researcher had gained access to the system. The researcher had earned the trust of the administration of this system and had received permission to work with the middle school science teachers in the system. This system was about 75 miles from the researcher's home. Thus, the proximity was feasible for the observations needed for this study. Yet, it was not

the system in which she works or lives, which allowed her to function as an "outsider" who was there to observe and learn.

The sample might also be considered a cluster sample. Gall et al. (1996) defines a cluster sample as a naturally occurring group in the population. The students in these three teachers' classes already existed in groups before this study was designed. The teachers were purposefully chosen, with the requirement that each be a teacher who had middle grades science licensure and who would be teaching a unit on cells to middle grades students in this rural school system in the 2004-2005 school year. There were three seventh and eighth grade teachers with middle grades science licensure in the school system where the study occurred, and each was planning to teach the unit on cells this spring. Due to the fact that the unit on cells is in the seventh grade North Carolina Standard Course of Study (NCDPI, 1999) for the 2004-2005 school year, and it will be in the eighth grade Standard Course of Study beginning with the 2005-5006 school year (NCDPI, 2004a), both the seventh and eighth grade teachers in this system agreed to teach the unit this year. Each of these three teachers agreed to participate in this study. The principal and the school system's central office administration were also supportive of these decisions.

The students were selected in clusters, as all students of the three selected teachers were invited to participate in the quantitative part of this study. Due to student absences, some students participated in both administrations of each test, but some were absent during at least one administration of the content test or the SAI II. (As explained in another section, there were make-up days for each testing, but some students were absent each day that a pretest or posttest was offered.) The seventh grade teacher, Ms. Nu, had four classes. A total of 86 students from her classes participated in at least one administration of the content test,

and 95 students participated in at least one administration of the SAI II. One eighth grade teacher, Ms. Delta, had four classes, with a total of 95 students participating in at least one administration of the content test and 100 students taking at least one administration of the SAI II. The other eighth grade teacher, Ms. Alpha, had 3 classes. From her classes, 65 students participated in an administration of the content test, and 62 students participated in at least one administration of the SAI II. Thus, there were eleven classes of students, from these three teachers' classrooms, who participated in the quantitative part of this study.

The principal stated that she used heterogeneous grouping for all of the science classes. She had ensured that each class had students with a wide range of reading and mathematics end of grade test scores. She also tried to make sure that each class had approximately 85% African American students and approximately 50% females. However, other factors that the principal did not discuss affected the class distributions, such as students leaving and others entering the school during the year. Nonetheless, the principal's intention was to create classrooms that were representative of the school population. These three teachers and their eleven classes of students enrolled in the science course formed the sample for the quantitative component of this research study. Table 3.5 shows the number of students, disaggregated by gender and by racial identity, in each teacher's classrooms who took the content pretest or posttest. Table 3.6 shows the number of students, disaggregated by gender and by racial identity, in each teacher's classrooms who took the SAI II pretest or posttest.

Table 3.5

Number of Students Who Took the Content Pretest or Posttest, Disaggregated by Racial Identity and By Gender for Each Teacher's Set of Classes

		Males			Females	
		Pretest	Posttest		Pretest	Posttest
Ms. Nu – No Microscope						
	African American	n = 26	n = 29	African American	n = 40	n = 41
	White	n = 5	n = 6	White	n = 7	n = 7
Ms. Alpha – Analog Microscopes						
	African American	n = 33	n = 33	African American	n = 18	n = 18
	White	n = 4	n = 4	White	n = 5	n = 5
Ms. Delta – Digital Microscopes						
	African American	n = 36	n = 38	African American	n = 36	n = 37
	White	n = 9	n = 11	White	n = 5	n = 6

Table 3.6

Number of Students Who Took the SAI II Pretest or Posttest, Disaggregated by Racial Identity and By Gender for Each Teacher's Set of Classes

		Males			Females	
		Pretest	Posttest		Pretest	Posttest
Ms. Nu – No Microscope						
	African American	n = 25	n = 32	African American	n = 40	n = 42
	White	n = 3	n = 4	White	n = 9	n = 6
Ms. Alpha – Analog Microscopes						
	African American	n = 33	n = 28	African American	n = 18	n = 17
	White	n = 4	n = 4	White	n = 5	n = 5
Ms. Delta – Digital Microscopes						
	African American	n = 40	n = 36	African American	n = 35	n = 36
	White	n = 9	n = 11	White	n = 6	n = 6

The seventh grade teacher, Ms. Nu, and her classes formed the comparison group. This group used the FOSS Diversity of Life kit (Lawrence Hall of Science, UC Berkeley, 2003a), including the text and pictures (still pictures in a book, as well as still pictures and movie clips on a CD-ROM). No microscopes were provided for this group. The seventh grade students were selected to form the comparison group because in the 2005-2006 school

year, they will receive instruction again on the study of cell theory. If the eighth grade teachers were to find the inclusion of microscopes to be an effective strategy, then these students would have the opportunity to use microscopes the next year with the eighth grade teachers. Also, the eighth grade teachers were particularly interested in learning to use the microscopes in teaching this unit since this unit of study will be moved to their grade in the 2005-2006 school year. One eighth grade teacher, Ms. Alpha, had used microscopes only occasionally in her teaching, so she volunteered to use the analog microscopes. The other eighth grade teacher, Ms. Delta, has used analog microscopes more frequently than Ms. Alpha. She also has used technology to enhance her productivity more frequently than the other two teachers, so she volunteered to try the digital microscopes with her students. However, all three teachers received training from a science educator from a university (not associated with the researcher) on using the FOSS Diversity of Life kit (Lawrence Hall of Science, UC Berkeley, 2003a), the analog microscopes, and the digital microscopes. After the study ended, there were about four more weeks of school where Ms. Nu and Ms. Alpha could borrow the digital microscopes and use them with their students if they decided that they would like to provide that experience for their students this year. Thus, the sample selection did not deprive any students from educational experiences that they would have received had this study not occurred in this system. Table 3.7 provides some information on the three teachers who participated in this study. (While this table provides some brief information regarding the treatment that was used with each teacher's classes, more details are provided on the treatments in the next section of text.)

Table 3.7

Teacher Information

Teacher	Grade Level	Teaching Licensure	Years of Teaching Experience	Treatment Option
Ms. Nu	7th	Middle School English language arts Science Social Studies	15	No microscopes
Ms. Alpha	8th	Middle School Science	5	Analog microscopes
Ms. Delta	8th	Middle School Science Math	20	Digital microscopes

Hypotheses

There will be a significant difference ($p<.05$) among the population mean posttest scores on the content test for the three groups (Digital, Analog, None) after adjusting for the effects of the pretest scores. The Digital group will be significantly higher than the Analog group and the None group.

There will be a significant difference ($p<.05$) among the population mean posttest scores on the Scientific Attitude Inventory II for the three groups (Digital, Analog, None) after adjusting for the effects of the pretest scores. The Digital group will be significantly higher than the Analog group and the None group.

The statistical analysis of the study involved descriptive statistics and tests of statistical significance. According to Gall et al. (1996), descriptive statistics are useful for displaying, organizing, and summarizing sets of data. The descriptive statistics in this study were used to organize and summarize data on the pretest and posttest scores for each group of students on each of the two assessment instruments used – the Scientific Attitude

Inventory II and the science content test. Descriptive statistics were utilized to report the mean scores of the male and female students of each group of students and to provide the mean scores of the African American and White students of each group of students.

The tests of statistical significance used include an analysis of covariance (ANCOVA) to compare the population means of the three groups of students on the Scientific Attitude Inventory II after adjusting for the pretest scores. Newton and Rudestam (1999) note that this method of data analysis helps to account for group differences and controls for regression effects. If a statistically significant difference were found (at the $p<0.05$ level,) then post-hoc tests, using Fisher's least significant difference (LSD,) would be conducted to determine statistically significant differences between the groups. ANCOVA was also used to compare the population means of the three groups of students on the science content test after adjusting for the pretest scores. If a statistically significant difference were found (at the $p<0.05$ level,) then post-hoc tests, using Fisher's least significant difference (LSD,) would be conducted on these data to determine statistically significant differences between the groups.

Treatment

All three teachers and their students used the kit, FOSS Diversity of Life kit (Lawrence Hall of Science, UC Berkeley, 2003a), to teach the unit on cells. Each teacher received the same training on using this kit, which includes the use of a CD-ROM that contains images and video clips of cells. The training for the teachers occurred on January 24, 2005, and was conducted by an assistant professor of science education at a college of education at a neighboring university unaffiliated with the researcher. The educator also provided each of the teachers with a review of using the analog microscopes and a

demonstration of how to use the digital microscopes. Each teacher had the opportunity to use each of the devices. The trainer showed the teachers how to capture, save, and transfer images with the digital microscope so that they could be viewed on a computer, even when the microscopes were not being used. This researcher was present at the training sessions as an observer, but not as a participant or instructor. All three teachers were provided an outline of lesson topics, kit activities, and lesson plans from the kit to follow as they taught the unit on cell theory. (More details regarding the staff development and the teaching schedule are provided in a later section of this chapter.)

The treatment was the introduction of analog and digital microscopes to the experimental groups. Ms. Alpha used six analog microscopes with her students in the unit on cells. Ms. Delta used three Digital Blue Digital Blue™ QX5™ (Prime Entertainment, 2005) computer microscopes and three ProScope™ (Bodelin Technologies, 2004) computer microscopes. A Digital Blue™ QX5™ computer microscope can be purchased for about $80.00 and is connected to the computer by a USB port. Each microscope comes with three lenses to allow magnification at 10X, 60X, and 200X. The microscope is accompanied by software that allows the students to view digital microscope images, capture and edit still pictures, make and edit digital video clips, and create time-lapse movies. The ProScope™ computer microscope costs about $745.00 for a set that includes the microscope and stand, and 10X, 50X, 100X, and 200X lenses, and a c-mount adaptor that allows it to be used with an analog microscope, converting the analog pictures to digital pictures. Like the Digital Blue™ QX5™ computer microscope, the ProScope™ is also accompanied by software that allows the user to view digital microscope images, capture and edit still pictures, make and edit digital video clips, and create time-lapse movies. As noted, this product also allows the

user to capture images from an analog microscope that the ProScope™ to digital images and save those images in a digital format. Detailed descriptions of the Diversity of Life kit, the Digital Blue™ QX5™ computer microscope, and ProScope™ computer microscope were provided in chapter 1 of this document. The qualitative component of this study investigated how the teacher used the two different types of digital microscope and how the students responded to the two types. The details of the treatment are outlined in Table 3.8.

Table 3.8

Treatment – by Group

	Ms. Nu	Ms. Alpha	Ms. Delta
	Seventh grade teacher and her students	An eighth grade teacher and her students	An eighth grade teacher and her students
Treatment:	Used materials included by the Diversity of Life kit, including handheld magnifiers and pictures. The pictures can be found in the resource book and on the CD-ROM that accompany the Diversity of Life kit. The CD-ROM contains both still pictures and video clips.	Used materials included by the Diversity of Life kit. Added the use of six analog microscopes for students to use in groups.	Used materials included by the Diversity of Life kit. Added the use of six digital microscopes for students to use in groups. (Three of the digital microscopes, the ProScopes™, were designed to be used with analog microscopes. Thus an analog microscope was provided for use in conjunction with a ProScope™ but not as analog microscopes used alone.)

One potential problem with these microscopes was concern that the image quality of the Digital Blue™ QX5™ may not be as clear as one might wish. Therefore, the teacher in the experimental group was provided with three ProScope™ computer microscopes, as well as three Digital Blue™ QX5™ models. Like the Digital Blue™ QX5™, the ProScope™ also connects to a computer by a USB port, and it also comes with multimedia software that allows the user to take still pictures and to make video clips and time-lapse movies. One advantage of this digital microscope is that it can be connected to a standard analog microscope. The ProScope™ can convert images from an analog microscope to digital pictures. However, this model, which costs about $745 for a microscope, stand, and lenses at 10X, 50X, 100X, and 200X magnifications, is much more expensive than the Digital Blue QX5™ microscope. Therefore, the cost is rather prohibitive for the school system to buy enough of these tools for a whole class of students to use in small groups. Thus, a teacher reading this research study might be interested in how well each microscope performed in the classroom. Information has been provided in chapter 5 that could help teachers decide whether they would prefer to purchase one expensive digital microscope and project the image on a projector for the class to view as a whole or whether they would prefer to invest the same amount of money in eight or nine of the less expensive digital microscopes to be used by small groups of students. Qualitative data collected and analyzed from observations of the students as they used these tools and from interviews with the teachers and students provided insightful information that could help other middle grades science teachers preparing to teach the unit on cell theory.

First Year of Kit Use

The three teachers in this study were supplied the same teaching materials, except for the microscopes. One teacher received no microscopes, one used analog microscopes, and one used digital microscopes connected to computers. However, all three teachers were using materials that were new to them and to their school system. In February 2004, the North Carolina State Board of Education (NCDPI) decided to accept bids for science education kits that could be purchased with money allotted for textbook purchases. Thus, this school year was the first year that the school system in which this study occurred has purchased the Diversity of Life kit for the middle grades teachers to use in the unit on cell theory. Therefore, the use of microscopes was not the only curriculum material that was new to these three teachers.

Using this kit was also a new experience for all three teachers. In past years, the teachers have been accustomed to using textbooks and more traditional methods, such as reading, classroom discussions, and written questions and answers to teach the unit on cell theory. The introduction of this kit was new to all three teachers. They received a day of staff development sessions that provided information on using this material, as well as the microscopes and the computer software that was part of the kit, to teach the unit on cell theory. During these sessions, the science educator emphasized the need for the teachers to use constructivist teaching methods. The materials in the kit are intended to encourage hands-on active learning. The school system had already decided to purchase this kit and to provide this staff development before this research project was scheduled. Since the school system had already decided to use the Diversity of Life kit, the researcher wanted to investigate the

role of microscopes in these three different classroom environments when this kit was being used.

Staff Development

The three teachers participating in this study received staff development on January 24, 2005, from a science educator at another university not associated with the researcher. The school administration contracted with the science education professor to provide staff development to the teachers on using these kits. Therefore, the professor was hired by the school system to spend a teacher workday with the three teachers involved in this study. She provided an outlined list of the lessons and investigations for the teachers. Then, she completed some of the activities with the teachers, modeling how to teach them, during this staff development day. Some activities were completed in detail, and others were at least discussed with the teachers. She made sure that activities that she thought might seem intimidating for teachers to set up or to conduct were completed during the staff development session. Teachers had the opportunity to ask questions and to share any concerns that they had regarding implementing the unit of study. Some of the lessons referenced materials located on a CD-ROM. She demonstrated their use for the teachers, and she had each teacher to use some of the materials to ensure that she knew how to access and run the software. During the staff development session on using the FOSS Diversity of Life kit (Lawrence Hall of Science, UC Berkeley, 2003a), the science educator also provided a refresher on using analog microscopes and a lesson on how to use each of the digital microscopes.

In addition to this staff development session on teaching the unit on cells, the middle grades science teachers in this school system participated in staff development offered in Raleigh on teaching students to use notebooks in science classrooms. At those sessions, the

teachers learned how to help students establish and use notebooks for recording observations and other data during science lessons. The teachers implemented the use of these student notebooks as they taught the unit on cell theory.

Schedule of Lessons in the Cell Theory Unit

The science educator who provided the staff development for the three teachers also created a schedule of lessons to guide the teachers as they implemented this unit of study. The detailed schedule can be found in Appendix C. Of course, no set of plans can totally remove a teacher's set of skills or manner of teaching, but a uniform set of lessons and materials was used to help minimize the individual differences. Also, school schedules are subject to change, often without notice. Therefore, each teacher was allowed to make accommodations to the schedule of lessons that were needed to match changes in the school schedules and in their personal schedules. For example, each teacher was absent for at least a couple of days during the five weeks that the study was conducted. Naturally, each had to make adjustments to accommodate her absences. Each teacher was a licensed, experienced teacher, so allowing each to make her own decisions about how to modify the schedule to allow for those circumstances was a reasonable and workable solution. In addition to individual adjustments, the generic schedule had to be modified to serve the needs of the group of teachers. For example, a day of field testing and a day of picture taking were both unexpected interruptions that had to be accommodated. The revised version of the schedule is available in Appendix D. In addition to the detailed schedules located in the appendixes, Table 3.9 provides a brief weekly listing of lesson topics to provide a general overview of what was occurring in the classrooms.

Table 3.9

Weekly Guide to Diversity of Life Lessons

Dates	Topics
March 14-18	Administer content and SAI II pretests Create miniponds for exploration later in the unit Begin "What is Life" set of investigations
March 21-24	Continue "What is Life" set of investigations and discussions
March 25-April 1	Spring Break
April 4-8	Animal and plant cell investigations
April 11-15	Protist investigations
April 18-22	Continue investigations of protests Explore contents of miniponds created at the beginning of the unit of study
April 25-29	Ribbon of life activity Review of unit Administer SAI II posttest
May 2-5	Administer content posttest Provide opportunities for making up posttests

Measurement Instruments

Two assessment instruments were employed in the quantitative component of this study. One was a science content test intended to measure how well the students learned the content taught by all three teachers on cell theory. The other instrument was the Scientific Attitude Inventory II, which was used to measure the students' attitudes toward science. Both assessment items were administered by the three classroom teachers to all of their students. Each was administered as a pretest before the unit of study on cell theory began and was given again as a posttest at the conclusion of the unit on cell theory. The Scientific Attitude

Inventory II was given to the students as a written assessment. The teachers read the directions to the students and answered any questions they had regarding how to mark the answers. Each student read the questions and choices silently and marked the answers on an answer sheet.

The science content test was given to the students in written form, but the questions and answer choices were also to be read aloud to the students. The plan for the pretest and the posttest was that each teacher would distribute written copies of the tests to all students in each of her classes. Once she provided the written copies and answer sheets to the students in a class, she was to read the directions, the questions, and the answer choices to the students. Each teacher was instructed to read each question and answer choice twice. She was also told that she could repeat the questions and answer choices at any time at the request of students. The purpose of this procedure was to help ensure that the content test was measuring science content knowledge, rather than reading comprehension. (While reading comprehension is an important goal, it is not the intended goal to be measured in this study.)

When the teachers gave the pretest, they followed those instructions. The day before the teachers were to begin administering the posttests, the researcher reminded the teachers that they would follow the exact procedures for giving the posttests that they had followed when giving the pretests to the students. She reminded them that they were to read the questions and answer choices on the content test. The next day, they were to give the Scientific Attitude Inventory II posttests, but there was a change in the schedule at school which would not permit them to give the tests to all of their students that day. Therefore, the teachers and the researcher made the decision that the Scientific Attitude Inventory II would be administered to the students over a two day period, as class schedules allowed. All three

teachers would wait until the third day to give the content posttest to the students so that no class of students would take the content test on an earlier day than another class. In the meantime, the teachers received training on administering the End of Grade tests to their students. Part of this training emphasized the fact that teachers are not allowed to read the questions on this test. The teachers involved in this study were thinking of those instructions when they administered the content posttest. None of the three teachers read the content questions aloud to their students when giving the posttest.

Science Content Test and Its Development

In North Carolina, there is no end of grade science test administered in the middle grades. (This practice will soon change, and field testing of the new eighth grade end-of-grade science test will begin in 2006.) Thus, there was no released state test that could be used to provide a content assessment on the middle grades unit on cell theory. Therefore, this researcher created a science content test intended to match the 2004 version of the North Carolina Standard Course of Study for the eighth grade study on cells. The paragraphs below outline how the researcher developed the content test that was used in this study.

First, the researcher created a test on cells from resources that were available to the teachers in the selected school system, including the Diversity of Life kit, the textbooks currently used in their classrooms (Parke, Stanford & Stiffler, 2000), and test bank items that were released from the North Carolina Department of Public Instruction, Office of Instructional and Accountability Services (1996a, 1996b). She used questions from these materials, adapted questions from these materials, and created some questions of her own.

The first test that she created was a generic test on the study of cells (see Appendix E). After creating this test, the researcher shared it with the science educator from another

university who conducted the training of the teachers for the use of the Diversity of Life kits and the microscopes. At first, the science educator and this researcher agreed that this test was an appropriate test on the study of cells. Then, the two met and discussed exactly what the teachers would teach each day during the unit on cells. They also re-examined the new North Carolina Standard Course of Study objectives related to cell theory that will be taught next year in the eighth grade (see Appendix F). The science educator and the researcher also examined the objectives of Project 2061 as they related to the middle grades study of cells to ensure that the unit of study that we are planning encompasses these objectives (see Appendix G).

As this science educator and the researcher looked over the objectives that the students should learn and the unit of study that was planned for all three teachers, they decided that the researcher should re-write the test to make it match the unit of study more precisely. The test was re-written to match the content in the Diversity of Life kit, the objectives on cell theory in the 2004 North Carolina Standard Course of Study that will be implemented next year in the eighth grade on the study of cells, and the objectives of Project 2061 (see Appendix G).

Once the researcher completed the second version of the test, she asked the science educator from another university, a science education specialist who works in the central office of a school system, and three local middle school science teachers (one of whom has National Board Certification,) to review the test for content validity and to provide feedback on this test. Their written and oral feedback were combined, and their suggestions are listed below.

Suggestions from teachers who reviewed the test:

- Have fewer "none of these" choices.
- All teachers suggested that there be 20 – 25 items.
- All teachers thought that the content of the test was an appropriate match to the 2004 North Carolina Standard Course of Study and to the Project 2061 objectives.
- They suggested that the researcher reword the following questions: numbers 13, 16, 20, and 24.
- They thought that all questions should have 4 answer choices. (Originally, one question had 3 choices, one had 5 choices, and the remaining questions had 4 choices.)
- They liked the fact that all questions were multiple choice questions and were in a format that they thought was similar to the one used in End of Grade tests.
- They thought that the level of difficulty was appropriate for eighth grade students.

The science education specialists (from the university and the school system central office) stated:

- The content adequately matches the content in the North Carolina Standard Course of Study, the Project 2061 objectives, and the specific content to be taught using the FOSS Diversity of Life kit.
- Reword question #22 to include the content that is in question #11 and omit question #11.
- Add a couple of questions that reference pictures. They did not recommend using a lot of pictures because they wanted it to be in a format similar to the questions they expect to see on the next end-of-grade test. There is also an issue on how black and white copies of the pictures will work. If the reproduction quality is not good, then the page that contains the pictures could be a color copy. However, they thought a couple of questions that referred to pictures would be valuable.

In addition to asking the teachers and science education specialists to review the test, the researcher gave the test to ten eighth grade students at a local middle school. While the students told her that they thought the test was challenging, they provided her with feedback that was helpful in refining the test. From evaluating the students' answers and their feedback that they provided, she made the following changes.

- She noted that question #8 had an error. The auto-correct feature had changed "protists" to "protests" without her noticing it. Many students missed this question, which prompted a closer evaluation of the item.
- She decided to reword question #9.
- She decided to omit question #15.

- She reworded question #24.
- She changed the last choice for question #26.

The researcher used Microsoft Word 2003 to calculate the Flesch-Kincaid Grade Level readability score for the content test. The results indicated that the readability grade level for this test was 5.7. The final version of this instrument is included in Appendix B. Two questions are listed below as examples.

1. The thick outer covering around the cell membrane of a plant cell is the:

   A. chloroplast.
   B. plant wall.
   C. cell wall.
   D. nuclear membrane.

2. The basic unit of structure in all living things is the:

   A. cell.
   B. tissue.
   C. organ.
   D. organelle.

After administering the content test, the researcher realized that question number 11, as listed below, had an error. There was no correct answer. Thus, this question was removed from the test. No answer was scored for question number 11, and the test became a 24-question instrument.

The Scientific Attitude Inventory II

The Scientific Attitude Inventory (SAI) was developed and field tested by Moore and Sutman in 1970. The authors' goal was to develop an instrument that measured one's attitude toward science. Twelve position statements, six positive statements and their counterparts – six opposing negative statements – were developed. The authors intended for the statements to reflect emotional and intellectual attitudes toward science. Then, the authors developed a group of attitude statements for each position statement. They presented those statements to a

panel of experts who selected the statements that they considered to be the most valid. This group of judges consisted of four scientists, four science educators, and two science professors. Moore and Sutman based the claim of content validity on the use of this panel of experts to choose the statements that were incorporated into the SAI. Sixty statements were selected for inclusion in the instrument and were presented on a four-category Likert-type scale. There were five statements selected for each of the six positive and six opposing negative positions, giving a total of 60 items. The authors field tested this instrument in three classes of tenth-grade biology, and the instrument has been used in numerous studies (Moore & Foy, 1997; Munby, 1983).

Nagy (1978) examined the Science Attitude Inventory and made suggestions for its improvement. He suggested the use of a fifth category (to be used as category "3" in the instrument) to allow the person responding to the instrument to choose "uncertain or cannot decide" for each item. He also expressed concern regarding the difficulty level of some of the vocabulary used in the instrument. He administered the inventory, using the additional "undecided" category, to 97 ninth grade students enrolled in a science course. When he analyzed the results of responses, he found that some of the items received a large number of "uncertain or cannot decide" responses. When he examined the statements that had the largest number of responses in this category, he noticed that those statements used more difficult vocabulary, such as "idea-generating," "objective," and "phenomena." He also noted two items that had similar meaning, but the one with more difficult vocabulary, received a response of "3" from 50 students; while the similar item with less difficult vocabulary received a response of "3" from only five students. He suggested that the SAI could be improved by simplifying the vocabulary used in the some of the items. Munby (1983) also

criticized the Scientific Attitude Inventory (SAI). He noted that this instrument has been used in at least 30 studies and was the most popular instrument for measuring attitudes toward science. Still, he voiced concerns regarding the instrument's validity.

In response to these criticisms, and based upon their desire to create an updated version of this instrument, Moore and Foy (1997) revised the instrument, resulting in the Scientific Attitude Inventory II (SAI II). One change that the authors made was to eliminate the use of words that were gender specific. They also followed Nagy's (1978) suggestions of simplifying the vocabulary. One example was that they changed the item that read, "When one asks questions in science, he gets information by natural phenomena," to "Scientific questions are answered by observing things" (Moore & Foy, p. 30). In addition, they shortened the statements whenever possible, again to improve readability. The authors followed Nagy's advice to change the Likert-type scale that consisted of four choices (agree strongly, agree mildly, disagree mildly, disagree strongly,) by adding a fifth category, offering a neutral or undecided response as the middle or third choice on the scale.

Despite Munby's (1983) expression of concerns regarding the content validity of the instrument, the authors maintained that the instrument has content validity, based on the use of a panel of experts in the field and the field testing of the instrument. Therefore, Moore and Foy (1997) decided to retain the original 12 positions, but they shortened the survey from 60 items to 40 items in order to make it easier to use. They removed two statements from each scale, except for the last sub-scale, which dealt with the person's desire to engage in scientific work.

Moore and Foy (1997) then field tested the revised instrument, known as the Scientific Attitude Inventory II (SAI II). They administered the revised instrument to 588

students in the sixth, ninth, and twelfth grades and compared the results of the 577 respondents. They compared the top and bottom 27% on subscales to see if there was a statistically significant difference between the top and bottom scores. For each of the subscales, there was a statistically significant difference ($p<0.05$) in the direction of the total score of the participants on the instrument. Thus, the t-test comparison of the high and low scorers on the two subscales provided an additional measure of validity for the instrument. As the authors noted, this analysis showed that each of the subscales contributes to the participants' overall attitude toward science.

Moore and Foy (1997) also computed a split-half reliability coefficient for the group of 557 respondents. A Spearman Brown correction for split-half reliability to the correlation coefficient gave a reliability coefficient of .805. They reported a coefficient of .781 Cronbach's alpha reliability coefficient for this group of 557 respondents.

Munby (1997) was critical of the validity of the SAI II. He continued to criticize Moore and Foy's (1997) claim of validity based on the panel of experts and stated that a panel should also have examined the revised version of the instrument. He did, however, acknowledge that the analysis of the subscales in the new instrument provided some evidence that the subscales measured what the entire scale measures, but he disagreed that the construct being measured by the SAI II is attitudes toward science. Munby (1997) then described his review of fifty-six instruments that have been designed to measure attitudes toward science, and he stated that none of them were appropriate instruments. He stated that his analysis of these instruments was too extensive for journal publication, so he focused his article on the SAI II, which he conceded is the instrument most often used for assessing attitudes toward science. He noted that there are no clear guidelines for validating these types

of instruments that are unanimously approved by people in the field. While Munby (1997) criticized the revised instrument, he did not offer any better or more suitable alternative to it. He also credited it as being the most often used instrument of those designed for this purpose.

While it appears that there is no attitude assessment instrument that is universally accepted as the best way to measure students' attitudes toward science, the one that according to Munby (1997) is used the most frequently is the Scientific Attitude Inventory and its current revision, the Scientific Attitude Inventory II (SAI II). Thus, it seemed that the best choice of instruments for measuring the students' attitudes toward science in this study was the Scientific SAI II. The researcher was granted permission from the authors to use the instrument in this study (R. W. Moore, personal communication, April 12, 2004).

The six constructs that the SAI II purports to measure are listed below:

1. The laws and/or theories of science are approximations of truth and are subject to change.
2. Observation of natural phenomena and experimentation is the basis of scientific explanation. Science is limited in that it can only answer questions about natural phenomena and sometimes it is not able to do that.
3. To operate in a scientific manner one needs to know what other scientists think; one needs to know all the scientific truths and to be able to take the side of other scientists.
4. Science is an idea-generating activity. It is devoted to providing explanations of natural phenomena. Its value lies in its theoretical aspects.
5. Progress in science requires public support in this age of science, therefore, the public should be made aware of the nature of science and what it attempts to do. The public can understand science and it ultimately benefits from scientific work.
6. Being a scientist or working in a job requiring scientific knowledge and thinking would be a very interesting and rewarding life's work. I would like to do scientific work.

A copy of the SAI II has been provided in Appendix A. The first six items from this inventory are listed below to provide a sample of the statements presented to the students.

1. I would enjoy studying science.
2. Anything we need to know can be found out through science.
3. It is useless to listen to a new idea unless everybody agrees with it.

4. Scientists are always interested in better explanations of things.
5. If one scientist says an idea is true, all other scientists will believe it.
6. Only highly trained scientists can understand science.

Students rated each statement. The directions asked the student to mark a letter on an answer sheet that corresponded to his/her feelings using the following scale:

- Mark "a" if you strongly agree.
- Mark "b" if you mildly agree.
- Mark "c" if you are not sure or cannot decide.
- Mark "d" if you mildly disagree.
- Mark "e" if you strongly disagree.

In this study, all participating students in the three teachers' classrooms, who were present on the days of the SAI II testing administration, were given the attitude survey as a pretest and a posttest. The students read the inventory silently and marked their responses on an answer sheet. As noted earlier, descriptive statistics and inferential statistics were employed to analyze the results.

Overview of the Qualitative Component

The purpose of the qualitative part of this study was to provide insights into how the students and teachers viewed the unit on cell theory when no microscopes were used, when analog microscopes were used, and when digital microscopes were used in the unit on cell theory. The researcher observed students to see how they responded to the addition of microscopes in the classroom and was particularly interested in observing the students' engagement in learning in each of the three situations. Student interviews provided insights into the students' reactions toward the unit on cell theory in each of the three classroom environments. Interviews with the teachers provided additional data regarding how the teachers viewed the addition of analog and digital microscopes into the middle school unit on

cell theory and how one teacher compared the use of two types of digital microscopes in her classroom.

The qualitative component of this study consisted of a case study. Merriam (2001) states that "the single most defining characteristic of case study research lies in delimiting the object of study, the case. . . The case then, could be a person such as a student, a teacher, a principal, a principal; a program; a group such as a class, a school, a community; a specific policy, and so on" (p. 27). She also states that if "the phenomenon you are interested in studying is not intrinsically bounded, it is not a case" (p. 27). The case in this study was the set of three licensed middle grades teachers who were teaching the unit on cells in this school system in spring 2005 and the students of those teachers. The qualitative component can be described more specifically as an instrumental case study, as defined by Stake (1995). He stated that the purpose of this type of case study is to help the reader understand an idea, rather than focusing only on learning about the particular case. In this study, the case provided data regarding the teaching of cells – with technology in the form of digital microscopes, with analog microscopes, and with the absence of microscopes – in a rural middle school. Participant observation, interviews, and video-taped class sessions provided data.

In light of criticism of the SAI II, as described in the section on the quantitative instruments, an important component of the qualitative part was the provision of additional insights into the students' reactions toward the learning activities and their attitudes toward science. The researcher interviewed selected students in all three groups. Answers they provided to questions such as, "If you were talking to your friends about using the hand-held magnifiers and CD-ROM images/regular microscopes/digital microscopes in this class, what

would you tell them?" provided data that was analyzed to provide understandings on how the students viewed the science learning activities that were provided. Yager and Penick (1986) stated that students' positive attitudes toward science are exhibited by their descriptions of science with words such as fun, interesting, or useful for the future. Fredricks et al. (2004) state that attitudes toward science are related to the students' emotional engagement in the science classroom and are displayed by affective responses, such as happiness, discontent, interest, or boredom. Therefore, as the researcher analyzed data from the student observations and interviews, she was looking for patterns that provided insights into the students' attitudes toward science, as defined above. Thus, this additional information should help to compensate for any short-comings which may be present in the attitude assessment scale and should add rich data to enhance the findings gleaned in the quantitative component of the study.

Selection of the Place, the Participants, and the Activity

As noted in the information provided on the sampling process in the quantitative section of this chapter, the school system where the study occurred was purposefully chosen as an appropriate match for a study designed to address the problems identified in this document. Those problems were reviewed in that section, and an explanation was provided of how this system is an appropriate choice for studying those problems. That section on the sampling technique also explained why the three teachers were chosen. The selected teachers were the three middle grades science teachers in that system who have a teacher's licensure in middle grades science and who were teaching the unit on cells in the 2004-2005 school year. These three teachers participated in the qualitative part as well as the quantitative portion of this study. In the quantitative part, all of their students were invited to participate.

In the qualitative part, all students were asked to participate as the researcher made observations, and twelve students were interviewed.

There were three types of learning environments. All three teachers used the FOSS Diversity of Life kit (Lawrence Hall of Science, UC Berkeley, 2003a) and the textbook *Integrated Science: Interactions and Limits* (Parke et al., 2000). In this report, a pseudonym has been assigned to each teacher. The teacher who used no microscopes was labeled Ms. Nu, the teacher who used the analog microscopes was called Ms. Alpha, and the teacher who used the digital microscopes was identified as Ms. Delta. Ms. Nu used handheld magnifying lenses, pictures from text sources, and images and video clips from the CD-ROM provided with the Diversity of Life kit. Ms. Alpha had access to those resources, and she also used six analog microscopes with her students. Ms. Delta used the text and CD-ROM resources, and she used six digital microscopes with her students. I interviewed these three teachers regarding the teaching of the unit on cells, and I specifically asked them to talk about their experience in using the magnifying devices and images provided to them. I also observed the classrooms of each teacher, as noted above.

From each of these three classrooms, I selected four students who were invited to participate in an interview with me. I wanted to make sure that I was choosing two students who had more favorable attitudes toward science and two students who currently had less favorable attitudes toward science at the beginning of the unit of study. Therefore, I used the results of the Scientific Attitude Inventory II pretest to select the students who were invited to participate in the interviews. (The students did not know that they are selected on the basis of an inventory score). I asked the male and the female whose scores were closest to the 33rd percentile and the 67th percentile in each of the three teachers' classes to participate in an

interview. I thought that having a range of student interest could provide insight in learning about how to foster student interest in science. I wanted to talk to an equal number of male and female students because I wanted to learn about helping both genders become interested in learning about science. Also, I checked the racial identity of the selected students. Ideally, three of the four students selected from each class would be African American. If the group of students initially selected from a class did not include three African Americans, then I replaced the student with the a student of the appropriate race of the same gender whose score was closest to the selected percentile. That way, I would be ensured that 75% of the students who are interviewed were African Americans and 50% of them are females. Students who were invited to participate in the interviews were given the opportunity to accept or decline with no pressure from the teachers or the researcher for them to participate. If a student chose not to participate, another student of the same gender and racial group whose score was similar to the score of the student who chose not to participate was invited to take part in the interviewing process. Those students who agreed to the interviews signed a permission form that specified that he/she agreed to this participation. In addition, the students' parents signed a form granting permission for the student to be interviewed by me. A list of the interview questions (see Appendix I) was attached to the permission form (see Appendix J).

Methods of Data Collection

Merriam (2001) recommends that data collection in a case study include participant observation, interviews, and document analysis. I used these three methods. Merriam also noted that one method is usually dominant over the others. Marshall and Rossman (1999) recommend the use of participant observation and interviews when the goal is to learn the

perspectives of the participants. In this case study, I was interested in learning the teachers' and the students' perspectives on the three types of learning environments. I was also interested in observing how the students used the magnifying devices as mindtools, so observations and interviews were a good fit for that goal, too. Those two methods provided the primary means of data collection. In the classrooms where digital microscopes are used, I was interested in learning how the students might use the multimedia software that was provided with the microscopes. Therefore, I planned to analyze any multimedia projects that they created. If the students were to use this software to create a presentation, it would be from their own initiative. The teacher had the option to choose not to include asking the students to create a presentation as part of the design of the unit on cells. Therefore, I realized that there may be no products to analyze. As it happened, the students did not create any multimedia projects. They captured and saved images, but they did not create a multimedia presentation.

As noted above, each of the three teachers were interviewed. I conducted the interviews during their planning times on days that were convenient to the teachers (see Appendix K). In addition to the formal interviews, the teachers frequently provided me information on what they were learning from participating in the study. In addition, at the request of the three teachers, I met with them as a group at the end of the study to have a group discussion about what they perceived as the advantages and disadvantages of each approach. They also offered their insight into what they would recommend for teaching the unit on cell theory in the future.

In addition to the discussions held with the teachers, I interviewed four students from each teacher's classroom. The students were interviewed during regular class time (see

Appendix I). I asked the students the questions that were written on the form. (The list of questions was sent home for parent review and permission prior to the interviews.)

I observed one class of each teacher at least twice a week during the unit on cells. (The schedule of lessons is presented in the information in this chapter on the quantitative component of this study. A more detailed schedule, including dates of observation, is available in Appendix D.) I had planned to ask the teachers to place a video camera on a tripod to film some of their classes on days that I could not be present to observe. Initially, they had agreed to this request. However, once the unit started, the teachers realized that they were not comfortable with having a video camera filming when I was not present. (I had loaned them a camera to use, but they were concerned about using a camera they considered to be expensive.) Therefore, no classes were videotaped when I was not there. However, they wanted a video tape to be made on one of the days that I was present. I taped one lesson of one class of each teacher. The tapes offered the advantage of allowing me to review student behavior after the study ended, providing a sort of re-creation of a class. (Each of the students who were videotaped had signed a school permission form granting permission to participate. Their parents had also signed the form. These permission forms were already in use by the school before the study began.)

In order to provide a structure for the classroom observations, I used a constructivist learning model created by Gagnon and Collay (2001). They labeled their model the Constructivist Learning Design (CLD). Their CLD model consists of six parts, which they say flow back and forth into each other. The first part is labeled as “situation,” and it is defined as the frame for student engagement. The situation provides the overall goals and tasks for the learning situation. The second element is “groupings,” the social structures that

will be employed during the learning experience. Third, "bridge" refers to the scaffolding that is provided to help the students connect the new learning to the knowledge they have already formed in their minds. Fourth, "questions" are used to help inspire students to analyze, synthesize, extend, and integrate what they are learning. The fifth element, "exhibit," refers to having the students share what they are learning with others. The authors also refer to the exhibits as "artifacts of learning" (p. xi). "Reflections" allow students to think critically about what they are learning, to apply their learning to other areas of the curriculum and to their lives, and to think about future opportunities for learning. The CLD model provided a basis for observation of the classrooms in this study and will supplied a common vocabulary for the researcher and the classroom teachers to employ as they discuss what is occurring in the classrooms. This model also helped to provide a framework for me as I analyzed the observational data.

Data Analysis

Merriam (2001) states that, "data collection and data analysis is a simultaneous activity in qualitative research" (p. 151). I followed her advice of beginning to analyze the data as they are collected. Creswell (1998) agrees with that suggestion and recommends a process of data analysis in case study research in which the researcher reviews the data as they are collected and begins to place the data into five or six categories that he/she finds while reviewing the information. Creswell prefers to start with a short list of categories and then expand the categories as he continues to re-review data and to review newly collected information. He cautions against developing more than 25 to 30 categories. Then, as he ends the data collection and continues to analyze the whole set of data, he attempts to collapse the categories into five or six groups. That method provides him with a structure for presenting

the findings. I attempted to follow his recommendations as I analyzed the data collected from observations, interviews, and document analysis. As noted, I also used the CLD model to help me analyze the data. A useful tool in analyzing the data was Microsoft Word 2003. This software allowed me to search observation notes and interview transcripts for details that I wanted to place in various categories.

Role as Researcher

My role as the researcher was that of an outsider who was there to observe, listen, and learn. However, to be effective in that role, I needed to have the trust of the teachers and the administrators. I had already been working on developing this relationship, and I perceived that the teachers welcomed me into their classrooms and that the administrators also embraced my presence. I continued to foster mutual respect as the study developed. I was a middle grades mathematics / science / instructional technology teacher in another public school system for 15 years. The fact that I have worked in a similar role to theirs helped me to present myself as a colleague as well as a researcher. I explained to the teachers that I have never used microscopes in teaching middle school science. I wanted them to understand that I was not trying to tell them that I had better ways of teaching than they did. I also did not want them to think that I believed that I was a better classroom teacher than each of them is. On the contrary, I wanted them to know that I respected them as classroom teachers. I was very grateful for the fact that they are willing to try new methods with their students and that they were allowing me to learn from their efforts. The working relationship proved to be very satisfactory. I think that the teachers realized how much I appreciated their contributions to this study. I was also very pleased with the fact that they repeatedly thanked me for introducing them to new methods.

I reassured the teachers that I was not there to evaluate their personal effectiveness as teachers. The teachers were provided with instructional materials and with staff development sessions on how to use them effectively. They were also provided with a schedule of lessons to teach. Therefore, they would not be following their own paths in teaching these lessons; rather, they would be following a prescribed set of plans that have been provided for them. Of course, no set of plans can totally remove a teacher's set of skills or manner of teaching, but a uniform set of lessons and materials was used to help minimize the individual differences. Also, I realized that all school schedules are subject to change, often without notice. Therefore, I expected each teacher to be able to make accommodations to the schedule of lessons that were needed to match changes in the school schedules and in their personal schedules. (For example, each teacher was absent for at least a couple of days during the five weeks that the study was conducted. Naturally, each had to make adjustments to accommodate her absences. Each teacher was a licensed, experienced teacher, so I allowed each to make her own decisions about how to modify the schedule to allow for those circumstances.) My observations were not focused on evaluating the teachers' methods. Instead, my observations were concentrated on what the teachers discovered as they used the materials and instructional activities provided for them. Even though I was an outsider to their classroom, my goal was for the teachers to view me as a colleague who, like them, was interested in learning whether the use of microscopes, and particularly digital microscopes, seemed to be an effective tool for their middle grades students in the study of cell theory.

I wanted the students to view me as someone who was interested in what they were learning and how they were learning it. I worked to earn their trust and confidence by showing interest in their learning activities and in their opinions and other comments

regarding the instructional materials and learning activities. Since I really did want to learn from them, I expected that the selected twelve students would see my genuine interest and would provide me with honest answers as I interviewed them. I viewed it as my job to help them see that I was not there to evaluate their work. Instead, I was there to learn from them.

In the role of researcher, I realized that I needed to be aware of my own biases as much as possible. One area to which I have already alluded is that I was aware that it was not my intent to evaluate the skills of the teachers. Naturally, when observing a fellow teacher's classroom, there is a tendency to want to evaluate the teacher. I think that being aware of that tendency helped me to remind myself of the dangers of falling into that pattern. I realized that if I were to evaluated the teachers' methods, I would jeopardize my rapport with the teachers. I also might taint the data for this study. Instead of evaluating the teacher, I focused on the effectiveness of the instructional strategies that they were asked to incorporate into their classrooms.

Another bias of which I needed to be aware was that I am a White researcher working in a school whose population is approximately 83% African American (National Center for Education Statistics, n.d). Two of the three teachers are African American, and one teacher is White. My racial identity could have an effect on how I interpret the data. There could be a temptation to view another culture through the lens of my own. I attempted to see the situation from the viewpoints of the participants. For example, I tend to assume that technology in the classroom provides a valuable asset; however, it is possible that some teachers and/or students may not value the presence of instructional technology. I think that if by showing respect for the teachers' and students' views, and by listening attentively to the participants, I was able to understand their point of view on issues pertaining to this study. In

fact, I think that I personally benefited from learning more about the perspectives of the African American teachers and students involved in this study.

In addition to listening respectively to the teachers and students, I also asked each teacher and student to read the transcript that I made from his/her interview. I had each to tell me if there was any part that I had not recorded correctly. I also asked each one to let me know if there were any comments I had recorded that did not represent what he/she intended to say. Each person read the transcript and had the opportunity to provide feedback. Each gave their final approval of what I had written (and had corrected if needed). This form of member checking helped to ensure that I was recording the information from the participant's viewpoint, not from my own.

Validity

Stake (1995) states that the concept of validity in a case study centers on the idea of trying to get the research right. My goal was to learn from the teachers and the students who participated in this study. As noted above, I realized the importance of establishing and maintaining a relationship based on mutual respect. I understood that I would gather accurate information only if the teachers and the students participated willingly. (Teachers and students were included in this study only if they decided to sign a letter of consent; see Appendix J and Appendix L for copies of these letters).

As noted above, I needed to establish an atmosphere of trust with the teachers to help them to realize that I did not intend to make judgments regarding their teaching practices. Rather, I saw them as collaborators who were helping me discover what works and what does not work in their classrooms. When an idea or activity did not work, I did not consider the event to be a failure. Instead, it was an opportunity for learning. Discovering what does not

work for these teachers is equally as valuable as learning what does work. Confidentiality was guaranteed to the students, as well as the teachers. Pseudonyms for teachers and students have been used.

In an effort to record data accurately, I tape recorded all interviews and transcribed the tapes. Each teacher and student was asked to check the transcription for accuracy. Stake (1995) recommended the process of member checking as one means of creating validity. As I began writing rough drafts, I asked each teacher to read the material that pertained to her classroom and asked for her input to make sure that I was accurately recording and interpreting the events. Teacher feedback was helpful as I revised the drafts.

Stake (1995) also recommends the technique of triangulation, which I used to compare data and to help ensure validity. Data collected from teacher interviews, student interviews, classroom observations, and student documents were compared and contrasted. Patterns that emerged helped to show where one form of data supported an idea gleaned from another form of data. Cases where two forms of data appeared to be in conflict were also helpful. This information helped me to examine the situation in more depth to determine how the seemingly conflicting data really fit. My fifteen years of experience in middle school classrooms also helped me in interpreting data collected from the classroom observations. Data from the variety of sources allowed me to provide a rich description which will add to the validity.

Summary of Qualitative Component

The qualitative part of this study was an instrumental case study. Stake (1995) emphasized that "the real business of case study is particularization, not generalization. We take a particular case and come to know it well" (p. 8). This case study was what Stake

defined as an instrumental case study. He said that the purpose of this type of case study is to help the reader understand an idea. Therefore, rich descriptions and learning contexts have been provided to help the reader understand the case and the ideas that it presented related to the use of microscopes – including a lack of microscopes, analog microscopes, and digital microscopes – during the unit on cell theory in a middle grade classroom in a rural school system.

Summary

This study consisted of a quantitative component and a qualitative component designed to complement one another. The combination of data from the Scientific Attitude Inventory II, the science content test, teacher interviews, student interviews, classroom observations, and analysis of video tapes provided information that was used to create a complex analysis of three classroom learning environments implemented in a rural middle school during the unit on cell theory. This study provided information for middle school teachers preparing to teach the unit on cells, and especially for teachers in schools similar to the one described in this document.

PRESENTATION AND DISCUSSION OF QUANTITATIVE DATA

Introduction

This study consisted of two parts – a quantitative component and a qualitative component. The results of the quantitative part are presented in this chapter, and the results of the qualitative part are provided in the fifth chapter. The sixth chapter includes a discussion of the findings and of how the findings of the two components complement each other.

The quantitative part of the study consisted of a quasi-experimental study situated in three middle school classrooms. Before the unit on cell theory was begun, each teacher administered the content test developed for this study and the Scientific Attitude Inventory II to the students in her classroom as a pretest. The unit on cell theory was then conducted for five weeks. At the conclusion of the unit, each teacher administered the content test and the Scientific Attitude Inventory II as a post-test. The results of these tests have been analyzed using Microsoft Excel to provide descriptive statistics and SAS 9.1.3 for Windows to conduct an Analysis of Covariance.

Hypotheses

Hypothesis One: There will be a significant difference ($p<.05$) among the population mean posttest scores on the content test for the three groups (Digital, Analog, None) after adjusting for the effects of the pretest scores. The Digital group will be significantly higher than the Analog group and the None group.

Hypothesis Two: There will be a significant difference ($p<.05$) among the population mean posttest scores on the Scientific Attitude Inventory II for the three groups (Digital,

Analog, None) after adjusting for the effects of the pretest scores. The Digital group will be significantly higher than the Analog group and the None group.

Analysis of Content Test Data

The content test was composed of 24 multiple choice questions. The raw score was reported for each student on each administration. The three teachers administered the content test as a pretest and posttest to each participating student in her classroom. Due to student absences, some students were not tested on one of the administrations. The teachers administered make-up tests to the students for two days after the initial administration. The researcher decided that after two days, an administration of the pretest would not be valid. The teachers started the unit of study on the fourth day, so she did not want the students to take the pretest once they had begun the unit of study. The same time frame was used for making up the posttest. Thus, students who were not present on one of the three days that the posttest was offered were not given the posttest. Table 4.1 displays the number of students, by teacher, who took the content test as a pretest and as a posttest. The table also provides the number of students who took both the pretest and the posttest. First, descriptive data have been provided regarding the pretest and posttest scores. For this presentation of data, all pretest and posttest scores were used, as it was not necessary to have each pretest matched to the posttest when determining the mean score for each group of students. However, when SAS 9.1.3 was used to perform an analysis of covariance (ANCOVA), scores of students who did not take both the pretest and the posttest were ignored. While a total of 248 students took at least one test, there were 213 students who took both the pretest and the posttest. Thus, 213 students' scores were used in the ANCOVA.

Table 4.1

Content Test – n by Teacher and Test Administration

Teacher	Treatment	Students who took pretest	Students who took posttest	Students who took pretest and posttest
Ms. Nu	No microscopes	79	83	75
Ms. Alpha	Analog microscopes	60	60	55
Ms. Delta	Digital Microscopes	86	93	83
Total *n*		225	236	213

Descriptive statistics were used to show the scores of students by teacher groups based on racial identity and gender. Table 4.2 presents the data disaggregated by racial identity and by gender for each teacher.

Table 4.20

Mean Content Test Scores by Racial Identity and by Gender for Each Teacher

	Males				Females		
	Pretest	Posttest	Difference		Pretest	Posttest	Difference
Ms. Nu – No Microscopes							
African American	8.31 (*n*=26)	13.76 (*n*=29)	5.45	African American	8.20 (*n*=40)	13.80 (*n*=41)	5.60
White	9.20 (*n*=5)	12.17 (*n*=6)	2.97	White	7.43 (*n*=8)	14.43 (*n*=7)	7.00

Table 4.2 (continued)

Ms. Alpha – Analog Microscopes							
African American	9.03 (*n*=33)	13.51 (*n*=33)	4.48	African American	8.83 (*n*=18)	15.67 (*n*=18)	6.84
White	12 (*n*=4)	16.5 (*n*=4)	4.50	White	8.80 (*n*=5)	13.6 (*n*=5)	4.80
Ms. Delta - Digital Microscopes							
African American	9.03 (*n*=36)	14.11 (*n*=39)	5.08	African American	8.36 (*n*=36)	14.41 (*n*=37)	6.05
White	9.78 (*n*=9)	14.1 (*n*=11)	4.32	White	11.2 (*n*=5)	16.33 (*n*=6)	5.13

A visual inspection of the data suggests that little differences are seen between the scores of the students in each teacher's class. However, statistical tests were run to provide more detailed analyses of the content test scores. The data were analyzed by SAS 9.1.3 for Windows using the means procedure. Table 4.3 supplies the results of this procedure. It provides the mean, standard deviation, minimum raw score, and maximum raw score for the pretest and posttest administrations of the content test for each of the three teachers. These data also show that very little difference exists between the mean scores of the students in each teacher's class.

Table 4.3

Means Procedure for Content Pretest and Posttest Scores by Teacher

Teacher	Variable	*n*	Mean	Standard Deviation	Minimum Raw Score	Maximum Raw Score
Ms. Nu – No Microscopes						
	Pretest	79	8.20	2.08	4.00	12.00
	Posttest	83	13.72	4.00	5.00	23.00
Ms. Alpha – Analog Microscopes						
	Pretest	60	9.15	3.17	1.00	17.00
	Posttest	60	14.37	4.65	5.00	22.00
Ms. Delta – Digital Microscopes						
	Pretest	86	8.95	2.98	4.00	18.00
	Posttest	93	14.39	4.38	4.00	23.00

The data collected by the administration of the content pretest and posttest were analyzed using SAS 9.1.3 for Windows. The analysis of covariance (ANCOVA) combines the use of regression and analysis of variance (ANOVA) to compare means while controlling for a quantitative variable, known as the covariate (Agresti & Finlay, 1997). The goal was to compare the means of the posttest scores of the content test for each of the three teachers (one who used digital microscopes, one who used analog microscopes, and one who used no microscopes) while controlling for the covariate, the pretest scores.

The first test to be examined in an ANCOVA is one that tests whether the slopes of the lines are the same. To test for homogeneity of slopes, a general linear model procedure was performed that used the pretest scores as the covariates, the posttest scores as the dependent variable, and the teacher (who used digital microscopes, analog microscopes, or no microscopes) as the class or level of treatment. In this model, the interaction of the independent variables (pretest scores and teacher treatment groups) was measured. No significant interaction was reported, as noted in Table 4.4. The lack of significance of interaction of the variables of teacher (who used either no microscopes, analog microscopes, or digital microscopes) and pretest scores justified the equal slopes assumption necessary for ANCOVA.

Table 4.4

Analysis of Covariance for Interaction of Variables Pretest and Teacher on Content Test

Source	*df*	Type III SS	Mean Square	*F*	*P*
Pretest X Teacher	2	27.13	13.56	0.91	0.40

The second procedure conducted involved testing whether each of the groups (none, analog, and digital) had the same line. A test for the main effect of teacher, controlling for pretest, was conducted. As Table 4.5 shows, the intercepts are not significantly different. Therefore, the same line can be used for all three teachers.

Table 4.5

Analysis of Covariance – Test for Main Effect of Teacher, Controlling for Pretest

Source	*df*	Type III SS	Mean Square	*F*	*P*
Teacher	2	6.792	3.396	0.23	0.7962

The next assessment involved testing for the effect of the pretest when controlling for the variable teacher (who used either no microscopes, analog microscopes, or digital microscopes). As noted in Table 4.6, the pretest contributed significantly to the model. Thus, the lines relating the posttest to the pretest were not horizontal.

Table 4.6

Analysis of Covariance – Test for Main Effect of Pretest, Controlling for Teacher

Source	*df*	Type III SS	Mean Square	*F*	*P*
Pretest	1	845.47	845.47	56.8*	<.0001

*p<.05

ANCOVA was used to evaluate the content test data. The variable pretest was controlled, and the variable teacher (Digital, Analog, None) was evaluated. The pretest scores contributed significantly to the model, but the treatment (use of no microscope, analog microscopes, or digital microscopes) did not make a significant contribution to the model. Table 4.7 presents the results of the variable teacher (who used either no microscopes, analog microscopes, or digital microscopes) when controlling for pretest scores.

Table 4.7

Analysis of Covariance – Test for Main Effect of Teacher, Controlling for Pretest

Source	*df*	Type III SS	Mean Square	*F*	*P*
Teacher	2	6.793	3.396	0.23	0.7962

The treatment of teacher (Digital, Analog, None) did not contribute significantly to the model. Therefore, additional tests to determine the differences between the three groups (Digital, Analog, None) were not needed. The hypothesis was not supported. There was not a significant difference ($p<.05$) among the population mean posttest scores on the content test for the three groups (Digital, Analog, None) after adjusting for the effects of the pretest scores. The Digital group was not significantly higher than the Analog group or the None group. The adjusted means of these three groups, as shown in Table 4.8, show that the means of the three treatment groups (Digital, Analog, None) were very similar when they were adjusted for the effects of the pretest scores.

Table 4.8

Least Squares Means for Effect Teacher

Teacher	Posttest LSMean	Standard Error
Ms. Nu	14.1928452	0.4489797
Ms. Alpha	14.1345309	0.5221819
Ms. Delta	14.5317761	0.4239999

The findings did not support Hypothesis One. There was not a significant difference ($p<.05$) among the population mean posttest scores on the content test for the three groups (Digital, Analog, None) after adjusting for the effects of the pretest scores. The Digital group was not significantly higher than the Analog group or the None group. The adjusted means of these three groups, as shown in Table 4.8, show that the means of the three treatment groups (Digital, Analog, None) were very similar when they were adjusted for the effects of the pretest scores.

Analysis of Hypothesis One

Hypothesis One: There will be a significant difference ($p<.05$) among the population mean posttest scores on the content test for the three groups (Digital, Analog, None) after adjusting for the effects of the pretest scores. The Digital group will be significantly higher than the Analog group and the None group.

There was no significant difference ($p<.05$) among the population mean posttest scores on the content test for the three groups (Digital, Analog, None) after adjusting for the effects of the pretest scores. The Digital group's mean posttest score was not significantly higher than the Analog group or the None group after adjusting for the effects of the pretest scores.

Analysis of Scientific Attitude Inventory II Data

Hypothesis 2: There will be a significant difference ($p<.05$) among the population mean posttest scores on the Scientific Attitude Inventory II for the three groups (Digital, Analog, None) after adjusting for the effects of the pretest scores. The Digital group will be significantly higher than the Analog group and the None group.

The Scientific Attitude Inventory II (SAI II) is composed of 40 items. Each item consists of a statement designed to reflect attitudes toward science. For each item, the students marked a letter on a five-point Likert-type scale. The directions printed on the inventory asked the student to mark a letter on an answer sheet that corresponded to his/her feelings using the following scale:

- Mark “a” if you strongly agree.
- Mark “b” if you mildly agree.
- Mark “c” if you are not sure or cannot decide.
- Mark “d” if you mildly disagree.
- Mark “e” if you strongly disagree.

Half of the items were stated in a positive manner, and half were worded as statements that reflected a negative attitude toward science. Moore and Foy (1997) provided a scoring guide indicating which statements should be calculated as a positive response and which should be calculated as a negative response (see Appendix M). Table 4.9 shows the point value assigned for each response for a positive statement and for a negative statement.

Table 4.9

Point Values for Each Response for Positive and Negative Statements

	Positive Statements	Negative Statements
A – strongly agree.	5	1
B – mildly agree.	4	2
C – not sure or cannot decide.	3	3
D – mildly disagree.	2	4
E – strongly disagree.	1	5

Moore and Foy (1997) also gave directions for scoring the items. This researcher created a template on Microsoft Excel to calculate the score for each student's set of responses. The first column of the spreadsheet indicates the question number. The next five columns are labeled A, B, C, D, E respectively. To the right of those columns is another set of five columns with the same labels. In the first set of columns, a "1" was placed under the letter that corresponded to the letter that the student marked for the item. For example, if the student marked "B" for the first item, then beside item number 1, a "1" would be placed under the first column labeled "B." Each cell in the second set of columns has a formula to calculate the points for the statement. If the statement is positive, then a value of "4" appears under the "B" in the second column. If the statement is negative, then a value of "2" appears under the "B" in the second column. (Rows that represented statements to be scored as "negative" were highlighted in yellow.) Another formula in the spreadsheet sums the values

in the second set of columns to provide the student's score for the inventory. The scores can range from 40 to 200 (see Appendix N).

The three teachers administered the SAI II as a pretest and posttest to each participating student in her classroom. Due to student absences, some students were not tested on one of the administrations. The teachers administered make-up tests to the students for two days after the initial administration. The researcher decided that after two days, an administration of the pretest would not be valid. The teachers started the unit of study on the fourth day, so she did not want the students to take the pretest once they had begun the unit of study. Due to scheduling problems at the school, the posttest of the SAI II was administered over a period of two school days. Make-up tests were administered over the next two school days. Thus, students who were not present on one of the days that the posttest was offered were not given the posttest. Table 4.10 displays the number of students, by teacher, who took the SAI II as a pretest and as a posttest. When the scores were analyzed by SAS 9.1.3, scores of students who did not take both the pretest and the posttest were ignored. While a total of 258 students took at least one test, there were 195 students who took both the pretest and the posttest. Thus, 195 students' scores were used in the analysis of covariance (ANCOVA). For the descriptive data provided later in this chapter, all pretest and posttest scores were used, as it was not necessary to have each pretest matched to the posttest when determining the mean score for each group of students.

Table 4.10

SAI II – n by Teacher and Test Administration

Teacher	Treatment	Students Who Took Pretest	Students Who Took Posttest	Students Who Took Both Pretest and Posttest
Ms. Nu	No microscopes	77	84	66
Ms. Alpha	Analog microscopes	60	54	50
Ms. Delta	Digital microscopes	90	88	79
Total *n*		227	226	195

Descriptive statistics were used to show the scores of students by teacher groups based on racial identity and gender. Table 4.11 presents the data disaggregated by racial identity and by gender for each teacher.

Table 4.11

Mean SAI II Scores by Racial Identity and by Gender for Each Teacher

	Males				Females		
	Pretest	Posttest	Difference		Pretest	Posttest	Difference
Ms. Nu – No Microscopes							
African American	132.36 (*n*=25)	132.78 (*n*=32)	0.42	African American	133.13 (*n*=40)	134.69 (*n*=42)	1.57
White	111.33 (*n*=3)	118.25 (*n*=4)	6.92	White	138.11 (*n*=9)	144.00 (*n*=6)	5.89
Ms. Alpha – Analog Microscopes							
African American	135.94 (*n*=33)	127.71 (*n*=28)	-8.23	African American	138.00 (*n*=18)	135.41 (*n*=17)	-2.59
White	135.75 (*n*=4)	135.5 (*n*=4)	-0.25	White	139.80 (*n*=5)	143.00 (*n*=5)	3.2
Ms. Delta - Digital Microscopes							
African American	134.38 (*n*=40)	136.14 (*n*=35)	1.77	African American	134.34 (*n*=35)	136.67 (*n*=36)	2.32
White	130.44 (*n*=9)	137.82 (*n*=11)	7.37	White	127.50 (*n*=6)	136.00 (*n*=6)	8.5

A visual inspection of the data shows that there are some differences in the scores. The most noticeable difference is between the scores of Ms. Alpha's students and the students of the other two teachers. Table 4.12 shows the difference between the mean of the SAI II pretest and the SAI II posttest to show the change in the mean from the pretest to the posttest administration. All groups of students in Ms. Delta's class and in Ms. Nu's class had a positive difference between the pretest mean and the posttest mean. In Ms. Alpha's class,

there was a negative difference between the pretest mean and the posttest mean for three of the four groups of students. Only one group of students in Ms. Alpha's class, the white females (n = 5) had a positive difference between the means of the two administrations.

Statistical tests were run to provide more detailed analyses of the SAI II scores. The data were analyzed by SAS 9.1.3 for Windows using the means procedure. Table 4.12 supplies the results of this procedure. It provides the mean, standard deviation, minimum score, and maximum score for the pretest and posttest administrations of the SAI II for each of the three teachers. These data also show that some difference exists between the mean scores of the students in each teacher's class. The most noticeable difference is that the pretest mean of the students in Ms. Alpha's class was higher than the pretest mean of the students in the other two teachers' classes. Conversely, the posttest mean of the students in Ms. Alpha's class was lower than the posttest mean of the students in the other two teachers' classes.

Table 4.12

Means Procedure for SAI II Pretest and Posttest Scores by Teacher

Teacher	Variable	*n*	Mean	Standard Deviation	Minimum Raw Score	Maximum Raw Score
Ms. Nu – No Microscopes						
	Pretest	77	132.61	12.83	97	169
	Posttest	84	133.85	13.78	97	161
Ms. Alpha – Analog Microscopes						
	Pretest	60	136.87	12.21	103	165
	Posttest	54	132.09	15.41	100	165
Ms. Delta – Digital Microscopes						
	Pretest	90	133.51	12.23	106	156
	Posttest	88	136.56	11.29	110	172

The data collected by the administration of the SAI II pretest and posttest were analyzed using SAS 9.1.3 for Windows. The analysis of covariance (ANCOVA) combines the use of regression and analysis of variance (ANOVA) to compare means while controlling for a quantitative variable, known as the covariate (Agresti & Finlay, 1997). In this study, the goal was to compare the means of the posttest scores for each of the three teachers (one who used digital microscopes, one who used analog microscopes, and one who used no microscopes) while controlling for the covariate, the pretest scores.

The first test to be examined in an ANCOVA is one that tests whether the slopes of the lines are the same. To test for homogeneity of slopes, a general linear model procedure was performed that used the pretest scores as the covariate, the posttest scores as the dependent variable, and the teacher (who used digital microscopes, analog microscopes, or no microscopes) as the class or level of treatment. In this model, the interaction of the independent variables (pretest scores and teacher treatment groups) was measured. No significant interaction ($p<.05$) was reported, as noted in Table 4.13. The lack of significance of interaction of the variables teacher (who used either no microscopes, analog microscopes, or digital microscopes) and pretest score justified the equal slopes assumption necessary for ANCOVA. The lines have the same slope, but different intercepts.

Table 4.13

Analysis of Covariance for Interaction of Variables Pretest and Teacher on SAI II

Source	*df*	Type III SS	Mean Square	*F*	*P*
Pretest X Teacher	2	520.8265	260.4132	2.70	0.070

Since the lines had the same slope but different intercepts, the second procedure conducted involved testing whether the intercepts were significantly different from each other. If the intercepts were not significantly different from each other, then the same line could be used for the three groups (none, analog, and digital). A test for the main effect of teacher, controlling for pretest, was conducted. As Table 4.14 shows, the intercepts are significantly different. Therefore, in the complete model without interaction, there is a significant difference between the intercepts for the variable of teacher (none, analog, or

Table 4.14

Analysis of Covariance – Test for Main Effect of Teacher, Controlling for Pretest

Source	*df*	Type III SS	Mean Square	*F*	*P*
Teacher	2	857.896	428.948	4.37*	0.0140

*p<.05

digital). Thus, separate lines may be needed for at least two of the levels of the variable. When controlling for the variable pretest, the variable of teacher (none, analog, or digital) contributed significantly to the model.

Since there was no significant interaction between the variables pretest and teacher, the next test to be conducted was to see if the variable pretest contributed significantly to the model when controlling for the variable teacher (who used either no microscopes, analog microscopes, or digital microscopes). As noted in Table 4.15, the variable pretest contributed significantly to the model. Thus, the lines relating the posttest to the pretest were not horizontal.

Table 4.15

Analysis of Covariance – Test for Main Effect of Pretest, Controlling for Teacher

Source	*df*	Type III SS	Mean Square	*F*	*P*
Pretest	1	15433.235	15433.235	157.06*	<.0001

*p<.05

The goal of the ANCOVA was to compare the means of the posttest scores of the SAI II for each of the three teachers (one who used digital microscopes, one who used analog

microscopes, and one who used no microscopes) while controlling for the covariate, the pretest scores. As shown above, the data met the assumptions needed the ANCOVA of homogeneity of slopes and significantly different intercepts for the regression lines. The data from the ANCOVA showed that overall the variable of teacher contributed significantly to the posttest score when controlling for the variable pretest. The adjusted means, or least squares means, for each teacher (none, analog, and digital) are reported in Table 4.16.

Table 4.16

Least Squares Means for Effect Teacher

Teacher	Posttest LSMean	Standard Error
Ms. Nu	135.368	1.22272
Ms. Alpha	131.714	1.40959
Ms. Delta	137.013	1.11560

The treatment of teacher (Digital, Analog, None) contributed significantly to the overall model when controlling for the variable of pretest. Therefore, an additional test to determine the differences between the groups (Digital, Analog, None) was needed. Thus, a post-hoc test, using Scheffe's method, was run to perform multiple comparison tests. The results were used to determine if any significant differences existed among the levels of the variable teacher. The results of this testing appear in Table 4.17.

Table 4.17

Results of Scheffe's Method

Alpha	0.05
Error Degrees of Freedom	191
Error Mean Square	98.26209
Critical Value of Studentized Range	3.04321

Comparisons significant at the 0.05 level are indicated by ***.

Teacher Comparison	Difference between Means	Simultaneous 95% Confidence Limits	
D - N	2.292	-1.786	6.370
D - A	3.111	-1.309	7.530
N - D	-2.292	-6.370	1.786
N - A	0.819	-3.766	5.404
A - D	-3.111	-7.530	1.309
A - N	-0.819	-5.404	3.766

When the Scheffe's multiple comparison test was run, no significant differences were found to exist among the levels of the variable teacher (none, analog, or digital.) Although the data from the ANCOVA showed that overall the variable of teacher contributed significantly to the posttest score when controlling for the variable pretest, when the more conservative Scheffe test was run to test for multiple comparisons, no significant differences were found among the levels of the variable teacher.

Analysis of Hypothesis Two

Hypothesis 2: There will be a significant difference ($p<.05$) among the population mean posttest scores on the Scientific Attitude Inventory II for the three groups (Digital, Analog, None) after adjusting for the effects of the pretest scores. The Digital group will be significantly higher than the Analog group and the None group.

There was a significant difference ($p<.05$) among the population mean posttest scores on the SAI II for the three groups (Digital, Analog, None) after adjusting for the effects of the pretest scores. However, the use of Scheffe's multiple comparisons test indicated that the Digital group's mean posttest score was not significantly higher than the Analog group or the None group after adjusting for the effects of the pretest scores. Thus, the findings did not support Hypothesis Two. The Digital group was not significantly higher than the Analog group or the None group.

QUALITATIVE COMPONENT – AN INSTRUMENTAL CASE STUDY

The qualitative component of this study consisted of a case study. Merriam (2001) states that "the single most defining characteristic of case study research lies in delimiting the object of study, the case. . . The case then, could be a person such as a student, a teacher, a principal, a principal; a program; a group such as a class, a school, a community; a specific policy, and so on" (p. 27). She also states that if "the phenomenon you are interested in studying is not intrinsically bounded, it is not a case" (p. 27). The case in this study was the set of three licensed middle grades science teachers who were teaching the unit on cells in this school system in spring 2005 and the students of those teachers. The qualitative component can be described more specifically as an instrumental case study, as defined by Stake (1995). He stated that the purpose of this type of case study is to help the reader understand an idea, rather than focusing only on learning about the particular case. In this study, the case provided data regarding the teaching of cells – with technology in the form of digital microscopes, with analog microscopes, and with the absence of microscopes – in a rural middle school. Participant observation, interviews, and video-taped class sessions provided data.

The purpose of the qualitative part of this study was to provide insights into how the students and teachers viewed the study of cell theory without the use of microscopes, as well as with the addition of the analog and digital microscopes into the unit on cell theory. I proposed that when students used digital microscopes to observe cells and to capture images of them, they may become more engaged in their learning than when technology is not present. Thus, I observed students to see how they responded to the addition of microscopes in the classroom. I was particularly interested in observing the students' engagement in

learning in each of the three situations. Student interviews provided insights into the students' attitudes toward the unit on cell theory in each of the three classroom environments. Interviews with the teachers provided additional data regarding how the teachers view the addition of analog and digital microscopes into the middle school unit on cell theory. Observations and interviews of the teacher who used two types of digital microscopes provided useful data on the effectiveness of these two tools.

Background Information

Detailed information was provided in chapter 4 regarding the selection of the sample and the demographics of the selected school system and the school. Details were also given regarding the materials that were used during the unit of study. There were three teachers in the school system who were licensed in middle grades science and who would be teaching the unit on cells during the spring of the 2004-2005 school year. All three teachers were located at one of the two middle schools that are located in the selected rural school system. The selected school has been identified in this report by the pseudonym of J. H. Strum Middle School. Each of the three teachers in agreed to participate in this study. A pseudonym was assigned to each teacher – Ms. Nu, Ms. Alpha, and Ms. Delta.

J. H. Strum Middle School is located in a rural North Carolina county school system. This school is the larger of two middle schools in this system. Each school houses students in grades six through eight. There are approximately 583 students who attend Strum Middle School. There is one principal, one assistant principal, one media center coordinator, and 34 teachers who work at this school. There were two science teachers in each grade level during the 2004-2005 school year. Of these six teachers, three hold North Carolina teaching licenses in middle grades science. In the spring semester of the 2004-2005 school year, two of the

remaining science teachers were lateral entry teachers, who are working on earning full licensure in middle grades science, and one was a full time substitute teacher.

The school system had purchased the Diversity of Life kit that was part of the Full Option Science System from Lawrence Hall of Science, University of California at Berkeley [UC Berkeley], (2003a) for the teachers to use when teaching this middle school unit on cell theory. As was decided before the study was planned, the middle school teachers would use the Diversity of Life kit this year to teach the unit on cells during the 2004-2005 school year. In addition, for this study, the three teachers were each assigned a different treatment. (A detailed explanation of how each teacher was assigned the specific treatment was provided in chapter 3.)

All three teachers used the materials in the Diversity of Life kit, which included handheld magnifiers, a book with pictures and text related to the topic, and still pictures, video clips, and other information provided on a CD-ROM. Each of the three teachers was provided access to a computer and video projector to share the information on the CD-ROM with the students. Ms. Nu was the seventh grade teacher who agreed to teach the unit on cell theory with no microscopes. Ms. Alpha, an eighth grade teacher, used six analog microscopes, and Ms. Delta, an eighth grade teacher, used six digital microscopes. As explained in chapter 3, two types of digital microscopes used in Ms. Delta's class. There were three Digital Blue™ QX5™ (Prime Entertainment, 2005) computer microscopes and three ProScope™ (Bodelin Technologies, 2004) computer microscopes. (Details regarding each microscope are provided in chapter 3.) The Digital Blue™ QX5™ microscope can be purchased for about $80.00, and the ProScope™ costs about $745.00. Ms. Delta and her students provided data regarding the use of both types of microscopes.

The Setting

Table 5.1, originally provided in chapter 3, provides an overview of the three teachers who participated in this study.

Table 5.1

Teacher Information

	Grade Level	Teaching Licensure	Years of Teaching Experience	Treatment Option
Ms. Nu	7th	Middle School English language arts Science Social Studies	15	No Microscopes
Ms. Alpha	8th	Middle School Science	5	Analog Microscopes
Ms. Delta	8th	Middle School Science Math	20	Digital Microscopes

Research Questions

As noted in chapter 2, a conference sponsored by the National Science Foundation (NSF) and conducted by the Appalachian Rural Systemic Initiative established a research agenda for examining factors that have an impact on learning and achievement in science and mathematics among students in rural schools. Seven categories of needed research were identified. One of those categories was instructional resources. Two researchable questions that they proposed should be addressed are the following:

> What is the accessibility, availability, use, and effectiveness of advanced digital technology to teach mathematics and science in rural schools?

> How can the teaching and learning of science and mathematics in rural schools be improved with the effective integration of technology? (Harmon et al., 2003, p. 54)

These two questions have relevance for the qualitative component of this study. Part of the first question was explored as a means of providing background. I interviewed the three teachers to determine the accessibility, availability, and use of digital technology to teach science at J. H. Strum Middle School prior to this study on teaching cell theory. The answers they provided to this question are given first. The use of advanced digital technology to teach science in this selected rural school, particularly the integration of technology in the form of digital microscopes, was the major emphasis of this part of the study. Thus, the following six research questions guided the qualitative part of this study.

- How might the selected middle grade students be engaged/disengaged in the study of cells when digital microscopes are available for their use compared with the availability of traditional microscopes or the lack of availability of any microscopes?
- How might the selected middle grade students in this rural school perceive the use of images (in text and on a CD-ROM), or the use of analog microscopes, or the use of digital computer microscopes (with corresponding multimedia applications) in their study of cells?
- When the selected middle grade students in this rural school are taught about cell theory, how do students perceive science instruction in classrooms that include the use of digital microscopes (and corresponding multimedia applications) and in classrooms that do not?
- How do selected middle grade students who have access to the use of digital computer microscopes, during the unit on cell theory, make use of the multimedia options that are available with these microscopes?
- How do selected middle grade students who have access to the use of digital computer microscopes, during the unit on cell theory, use digital microscopes as mindtools in their learning about cells?
- What comparison information can we learn from the selected middle grade students who have access to the use of digital computer microscopes, during the unit on cell theory, regarding the use of two types of digital microscopes, the Digital Blue™ QX5™ microscope and the ProScope™ digital microscope, in their study of cell theory?

Examination of the Background Question

What were the accessibility, availability, and use of digital technology to teach science at J. H. Strum Middle School prior to this study on teaching cell theory?

The three teachers stated that digital technologies for teaching science at J. H. Strum Middle School prior to this study on teaching cell theory were very limited. Ms. Nu replied that in her classroom she had one computer that worked part of the time and one overhead projector, but not a projector that connects to a computer. "That was the extent of the technology," she said. She is grateful that the computer is connected to the Internet, but she wishes that the computer were more reliable and that she had more computers for her students to use. Ms. Alpha said, "Our resources are very limited. Most classrooms have one computer, but with 26 students, that makes it very hard to meet our needs. And there are often problems with the one computer. There is always a virus or the computer is stalling out. Tech support has worked on my computer several times, but it's still not working well. There were absolutely no digital microscopes. I believe that the school does have one digital camera, but I have not used it. There is not much access to technology."

Ms. Delta agreed with the other two teachers that the technology available to the teachers is very limited. She noted that she has one computer and that it is connected to the Internet. Like the other two teachers, she reported that the computer located in her classroom does not work well. She is participating in a grant and has a laptop on loan to her. That computer works well, but she will have to return it to the grant organization once her participation in the grant ends. She has one more year to be involved in that program. Then, she will return the computer to allow someone else to have an opportunity to participate in the grant and to use the computer.

Ms. Delta also agreed that the availability of the instructional technology is very limited at this school. She said that before this research project began, the school had one projector that could be connected to a computer and used to display the computer output on a screen for the class to view. She noted that having only one projector for the entire school to share was a major problem. She said that most teachers did not use the projector because of scheduling difficulties. She added, "We had to plan so far in advance to know exactly which day we would use the projector. It should be an integral part of what we are doing. For lessons to work as they should, we should have better access. In science, we could show short video segments, present pictures and video clips from the Internet, and present other materials to our students if we had ready access to a projector. We need to use a variety of teaching methods each period, so we might need the projector for part of the class time." She mentioned that she needs to have it available for parts of the period for a few days each week. If she can only access it on one day, and she has to try to cram all of the computer use into that one period, she thinks that the students do not receive the same benefit as when she can use the projector for short periods of time on a regular basis. While she thinks that the ideal would be to have a projector for her room, she knows that option is not feasible. However, she would really like to see the school have one projector for each grade level of teachers to share. She thinks that would be a move in the right direction toward increasing the availability of accessibility of digital technology that would help her to use the methods she would like to use with her students.

Ms. Delta and the other two teachers were very pleased that a couple of weeks before this study began, the school acquired one station that they called an "Educart." This system consisted of a new computer that was connected to a projector and a printer. Ms. Delta and

Ms. Alpha have used this Educart and are pleased with it. All three teachers are hoping that the school will have at least three of these systems next year so that each grade level could share one. They agree that the addition of two more Educarts would help to increase the availability of technology for their classroom use. When I spoke with the principal, she mentioned that these teachers had presented this request to her and that she has made that a goal for next year. She is hoping to have two more of these carts available to the teachers next year. The three teachers agree that meeting this goal would be one step toward increasing the availability of digital technology to their classrooms. At the completion of this study, all three teachers agreed that they would like to have a set of seven laptop computers, seven digital microscopes, and one computer projector that could be shared by the science teachers. They thought that the six science teachers in the school could share these materials. Detailed discussions regarding their thoughts about the use of digital microscopes are provided as each of the research questions are explored in the following sections of this chapter. Their thoughts regarding the use of these microscopes will be provided there. However, at this point, I am simply noting that they would like to see this particular increase in the accessibility and availability of digital technologies in their school.

Finally, Ms. Delta noted that the school has two computer labs, but they are only available for the science teachers to use with their students during one period of the day. One lab is used for providing computer based practice in language arts and mathematics with the goal of helping students to increase their performance on the end of grade tests administered each year in these subject areas. The other lab is used for preparing students to take the North Carolina Test of Computer Skills that is administered to eighth grade students. (If students do not pass this test in the eighth grade, they may take it in subsequent grade levels. However,

passing this assessment is a requirement for high school graduation.) The students use this lab to learn skills such as word processing, spreadsheet use, and database management to help them meet the technology objectives in the North Carolina Standard Course of Study and to help them prepare for the North Carolina Test of Computer Skills. Ms. Delta explained that having access for only one group of her four classes of students made using a lab almost impossible for her. She also thought that physically moving to the lab during the class period was disruptive to teaching. As mentioned in the preceding paragraph, she would prefer to have a set of computers that she could share with the other science teachers and that could be moved to each of their classrooms rather than trying to share a computer lab with other teachers.

All three teachers stated that they used the computer. However, due to the lack of availability, accessibility, and reliability, they seldom used the computer with their students. They tended to use the computer to research information that they used in developing their lesson plans. They also were more likely to present the information, gathered by use of the computer and the Internet, with their students in a paper format, rather than in a digital format. No digital microscopes were available. One digital still-shot camera was available at the school, but the teachers did not think that it was accessible for their classroom use. They thought that only the media center specialist was allowed to use that camera. Also, there was one video camera that belonged to the school, but none of the three teachers felt comfortable asking to use the camera, and none of them knew how to incorporate its use into the classroom. No tripod was available to use with the camera. The teachers were not aware of any other digital technologies that were available for their use in teaching science.

An Examination of the Six Research Questions

The qualitative component of this study was centered on six research questions.

1. How might the selected middle grade students be engaged/disengaged in the study of cells when digital microscopes are available for their use compared with the availability of traditional microscopes or the lack of availability of any microscopes?
2. How might the selected middle grade students in this rural school perceive the use of images (in text and on a CD-ROM), or the use of analog microscopes, or the use of digital computer microscopes (with corresponding multimedia applications) in their study of cells?
3. When the selected middle grade students in this rural school are taught about cell theory, how do students perceive science instruction in classrooms that include the use of digital microscopes (and corresponding multimedia applications) and in classrooms that do not?
4. How do selected middle grade students who have access to the use of digital computer microscopes, during the unit on cell theory, make use of the multimedia options that are available with these microscopes?
5. How do selected middle grade students who have access to the use of digital computer microscopes, during the unit on cell theory, use digital microscopes as mindtools in their learning about cells?
6. What comparison information can we learn from the selected middle grade students who have access to the use of digital computer microscopes, during the unit on cell theory, regarding the use of two types of digital microscopes, the Digital Blue™ QX5™ microscope and the ProScope™ digital microscope, in their study of cell theory?

Examining the Data Related to These Questions

The data related to the first three questions are interrelated. The classroom observations, the student interviews, the video tape analyses, and the teacher interviews provide insights into the areas addressed in the first three research questions – the engagement of the students during the study of cells, the students' perceptions of the use of images (from a book, a CD-ROM, analog microscopes, and digital microscopes) in the study of cells, and the students' perceptions of the science instruction. I decided that presenting a set of related information, rather than fragmenting it into the three separate topics, provides a more holistic view of the three classrooms. Thus, I am presenting data from these sources

related to these three topics. The data from the observations, video tape analyses, and the student interviews provide the reader with information to form a mental construct related to the scenario that was occurring in each of the three classrooms. After presenting this set of information, I addressed each question specifically and referenced some of the detailed descriptions and quotations that are provided in this section. I also added information from the teacher interviews to help answer these three research questions.

Introduction of the Unit and the Magnification Devices

A weekly outline of the topics that each teacher taught is located in Table 3.9 in chapter 3, and a daily outline (which the teachers modified to suit their needs) is in Appendix D. These outlines provide an overview of the lesson topics that each teacher was using. The first lesson that the teachers taught was a lesson on lab safety. They reminded the students of lab safety procedures, gave the students a written learning activity designed to remind them of the rules of the classroom that need to be observed during science investigations, and had the students to sign a science safety contract. All three teachers began the unit of study with activities that focused on the definition of living. The Diversity of Life (Lawrence Hall of Science, UC Berkeley, 2003b) kit provided cards containing pictures of items which students sorted as living or non-living. The teachers led discussions with the students as they tried to decide which category was appropriate for some of the items, such as a carton of eggs and an ear of corn. This activity lasted for about three days as the students discussed what it means to living or non-living. The teachers eventually led them to develop a list of characteristics of living things and non-living things. They also created a category of "was living" as opposed to "never lived," and they decided that some living things could be "dormant" for a period of time.

The next set of activities focused around a set of six vials that the teachers prepared for each group of students. Each vial contained a small amount (measured with the "mini-spoon" provided in the kit) of one of the following items: red sand, yeast, polyacrylate crystals, radish seeds, and brine shrimp. The students were not told what substances were in the vials. The teachers referred to the materials as "mystery substances," and each was identified by its vial label, such as Vial A or Vial B. On the first day of the investigation, the students observed the materials in the vials. They drew sketches of what they saw and wrote notes about their observations. The students tried to determine if each item was living or non-living. On the second day, they observed the materials in the vials for changes and recorded any changes that they noticed. Then, they added water to the vials. The teacher provided one third of the groups with plain bottled spring water to add to their vials. One third of the students added bottled spring water with sugar dissolved in it, and the other third added bottled spring water with salt dissolved in it. (Each group filled each vial about two-thirds full with the water or water solution.) The students in each group observed the vials and recorded the changes they noticed. For the next couple of days, the students continued to observe the materials in the vials and to make recordings about their observations. They also traded vial sets with other groups who used differing water solutions so that they could observe the vials in all three conditions.

As the students observed the vials, they used the hand magnifying lenses that were provided in the Diversity of Life kit. The students spent two days observing with hand lenses, recording observations, and participating in small group and class discussions regarding which items they thought were living and what evidence made them think that the item was living. On the second day, the brine shrimp were starting to hatch. The students could

observe their movement. With the handheld magnifiers, the students could see that something was emerging from some of the "balls" in the vial. They said that it appeared that the items were swimming. The students were also interested in the fact that the polyacrylate crystals became larger after the water was added. Some students thought that they were growing. Students also noticed the yeast moving in the water. The students in each of the three teacher's classes watched the vials, took notes, and participated in discussions.

On the third day of vial observations, Ms. Nu had her students use the handheld magnifiers and the flashlights that were provided in the Diversity of Life kit. The students still did not know what the materials were in each of the vials. They referred to the items by their vial labels, such as "Vial A." Students observed that changes were occurring in the vials. (I am referring to the items here by their names, but the students used the vial labels to describe what they were observing.) Two groups commented on how the sand and the shrimp looked alike, but acted differently. The sand stayed at the bottom of the container, while the shrimp moved. One group of male students observing the brine shrimp with the handheld magnifier had the following conversation. "Let me see," one of the students said. A second student replied, "You've already seen." The first student answered, "Well, I didn't see them good. I need to see again." A female student in another group asked, "Are these real?" Then, one group noticed that the brine shrimp responded to the light when they placed the flashlight to the side of the vial, the brine shrimp swam away from the light source. They pointed out this fact to a neighboring group, and then the information was quickly shared with all the groups. Each group of students began noticing that their brine shrimp were moving from the light. I noticed that the students were smiling, were looking at the vials, and were discussing the observations with their group members.

All groups noticed that the polyacrylate crystals had formed larger crystals, although they struggled to find the vocabulary to express that thought in words. Some students thought that the crystals were living and had grown. Others thought that the crystals looked like ice and that it might not be alive. Three groups in Ms. Nu's classroom thought that the yeast solution was salt water. One student noted that yesterday, it was brown and dirty looking. Today, it was white and foamy and cloudy. All of the students in the classroom were engaged in observing the vials and in drawing their observations in their notebooks. I did not notice any students who were not participating in the activity. At the end of the class period, Ms. Nu collected the handheld magnifiers. One of the male students attempted to keep the one he was holding. She noticed and confiscated it from him.

On this same day, Ms. Alpha introduced her students to the analog microscopes. She asked how many students had used a microscope in the past. Only one student indicated that he had used one. She showed them the parts of the microscope and how to handle the microscope and the slides. She then used materials from some of the vials to create slides of each substance that the students were observing in the vials. Students were sent to the microscope in the same groups that had been formed for working with the vials of materials. Ms. Alpha allowed the students to observe the materials under the microscopes. The students noticed that the opaque materials were very difficult to see with the microscope. They could only see an outline of a radish seed. One student commented that the dry yeast "looks like brown rocks." One group was using the microscope to examine the red sand. They could not see any detail, so they decided to turn off the microscope's light. One female student said, "Without the light, I can see color and texture. With the light, it looks black. How come the

light made it turn black?" They realized that they could view the opaque items with more detail using the handheld magnifier and flashlight than they could with the microscope.

The polyacrylate crystals were translucent, so the students could view them under the analog microscopes with more detail than they could see the opaque objects. As they were viewing the crystals, one group of students had the following conversation. A male student said, "Let me look first. You always get to look at it first." Another male said, "Man, you can see the crystals under there. I saw them!" The first student said, "Let me see. It looks like salt." The first student replied, "Man, I said that first." A female student pleaded, "Let me see." Then, she exclaimed, "Whoa. This looks different under the microscope than it did in the vial!"

The students viewed the brine shrimp both with the handheld magnifiers and the analog microscopes. One group of students, when using the handheld magnifiers, commented that the brine shrimp looked like swimming bugs. The students also noted that the brine shrimp swam away from the light source. The students observed the brine shrimp under the microscope, but they could only see an outline of the animal. They were not able to view any details of the shrimp's body.

Ms. Delta introduced her students to the digital microscopes. She showed them how to use the ProScope™ and the Digital Blue™ microscopes. When she sent them to the microscopes in groups, she circulated among the groups to help them learn the specifics related to using that particular microscope. One difference in the digital microscope and the analog microscope is that the digital microscope has available the ability to record the specimen using lighting from above or below the slide. Both models of digital microscopes can be used as handheld magnifiers and can be used to observe opaque objects, as well as

more translucent specimens. The first slides that she had the students to view contained samples of brine shrimp in a salt water solution. The students placed the slides under the microscopes. Following the teacher's instructions, they viewed the shrimp on low power. As they focused the view on the screen, the students began commenting on what they were viewing and were reacting to what they saw. Two females started dancing and giving each other "high fives" as they watched some brine shrimp swimming on the screen. One male student said, "Oh, they're moving! Oh junk! Hey, they're swimming! Look!" Another male student in his group smiled as he said, "That's neat!" Another student said, "Oh man, I just saw one hatch. That is so neat. Just like watching a dog have babies. Look, that one just attacked another one. Can you believe it?" A male student who I had noticed usually tended to be quiet when working in his group said with a smile, "That's nice." The female student beside him said, "Yeah, that's nice."

Ms. Delta reminded a group of students that they could use the microscope to take a picture of what they were viewing on the screen. She then demonstrated the process to the group. One of the students said, "We can take pictures? Oh wow, we can even make a video of this. Look at that! Look at that!" Students continued to view the slides and take pictures. The following comments were made to other students in their groups as they worked.

> "Look - we have eggs. We have some hatching, we have live ones, and we have dead ones."
> "Who would ever have thought that all those shrimp could be inside that drop of water?"
> "What is that red spot? It looks like his eye, but it's dark on all the others. I wonder why this one is red."
> "Are those shrimp making love?"
> "There they go! There they go! Ooh ooh ooh! They're swimming so fast!"
> "When we first looked at those eggs, I thought they were dead. Then, we put the water in there and they started moving around, so I knew they had to be alive. She didn't think so. Now, we can see them alive and swimming around. I told you they were alive! I was right!"

> "I can't believe anything can be this small. I thought ants were the smallest thing there was. These are smaller than ants!"
> "I have one hatching. That's why I'm taking a movie."
> "Who eats this shrimp?"
> A female student was sick and did not feel like participating in the group work. One of her male teammates said, "That's too bad. We get to play with the scopes and she don't feel like it."

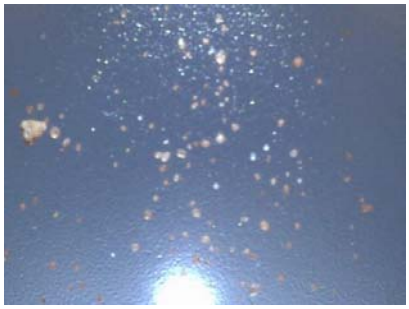
As class ended, the teacher gave instructions for the students to clean up their work stations. The students ignored her directions. I heard one student ask, "Do we have to go?" Another student said, "Oh no, Ms. Delta, it's time to go, and I don't want to leave." That comment was followed by another student who asked, "Do we have to change classes, Ms. Delta? Why can't we just stay in here?" It is interesting to note that the students were scheduled to leave science class for their elective classes. The students' mathematics teacher stopped by Ms. Delta's room later in the day. She commented to me that when the students came to her class that afternoon, they told her how much they had enjoyed the science class and how they had not wanted class to end. One of the students told her, "You have to go by Ms. Delta's room and see those shrimp. You won't believe your eyes." She then noted that students were shaking their heads in agreement. She said, "I had to come down here and see what in the world had gotten those students so excited about science."

On the fourth day, the teachers told the students what the items were in each vial. The students in each of the classrooms noticed that the brine shrimp that were in the salt water were continuing to swim. The ones in the plain water and in the sugar water were sinking to the bottom of the vial. When they opened some of these vials, they discovered that the material smelled badly, which they decided might be the smell of dead brine shrimp. Each teacher had prepared a salt water solution of brine shrimp in a half gallon container to supply additional brine shrimp for the students to observe. These specimens were used by the

students to observe the brine shrimp using the magnifying devices. The students also noted that the yeast in the sugar water smelled stronger than the samples in the salt water and plain water. The sugar water sample also looked more cloudy and more foamy. However, none of the teachers held a discussion with the students regarding which solutions might provide a better environment for some living specimens and why some environments might be better for one species and less appropriate for another.

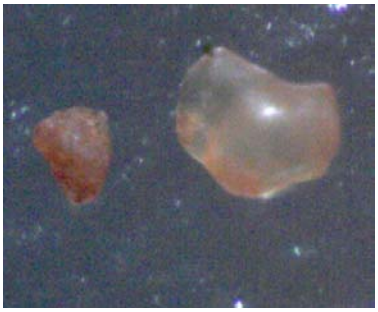
Ms. Delta's students continued to work with the digital microscopes. They viewed wet and dry samples of the items that they had been observing in the vials. One student noted that the dry yeast looked like a marshmallow. The students were surprised at how each item looked when magnified by a digital microscope. I was surprised at how much better the translucent and opaque objects could be seen with the digital microscopes when compared to the analog microscopes. Some of the pictures that the students took with the digital microscopes of the samples from the five vials are presented in Figure 1 below. (Most of the pictures in this chapter that were taken by the students are from the Digital Blue™ QX5 digital microscopes. In the classroom, the ProScope™ digital microscopes were connected to Apple™ Computers. When I tried to transfer the picture files to my computer running Microsoft® Windows® XP, some of the files became corrupted. However, some pictures from this type of digital microscope were salvaged and are presented later for consideration in comparing the two types of digital microscopes.)

Pictures taken with the Digital Blue™ QX5™ microscope:



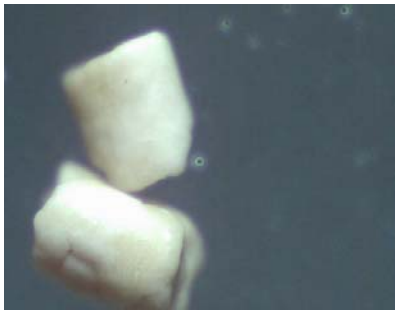
Red sand at 10X

Red sand at 60X



Red sand at 200X

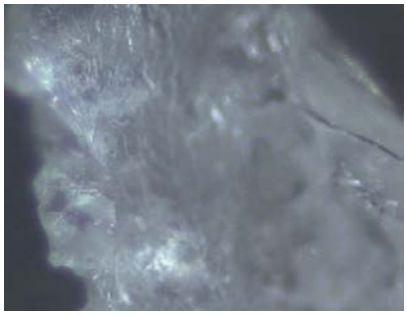
Yeast at 10X



Yeast at 60X

Yeast at 200X

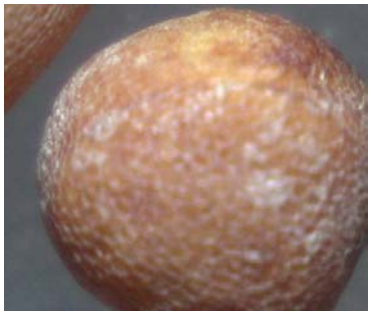
Polyacrylate crystals at 10X



Polyacrylate crystals at 60X

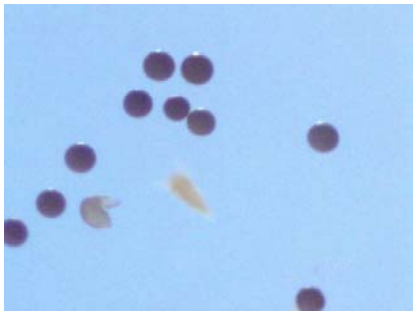
Polyacrylate crystals at 200X

Radish seed at 10X

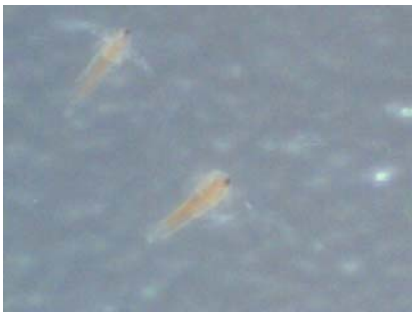


Radish seed at 60X

Radish seed at 200X



Brine shrimp and eggs at 10X



Brine shrimp at 60X

Brine shrimp at 200X

Figure 1: Pictures of substances in the five mystery vials

After students completed the investigations using the vials, each of the three teachers held discussions with the students regarding what they had seen and done. Ms. Delta's students had saved pictures of the samples they had viewed with the microscopes. However, Ms. Delta did not take advantage of the opportunity at this time to show those pictures to her students and to use them as they discussed what they had learned from the activities. They talked about what they had seen. They had discussions about what each vial contained and whether or not each substance was living. They also talked about how they knew if each item was living or non-living. However, they did not refer to any of the pictures or videos that they captured while conducting the investigations. When I interviewed Ms. Delta, she noted that she had missed opportunities to use the pictures as teaching tools with her students. She stated that she was so focused on having them do the work in a hands-on fashion that she

neglected having them to use those pictures to help them process what they had done and what they had seen. She noted that this omission would be the major way that she plans to change her teaching of this unit next year. She used the pictures at the end of the unit. Next year, she said that she would use the pictures to lead a class discussion about every three days. Ms. Delta had saved the pictures on a CD-ROM, so she had the pictures available for her students to see as a large group or in small groups at the computer, but she did not take advantage of that resource with her students until the last couple of days of the unit. She did print some of the pictures and place them on a bulletin board in the hall. However, she did not take her students into the hall to discuss any of the printed pictures with them. Thus, perhaps Ms. Delta's students missed an opportunity for engagement in the learning. There was much evidence that the students were mentally, emotionally, and physically engaged when the digital microscopes were in use. However, an opportunity to use the pictures as way to help the students process the abstract concepts related to the idea of "what is life" was missed until the end of the unit. Therefore, the students did not have the opportunity to become as fully engaged mentally as they might have if the teacher had used the pictures during the unit of study to help them build a bridge to connect what they did and what they saw to the abstract idea of what it means to be living or nonliving.

Ms. Nu's students examined the materials in the vials with the handheld magnifying lenses supplied with the Diversity of Life kit. The students were writing their observations and making sketches in their notebooks. The students could see that something was moving in the vials that held the brine shrimp.

Ms. Nu asked to borrow the disk of pictures that Ms. Delta's students took with the digital microscopes. She used the computer and the projector to display the pictures and

videos on a screen for her students to see. Her students never worked directly with any microscopes, but they viewed the pictures taken from the microscopes. They also viewed similar pictures of brine shrimp that were provided on the Diversity of Life CD-ROM. All of her students were watching the screen as the pictures were displayed. There were expressions of "ooh" and "wow" as they students viewed the pictures. One student exclaimed, "I didn't know that yeast looked like a marshmallow." (I thought it was interesting that a student in Ms. Delta's class and a student in Ms. Nu's class expressed the idea that when magnified, yeast looks like a marshmallow.) Students were also saying, "Look at those brine shrimp." "That one is hatching!" "I see them swimming."

Ms. Alpha had a closing discussion on the vials with her students. Like Ms. Delta, she chose not to use the images from the CD-ROM (or other images taken in Ms. Delta's classroom) with her students. She relied on the students' memories of what they had viewed. She focused her discussion on what was living, what was nonliving, and how they had reached the conclusion for each substance's classification.

Plant and Animal Cells

The FOSS Diversity of Life Course kit (UC Berkeley, 2003a) purposely has students to explore the concept of life at the multicellular level before introducing them to the concept of life at the cellular level. This sequence allows them to learn about the concept of life before introducing the cell as the basic unit of life. In addition, this sequence provides an opportunity for students to become familiar with the magnification devices while working with specimens that could be viewed without magnification before working with specimens that require microscopic magnification for viewing. It also permits the students to work with more concrete ideas before transferring those concepts to an abstract level. After the

investigations with the vials, the teachers had the students to investigate plant and animal cells. The plant cells were from the elodea plants that were furnished with the Diversity of Life kit and from potatoes and celery stalks purchased from a local grocery store. The animal cells were obtained from cheek scrapings that the students performed, following the directions in the Diversity of Life kit materials.

Ms. Alpha and Ms. Delta prepared thin slices of potato and placed the slices in vials of water for the students to use with the microscopes. They used the kit materials to prepare a tray of supplies for each microscope station. The two teachers worked together to create the following list of procedures for their students.

1. Get a clean slide for your group.
2. Place 1 drop of methylene blue on the slide.
3. Add 1 slice of potato.
4. Add 3 drops of distilled water.
5. Start with lowest magnification.
6. Get the clearest picture that you can find.
7. Make a drawing of what you see. (Ms. Delta's students will also take a picture.)
8. Write down written observations of what you see - color, shape, size, texture.

Ms. Delta's students were smiling as they began preparing their slides and viewing them with the digital microscopes. The students seemed excited as they began viewing pictures. Then, some became frustrated because they were having difficulty adjusting the focus on the microscopes. Ms. Delta reassured them that scientists often deal with frustration before they experience success. She told the class, "The same frustration that you were experiencing at not being able to get the pictures focused and not knowing what you are seeing - This is the same thing that scientists experience as they experiment. They often do not know what they are seeing. They keep looking and trying to find better ways of seeing and trying to understand what they are seeing." The students stopped complaining and went back to working seriously with their microscopes. As they began to figure out how to get

focused pictures, they began to express surprise and amazement at what they were viewing. Some of the comments that they made are listed here.

> A male student looked at Ms. Delta as she approached his group and said, "Oh! That looks fake. Are you sure ya'll didn't paint that?"
> Another male student exclaimed, "Look at that! Come look!"
> A female student was looking at the potato cells under 200X magnification . Ms. Delta asked, "What do you think?" The student smiled and replied, "I don't know. I didn't think a potato would look like this." A male in her group added, "I can't explain it."

Some of the students commented that the potato slice looked like ice crystals. Another group of students said that it looked fish scales.

Students were working together in groups to view the slide and to focus the image. I noticed that in most groups, one student would be moving the slide to find the best location to view. Another would be holding the computer mouse, and another would be adjusting the focus on the microscope. The students were watching the screen as a group and were touching the screen as they discussed the image they were viewing. Students were also taking pictures and drawing pictures. They would glance at the computer screen, draw a little, and glance back at the screen.

There were twenty-two students in this class. At the beginning of the class period, Ms. Delta told her students, "If you get out of your group, you will return to your desk and not be allowed to work with your group at a microscope." The fact that the teacher was using the loss of privilege of participating in the science class as the consequence for misbehavior was an indication of the level of engagement that the students were exhibiting. This new policy was an indication that the teacher had perceived the students' desire to participate in the class. The students were working in groups of three or four students at each digital microscope. During the class period, I only saw two students who were not engaged in the

activity at some point during the lesson. Ms. Delta noticed that one of those students was not involved in the assigned learning activity. She reminded him, “DeSean, you will not be allowed to participate in this activity if you choose to talk about other topics besides the work at hand.” DeSean returned to the assigned activity. I did not see him engaging in off-task behaviors at any other time that period.

Both Ms. Delta and Ms. Alpha used participating in the class as an incentive for good behavior on the days that the students were using the microscopes. If a student were misbehaving as he/she worked in a small group using the digital or the analog microscope, the teacher spoke to the student. She would tell him/her that if he/she continued the disruptive behavior, then he/she would not be allowed to participate in the learning activity. The incentive to participate in the classroom learning activities was sufficient to stop the problem. Ms. Delta was particularly fascinated one day when one of her male students was off-task and was distracting another student. She reminded him of the need to change his behavior. For a few minutes, he discontinued the behavior and returned to drawing and labeling what he was viewing with the digital microscope. Then, he began talking loudly to another student about a topic that was not related to the instruction. Ms. Delta told him to return to his desk (away from the laboratory table where his group was working.) She noticed that in about one minute, he quietly slipped back to where his group was working and continued his work on the lesson. Ms. Delta decided not to say anything to him about returning to his group as long as he was following the directions that she had provided to the class for the lesson. He did not exhibit any more off-task behaviors, and he did not talk loudly or distract his group members after he returned to his group. Ms. Delta was very pleased that he had chosen to participate in the learning activity and that the possibility of

being removed from the academic setting was a deterrent to his misbehavior. In contrast, I did not observe any instances where Ms. Nu used the threat of removing a student from the learning situation in order to stop a student's off-task behavior or other form of classroom misbehavior.

Ms. Alpha's students followed the procedures that she and Ms. Delta had outlined for viewing potato cells. Similar to Ms. Delta's students, Ms. Alpha's students had trouble adjusting the focus on the microscope at the first of the class period. At one station, one student was looking through the microscope, and the others in her group were watching her. She said, "It looks like little dots." After three minutes, three students had tried to get the microscope focused. I looked through the microscope and saw that they had not managed to get an acceptable level of focus. The teacher came to their group and focused it for them. One student said, "Hey! Look at this!" Another in her group said, "Let me see." A third student took his turn to view the focused image and exclaimed, "Oh! I got it. Yeah, I got it." A fourth student said, "I want a turn." Ms. Alpha approached another group of students. In this group, two of the female students were laughing and talking, but not about potato cells. Ms. Alpha asked one of the students in the group, "What do you think of this slide?" He replied, "It's pretty." She asked him, "Did you know that a potato looked like that?" He answered, "No." He did not provide any elaboration. Ms. Alpha asked a student in another group what she thought of the slide. She said, "It's Okay." I noticed how differently the students in Ms. Delta's classroom had responded to seeing the images.

The students began drawing the images they had viewed. Each student would look through the microscope then try to draw what he/she had seen. I heard students complain about having to wait to see the slide again as they were trying to draw a sketch of the image.

I noticed that the students were finding it necessary to try to draw from memory because they were not able to look at the slide frequently while they were working on their sketches. Most students were on task, but the level of enthusiasm in this classroom was much lower than what I had experienced in Ms. Delta's room. The fact that Ms. Delta's students could spend more time actually viewing the slide and could discuss what they were seeing with other students who could view the same image at the same time seemed to make a difference in the level of engagement.

Another complaint that Ms. Alpha's students voiced was that their eyes became very tired if they focused on the image for more than a few seconds. Some commented that after a little while, their vision would become fuzzy and they could no longer see the image clearly. Ms. Delta's students did not incur this problem because they were using both eyes to watch a computer screen, which of course was much larger then the eyepiece of an analog microscope.

Ms. Nu's students had to rely on text and pictures to learn about plant cells. She had the students to read the material in the supplementary book provided with the Diversity of Life kit. She asked a student to read a paragraph. Then she discussed the content in that paragraph with the students. The Diversity of Life kit includes 15 copies of the book, so pairs of students were sharing a book. All students were asked to follow the reading silently in the book. I noticed that none of the male students had their eyes turned towards the text. All of the female students except one appeared to be looking at the words. The teacher reminded the students to read along silently. All of the male students continued to look away from the text.

Ms. Nu discussed terms, such as plant cell wall, cytoplasm, and chloroplasts, with the students. She then wrote each cell part on the board and read a definition of each. The

students were asked to copy the definitions that she dictated. All but two male students were writing in their notebooks as she provided the definitions. Ms. Nu also discussed a diagram of a plant cell that was in the book. I noticed that two male students were talking and giggling. The teacher then asked the students to draw a sketch of a plant cell, based on the picture in the book. They were to make their drawings in their notebooks. The teacher asked them to use the picture as a guide to label each part of the plant cell. As the students began their sketches, I noticed that six of the students were whispering to their partners. Two females were holding their book in front of their faces, which gave me the impression that they did not want the teacher to know the topic of their discussion. One male was not looking at the book or working on a drawing. Instead, he was staring into space and singing to himself. Eventually, all of the students seemed to be conversing with their partners. I heard students discuss the school dance which was to be held soon, I heard them talking about another class, and I heard giggling. However, I did not hear any students talking about plant cells or their sketches.

I found it interesting that Ms. Nu discussed the concept of a cell as the unit of a living organism with her students. She also discussed all the parts of the plant cell. In contrast, Ms. Delta did not use the word “cell” with their students during the entire class period. She did not explain to the students that they were viewing units, called cells, which make up the potato tissue they were examining. She also did not point out to the students that the cells had cell walls, even though those structures were visible with both types of microscopes that were used. Rather, she was hoping that the students would discover for themselves that they were viewing cells and that plant cells have cell walls. None of the students said the word “cell” or asked if the shapes that they were viewing might be cells. Also, none of the students

labeled any parts of their cell drawings. They simply drew a sketch of what they saw and tried to write a description of the image.

Ms. Alpha did talk to her students about plant cells, but she did not connect the vocabulary to the microscopic images they were viewing or to the sketches they would draw. At the beginning of the class period, she wrote the following words on the board: Nucleus, Endoplasmic reticulum, Golgi bodies, Central vacuole, Chloroplast, Cytoplasm, Cell membrane, Lysosome, Peroxisome, Mitochondria. She used the computer and projector to show them a diagram of a plant cell from the Diversity of Life CD-ROM. The diagram showed some of these parts. However, that diagram did not look like an actual image of a plant cell as viewed under a student microscope. Then, the students used the analog microscopes to view the potato slices. Ms. Alpha did not discuss with them that they were viewing potato cells. She only told them that they were looking at a slice of potato. The images that they saw did not resemble the sketch she had projected from the disk. She did not point out any of the visible parts of the potato cell to the students, such as the cell walls.

The next day, Ms. Delta and Ms. Alpha's students did cheek scrapings to view an example of animal cells. Ms. Delta used the word "cells" for the first time to discuss what the students were viewing. She told them that they had seen plant cells when they looked at the potato slices and that today they would see animal cells from their own cheeks. However, neither teacher had a discussion with the students regarding any differences between animal and plant cells. They also did not discuss any concepts related to the cell as the basic unit of life.

The students in both Ms. Delta's classroom and Ms. Alpha's classroom were amazed that the tissue in their mouths looked like it did when stained and viewed with a microscope.

They seemed to be fascinated with the images. However, I did not hear any students discussing the fact that they were viewing cells or that their bodies were made of cells. They did, however, realize that the samples had come from their own bodies, and they were surprised at how it looked. One student in Ms. Delta's class said, "Come here, Ms. Ennis. You have to see this. Have you ever seen this before?" As with past lessons, students in both classes made sketches and written observations. One female student in Ms. Alpha's room said, "I cannot believe that came from your cheek."

The next items that were viewed by Ms. Delta and Ms. Alpha's students were the samples of elodea leaf that were supplied in the Diversity of Life kit and pieces of celery stalks purchased at a local store. Both teachers continued to give directions for the investigations. They also required the students to draw sketches and to write observations in their science notebooks. I noticed that the students in Ms. Delta's classes were continuing to point to the screen and to have group discussions regarding the images they were viewing. As one group looked at an elodea leaf, a female student asked, "What do you think that white place is?" The students in her group could see exactly what white spot she was questioning as she pointed to the area on the screen. Another female student in her group replied, "It must be a tear in the leaf." The first student said, "Yeah, but look at the leaf. I don't see a tear." The second student said, "Maybe it's too small to see without the microscope." (The students were using the ProScope™ and could view the slide below the microscope. Therefore, they could view the specimen with the microscope and without it, without having to move the specimen away from the microscope.) I noticed that the students were asking more questions of their group members, and they were having more discussions regarding the images than

the students were having in Ms. Alpha's room, where they could not view the image as a group.

While Ms. Delta and Ms. Alpha continued the exploration of plant cells, Ms. Nu continued to have her students use the books that were part of the Diversity of Life kit. She asked the students to answer the questions in the chapter that related to plant cells. She then discussed the questions and answers with them. She also used an old set of textbooks to have her students continue to read about plant cells and to answer questions from this source. In addition, she used the computer and projector to show her students pictures of plant cells from the Diversity of Life CD-ROM. Finally, she asked each group of students to draw, label, and color a diagram of a plant cell to be displayed on the classroom wall.

Exploration of Protists

I had wondered if the students' fascination with the digital microscopes might start to fade at this point, but I saw no evidence that the students were losing their interest in using the digital microscopes. None of Ms. Delta's students or Ms. Alpha's students had viewed protitsts before this unit of study. Both teachers' students expressed amazement that organisms they could not see without a microscope could live within a drop of water. One of Ms. Delta's students said, "I thought those brine shrimps were the smallest things that would live in the water. I didn't know stuff you couldn't even see at all could live in this water."

The most striking difference between the engagement of the students in Ms. Delta's classroom and those in Ms. Alpha's classroom came when students were viewing the protists. The first protists they viewed were the paramecia. Then, they looked at euglena and at some stentors. The protists were purchased with the Diversity of Life kit. One problem with analog microscopes was the fact that the protists were moving quickly across the

viewing area. The Diversity of Life kit did not recommend any type of chemical to slow the movement. The investigation guidelines did suggest placing a strand of cotton across the slide to trap the protists in an area. Both Ms. Alpha and Ms. Delta tried this procedure, but they did not find it to be useful. Thus, the protists would glide across the screen. Ms. Alpha's students showed confusion over what they should be viewing. Ms. Alpha would visit a group and find a protist she wanted the students to see, but it would move before the student could view it. Also, if a student found something interesting, the organism had moved before the teacher could confirm what the student had seen and before another student had the opportunity to view the specimen. I heard one student say, "I can't see nothing." Another student asked, "How am I supposed to know what I'm seeing?" Also, Ms. Alpha's students continued to spend most of the lab time waiting for a turn to view the slide. I heard one student ask another in his group, "What does it look like." She replied, "I don't know. I ain't seen it yet."

In contrast, Ms. Delta's students could watch the screen as a small group. Ms. Delta worked with each small group of students to verify that they were seeing the protists. The small groups of students were able to discuss what they were viewing with their fellow group members. They were talking excitedly, smiling, and pointing at the screens. I heard the following conversation from one of the groups in Ms. Delta's room. One student said, "There he go!" Another said, "Wonderful view." A third student added, "That's a great picture!" From another group of students, I heard, "Oh, look at that! Look, look, look!" A third group discussed the paramecia when they first saw them on the screen. One student said, "Look, they're moving. They're moving!" Another added, "They look like tadpoles." A third student said, "No. They look like white bugs. Look at them moving." The second student said,

"That's amazing. How can they be in that drop of water?"

At first, both Ms. Delta's students and Ms. Alpha's students were finding it difficult to draw a protist. Ms. Alpha's students were particularly frustrated. I watched as a student would view the slide, begin to make a drawing, wait a turn to look at the slide again, and then realize that the protist he/she was attempting to draw was no longer in the viewing area. At first, Ms. Delta's students were showing some frustration, also. Even though they could look at the screen without having to wait a turn, they still were having difficulty with the fact that the protist would swim across the screen and out of the viewing area. Another protist might appear, but it would be in a different position. Also, the shape of the paramecium was altered as it moved and flipped. It might become elongated, and then it might be more round. As it moved, different views were available for the students. They found the various views to be interesting, but they had trouble figuring out what to draw. Then, one student said, "I know. I'll just take a picture and then draw that." Word quickly spread about the classroom regarding this new approach. The students found it very helpful to be able to study a picture of the protist because they could view it in more detail when they had a steady image to observe.

When I was reviewing the videotape of Ms. Delta's class and Ms. Alpha's class as they worked with the microscopes, I was reminded again of the difference in the student behavior exhibited with the use of the digital microscopes as compared to the analog microscopes. In Ms. Delta's class, I noticed that two males and one female were focused on the computer screen for two minutes. As the camera moved from this group of students, they were still looking intently toward the screen. In contrast to that scenario was the video of Ms. Alpha's classroom. I noticed that each student spent more time looking into space than

looking into the microscope or making a sketch and recording observations. I noticed one student who was trying to look at the slide and trying to make a drawing. He would glance at the microscope, then draw for a couple of seconds, then stare into space as he waited for another turn at the microscope, then look into the microscope again. One other student was taking turns with him looking into the microscope and trying to draw. The other two students in that group were just watching them. Thus, the videos served as a reminder of how much more actively engaged the digital microscopes allowed the students to become than the analog microscopes did.

Ms. Delta waited until the end of the unit of study to tell her students that each protist was a single-celled organism. Ms. Delta also shared some of the pictures and videos that her students had taken and used them as a review with her classes on the last day of the unit. Ms. Alpha shared the information with her students regarding the fact that each protist is a single-celled organism at the beginning of the study of the protists. She also used the computer projector to show them some pictures of protists from the Diversity of Life CD-ROM. However, she did not talk about whether these pictures resembled what they had viewed under the microscopes. She also did not emphasize to her students that each protist they had viewed was a complete organism made of just one cell. They did have a brief discussion regarding the fact that the protist was living and was carrying out the processes of life.

Ms. Nu taught about protists by using the book and the CD-ROM provided in the Diversity of Life kit. The students took turns reading aloud the material related to protists. As one student read aloud, the others were asked to read silently. Ms. Nu discussed each section with the students. She also had them to write vocabulary words that she identified for them. She also told them that they had read about three types of protists and about the way that

each one moves. Then, she wrote the word "cilia" on the board and asked the students to copy the word. Then she asked, "What is it?" No one volunteered an answer, so she added, "Flip to your glossary." A student read the definition aloud. Then she instructed the students to write the following words after the word "cilia" – "tiny hairs that act like boat oars to move the paramecium." She then led a brief discussion concerning how boat oars are used to move a boat, and cilia are used to move the paramecium. Next, she had them to write "pseudopod" and to record that it acts like a fake foot for an amoeba. She continued to list vocabulary words, such as euglena, flagellum, chloroplasts, chlorophyll, and eyespot. For each word, she had students to read the definitions aloud, and she provided them some information to copy into their notebooks. As I observed the twenty-one students in this classroom, I noticed that most of the students were raising their hands to read definitions and most were writing. However, one student was flipping a pencil in the air. Another student was staring at his shoes, one student was flipping through the book, one student was making gestures across the room, and two students were whispering to each other.

The next day, Ms. Nu used the Diversity of Life CD-ROM to show the students still pictures and video clips of each of the protists they had discussed in class the preceding day. She showed the students how each one used a means of locomotion to move from one place to another. Students were asking questions such as, "Do they really look like that?" "How do you know that's real?" "Ms. Nu, have you ever seen one of those things?" All students had their eyes focused on the screen while she was showing them the videos.

Student Interviews

When I interviewed the students, I noticed that all twelve of the interviewed students indicated that they enjoyed the unit on cells. The students enjoyed using whatever

magnification devices that were provided for them, whether it was handheld magnifiers, analog microscopes, or digital microscopes. The students also enjoyed viewing digital images, from the CD-ROM and from the digital microscopes for those who had access to them. The students in Ms. Nu's room were very enthusiastic about seeing the pictures displayed on the screen from the computer and projector. Table 5.2 provides information about the students who were interviewed. (As with all names in this report, pseudonyms have been used.)

Table 5.2

Students Who Were Interviewed

Teacher	Pseudonym	Gender and Racial Identity
Ms. Delta's Class		
	Robert	White Male
	DeAndrea	African American Female
	Laqueta	African American Female
	Ike	African American Male
Ms. Alpha's Class		
	William	African American Male
	Kayla	White Female
	Quanda	African American Female
	Rashad	African American Male

Table 5.2 (continued)

Ms. Nu's Class		
	Scott	White Male
	Kendrick	African American Male
	Alyssa	African American Female
	Tanisha	African American Female

Student Interviews from Ms. Nu's Class

From Ms. Nu's class, Kendrick said that he really liked using the handheld magnifiers because he could see things for himself. He added the following comments about the handheld magnifiers. "I could pick up what was to learn easier because I could see it better. It was close in my hand. We could look close at what we were doing." Kendrick also liked viewing the pictures and videos from the CD-ROM because "you could see what the teacher was talking about. You could see it more clear. I would tell Ms. Nu to keep doing a good job using the magnifiers and the CD-ROM images. They matched up. The handouts went along with the CD-ROM images. She should keep explaining to students what they are seeing."

Scott, another student in Ms. Nu's room, said that using the handheld magnifiers and viewing the digital images helped him to understand what he was reading in the supplemental book that came with the Diversity of Life kit. He said, "When you read the book, you could understand it. We read and looked at pictures and answered questions. Reading made more sense because we had seen the pictures from the computer." His advice to middle grades science teachers who teach the unit on cell theory is to "let the students look through magnifying glasses more often." Tanisha stated that she liked everything about the unit of study on cell theory. She said, "I like that you could see many things on the magnifying

glass." She also thought that the images projected on the screen from the computer were helpful to her in this unit. She noted that the images from the computer "show details about plant cells. You could see the details of the plant and animal cells. It helped us to learn about cells."

The fourth student I interviewed from Ms. Nu's class was Alyssa. She was very enthusiastic about the use of the magnifying lenses and the images from the computer. When I asked her what she liked about the unit of study, she replied with a smile, "Everything was interesting – all of it!" She said that she liked using the handheld magnifiers because "you could see more. We looked at baby shrimp, and we saw algae in our pond water" (referring to the samples taken from the mini-ponds they constructed following the directions in the Diversity of Life kit.) She indicated that the digital images were also very interesting and added, "We looked at shrimp, and we saw how the paramecium reproduce. It gave us good details about it."

Student Interviews from Ms. Alpha's Class

One student I interviewed from Ms. Alpha's class was Rashad. He said that he really enjoyed learning about cells. He said, "I learned about many cells that I didn't know existed, for example, paramecium, volvox, euglena. It's so many cells that we learned about. I never knew cells had guts. We learned many things a scientist does." He said that what he liked most about using the analog microscopes was that "you can see things with a microscope that you can't see with your regular eyes – like how things is contained within a cell. We looked at plant cells - I think it was the elodea. It looked like a wall of bricks. When we did our cheek cells, it looked like specks with purple dots." Rashad added, "I really enjoyed it. I never really knew all these cells existed. I enjoyed this unit more than others. Actually seeing

the movement of the cells and the activities they do, it was interesting." When I asked Rashad what was helpful to him in learning about cells, he replied, "I think looking in the microscope and writing down what you saw - that helped me the most. Actually seeing it in real life helped me to understand it. It's better than looking in a book. I really didn't like the book part. I can't see how the cells really look and how they move. To me, it's really better using microscopes than anything else." His advice to a middle grades science teacher included, "I would tell her we need to use them more often - not only with cells, but more other things."

Another student I interviewed from Ms. Alpha's class was William. Ms. Alpha provided me with some background information concerning William. She said, "This is a student who has been absent a lot and has failed the end of grade tests." As I interviewed William, he was a little reluctant as he answered each question. However, he was very serious about the interview. He also checked my written transcript very carefully. He told me that he really liked using the microscope. He enjoyed seeing the cells and what was really going on in the cells. In fact, when I asked him what was interesting about this unit on cells, he replied, "Everything was interesting." As we talked, he added, "It was exciting using the microscope. It was fun. You see cells that you couldn't see with your naked eye." He concluded, "Using the microscope was most helpful to me."

I noticed as I interviewed the two female students from Ms. Alpha's class that they smiled and appeared excited each time I asked them about working with the microscopes. When I asked Kayla about working with the analog microscopes, she said, "I liked it a lot. It was better than reading the books all the time. I liked the whole hands-on kind of thing. You got to actually like look at them instead of just reading about them. You could see how they

behaved or whatever. Using the microscope helps you understand better. It was fun. I like science." She added, "I wish they [microscopes] were in all science classrooms. I think they would give you a better understanding of what you were doing." When I asked her what learning activities were most helpful to her, she replied, "Writing down what we did as we did it. That way you could go back to it." I asked her what she would like for her teacher to know about this unit of study, and Kayla replied, "That I would want to do it again."

The other female I interviewed from Ms. Alpha's class was Quanda. When I asked her what she liked about using the analog microscopes in this unit of study, she replied, "being able to see the small objects as larger. Being able to see the different wholes in organisms - the different parts - the way they were breathing and living inside. It helps you to see objects you will never see with the normal eye – with a close-up view." I asked each student what they did not like about using the microscopes. The other three students indicated that they liked everything about using the microscopes. However, Quanda said that what she did not like was "not being able to see some objects in closer view and having to wait my turn to see the objects." Yet, she was very enthusiastic about the unit and the use of the microscopes. She said, "I don't think there was a part that wasn't interesting to me." Then she added, "I've learned a lot through looking at microscopes. It's given me much more ideas about how scientists use microscopes to study science and how scientists use them to make medicines and stuff like that." Quanda said that she would tell other students who were not in Ms. Alpha's class that "that using the microscopes has been fun but informative at the same time. You can learn a lot more by looking through the microscope than with your normal eye." Her advice for Ms. Alpha when she teaches this unit of study next year included, "Take it step by step. Let the students write plenty of notes about what they are doing. Show them

how to get close up on certain objects. That way, they'll be able to see them close up." Quanda added, "Drawing the paramecium helped me to form it in my own mind and to understand what I had seen in the microscope." She concluded her interview with the following statement regarding the use of analog microscopes, "It can be very informing and entertaining at the same time."

Student Interviews from Ms. Delta's Class

I interviewed Robert about his experience with the digital microscopes in this unit on cell theory. He said, "I found out interesting things like the paramecium and the amoebae can be found in a river - in fresh water, and I didn't know amoebae existed. I learned that there are many different cells - like protists - that have a nuclei, and prokaryotic that don't have nuclei, and they are called bacteria. We were able to look at the cheek cells. I didn't know what they looked like. We got to look at cells I didn't know were there – too small to see with the naked eye – like paramecium and euglena swimming around. We observed things up close in their natural habitat." Robert said that he had used a regular microscope in the past, and he noted that he preferred using the digital microscopes to the analog microscopes. He offered these insights, "You could look at it on a monitor on the computer instead of having to put your eye on the sight piece of a regular microscope. You could enlarge and adjust the picture. You can change the light quality." Then he added, "Glasses especially make it difficult to see in the eyepiece." I realized that point was particularly important to Robert because he wears eyeglasses. Another advantage that he noted regarding the digital microscopes was that groups of students could view a screen. "We had brine shrimp, and all were dead, but we were able to go to another group and watch theirs. That way nobody missed out." Robert gave a third reason for preferring the digital microscopes to the analog

microscopes. He stated, “When we found colonies of brine shrimp or euglena or paramecium, we took pictures. Then, we could show them to the teacher. We took movies of the paramecium eating. We could see them moving to the yeast, and we used it to show the teacher what we'd been looking at.” I asked each of Ms. Delta’s students the following question, “If you could erase this unit and start again, would you want to use the digital microscopes?” Robert replied, “Yes ma’am. When you're just reading about them in the book, you don't see how they move or act. Like the brine shrimp - You shine a flashlight; they move away. It gets you more involved with the activity, instead of just reading abut it.” When I asked Robert if he wanted to tell me about anything else he had learned in this unit, he replied, “That there is bacteria and protists and organisms living everywhere - in our drinking water and body. Cells are everywhere.”

The other male student that I interviewed from Ms. Delta’s class was Ike. Like Robert, Ike indicated that he really liked using the digital microscopes and was anxious to share some concepts he had learned. He stated, “We learned about how cells like to eat food and move around. You could see it under the scope. They grow and release gases and everything. We learned about the way the paramecium eat food and when they eat it, they changed color. When they eat, some goes into the cell. Flagella were interesting. When you see it on the scope, they moved the cell around – the euglena.” (To clarify Ike’s comment about the paramecium turning colors when it ate, I add this explanation. Following the directions in the Diversity of Life kit, the teacher and the students used yeast that they had dyed with Congo red stain to feed the paramecium. The point of dying the yeast was so the students could see the red yeast when the paramecium ingested it.) He continued telling me what he learned as he added, “We learned how brine shrimp be little eggs. Then, we put

water in it, it start flying. How the euglena is green and stuff." Ike said that he had used an analog microscope "for a little while" in a previous unit of study, but he said that he preferred the digital microscopes to the analog microscopes. He explained, "I like the digital better than regular microscopes. I liked using them because it's more better than the old ones. You get more closer up. You could really see the stuff moving. We could all see it." He also pointed out the advantage of being able to take pictures with the digital microscopes. He added, "It gave you pictures. What you see, you can magnify it larger. If you can't hardly see it, you can make it larger." Ike said that Ms. Delta definitely should use the digital microscopes next year when she teaches this unit. He also offered the following advice to her. "About the book - the part about the paramecium – the resource book in our kit - I think the Diversity of Life book gives you more information than the regular book. It's best to read the book and then go to the computer so you know what you're looking at. We usually would see first, then read." When I was concluding Ike's interview, I asked him what else I should know about this unit of study on cells. He smiled and said excitedly, "It was fun!"

One of the female students from Ms. Delta's class that I interviewed was DeAndrea, who shared information that she learned from using the digital microscopes. She said, "I learned that there are many different kinds of cells, and I learned a lot of stuff that I didn't think I would learn. It was more interesting than what I used to learn about. I found that these things were floating around. They were brine shrimp. I never heard of them. They were interesting. Paramecium were interesting. I liked the volvox and the stentors, and I liked the amoebae, too. That was good." When I asked her what she found most interesting in this unit, she replied, "All of it was interesting to me because I like learning about things different - not like I used to know about." DeAndrea stated that she liked using the digital microscopes. She

added, “I like it because it shows up the way you want it. It shows up good, and you can take a picture and stuff. And I liked it because I never used anything like it before.” She said that she had used an analog microscope once, but she preferred the digital microscopes “because it helps you to see more and learn more. I liked taking the pictures because you could see them bigger, and I liked making movies. You could play them back on the computer. It gave you things you might have missed or something.” When I asked her what she did not like about using the digital microscopes, she replied, “When they don't work, like when the light was dim or the picture was not clear sometimes. I learned how to make the picture better, by turning the focus knob – to make it clear – make it look like you wanted.” DeAndrea’s advice to Ms. Delta regarding teaching this unit next year included, “I would want her to know that it's a good use to look at different types of cells - or anything you want to look it. It will show more than you think is there and what kind of environment they live in.” I closed the interview with DeAndrea by asking her what else she wanted me to know about this unit on cells and the use of digital microscopes. She told me, “I would want you to know that it's a good learning experience and you'll learn more about cells. It’s interesting, and you wouldn't think it would be – to get a higher education. When you get to a higher grade, you would know more. Each of us saw stimulating things about science.” She paused a few seconds, smiled, and added, “I liked it. It was fun. It was a good experience for me because I got to learn about new things I didn't think I would learn about. It was fun from beginning to end!”

The final student I interviewed was Laqueta, another female student from Ms. Delta’s class. I asked Laqueta what she learned from this unit of study, and she told me, “I learned that some cells are different and some cells are the same.” When I asked her about her experience using the digital microscopes, she said, “Well, we looked through the microscope

at paramecium and amoebae and some other things. You get to see different things. You get to see what's inside of them – like inside the paramecium and stuff. It helped me to learn about cells and helped us grow up to be scientists." She told me that everything in this unit was interesting. When I asked her what she did not like about using the digital microscopes, she replied, "I don't dislike nothing." She said that she had never used a traditional microscope, but she did not think she would like it as well as the digital microscopes. She said, "I liked seeing the screen with the others my group. And, it helped me to see what other groups were working with." She also stated, "I liked how you could take pictures with the digital microscopes. I liked it, and it helped me learn." When I asked her what type of learning activities were most helpful to her, she replied, "the worksheet about amoebae and what we had to do with our groups and fill out information. Looking at the cells and recording the data." When I asked her what she would like to tell Ms. Delta, she replied, "I want to tell her that it's interesting, and thanks for letting us do this. and these microscopes helped us learn more about science." As I concluded her interview and asked her what else she would like for me to know regarding the use of digital microscopes, Laqueta responded, "It was fun and it helped me to learn more."

Research Question One

How might the selected middle grade students be engaged/disengaged in the study of cells when digital microscopes are available for their use compared with the availability of traditional microscopes or the lack of availability of any microscopes?

The evidence presented regarding the classroom observations suggests that students in each of the three classrooms were engaged in the unit of study on cell theory. Students in Ms. Nu's room were involved in reading the textbook, examining pictures from the

supplementary textbook supplied with the Diversity of Life kit, using handheld magnifiers to view specimens that did not require a microscope lens to see them, and viewing images projected from a computer onto a screen for the class to view as a whole group. Ms. Alpha's students were engaged through the use of the analog microscopes, the drawings and observations they made while using the microscopes, the pictures and text in the supplementary book in the Diversity of Life kit, and the pictures from the CD-ROM that she displayed on the screen for the students to view as whole class. Ms. Delta's students were engaged through the use of digital microscopes, the drawings and observations they made while using the microscopes, the pictures and video clips they recorded with the digital microscopes, the pictures and text in the supplementary book in the Diversity of Life kit, and the use of the CD-ROM in small groups at their assigned computer stations.

The classroom observations suggest that students in all three classes were participating in the learning activities most of the time. However, when comparing the observations, the students in Ms. Delta's classroom seemed to be more engaged than the students from the other two classrooms. They were able to view more images directly than students in Ms. Nu's classroom. Ms. Delta's students were also able to spend more time actually viewing the microscope images than the students in Ms. Alpha's classroom. Also, Ms. Delta's students were able to discuss what they were viewing with other students and with the teacher who were could view the specimens together. In addition, as one of Ms. Delta's students noted, the students could use the pictures they made with the digital microscopes to show the teacher what they had seen. They could also use those pictures to review images they previously viewed. Thus, the use of the pictures that the students took with the digital microscopes seemed to increase their engagement in the learning activities.

From the observations and the students' interviews, I concluded that the students in each group enjoyed the magnification device that was provided to them. The students' interviews reminded me of how important it was to each group of students to be able to see the images directly. As Kendrick, one of Ms. Nu's students, stated regarding the handheld magnifiers, "I could pick up what was to learn easier because I could see it better. It was close in my hand." Thus, holding the specimen and seeing the organisms for himself was an important part of his engagement with the learning. A review of the classroom observations reveals that the students in Ms. Alpha's classroom had more opportunity to view the organisms directly than Ms. Nu's students because the handheld magnifiers were only useful for specimens that were not microscopic in size. Ms. Delta's classes had more opportunities than Ms. Alpha's classes for direct observations because the students did not have to take turns viewing the screen. They were also able to focus for longer periods of time, without eye strain, as they waited for protists to pass across the screen. As evidenced by the classroom observations, their engagement was enhanced by the opportunity for sustained viewing and the opportunity to discuss the images with their group members and with their teacher.

From the descriptions of the classrooms, a pattern of student engagement emerged. Fredricks et al. (2004) reviewed research on engagement in learning and concluded that behavioral engagement includes the adherence to classroom and school rules and student involvement in learning tasks. While many of the students in Ms. Nu's classroom appeared to participating in the reading and writing activities, the descriptions provided of the classroom behavior show that during one class session, about a third of the students had their eyes averted from the page when they were supposed to be reading. The observation data also provided information about students who were displaying off-task behaviors while the

teacher was leading the class discussions related to the readings. The observations of Ms. Alpha's classroom showed that her students were interested in viewing the microscope slides. However, they often wasted time and had conversations unrelated to the topic while they waited their turns to view the slides. There were usually four or five students in a group using an analog microscope, which meant that each student could view the microscopic image only one-fourth or one-fifth of the time that they were using the microscopes. The frustration they expressed as they were unable to see the same protist on the slide as the teacher or a group member had seen was another indication that their engagement level was not at the maximum level. Observation data indicate that in Ms. Delta's classroom, all the students in a group were able to view the screen the entire time that they were using the digital microscope. They did not have to wait a turn to see the specimen, and they could discuss what they were seeing with others in the group, who were viewing the same images. Thus, their involvement in learning tasks was at a higher level than the students in the other two classrooms.

The observations and the students' interviews indicated that the students in each of the three classrooms enjoyed the unit of study. Fredricks et al. (2004) defined emotional engagement as the students' affective responses in the classroom, including happiness, discontent, interest, and boredom. As shown in the students' interviews, the students in all three classrooms expressed their enjoyment of the learning activities and talked about their interest in this unit of study. Thus, their interviews provided evidence that students in each of the three classrooms were emotionally engaged in the learning activities. Also, their responses to the images they were viewing in each classroom corroborated this evidence.

As the students discussed what they learned about cells in their interviews, more data were provided that suggested that the students in all three classes were engaged in the learning activities. All of the students expressed interest and enjoyment in the unit of study. Also, all of the students shared facts and concepts that they had learned during this unit. However, the students in Ms. Delta's classes provided more elaboration concerning what they had learned. That fact provides further evidence that her students were more engaged in their learning than the students in the other two classrooms.

The students' reactions to their learning activities, as recorded in the classroom observations, provided additional evidence that the students in all three classrooms were engaged in their learning. In all three classrooms, I heard students expressing interest in the images they were viewing. However, the comments from the students indicate that the students in Ms. Delta's classroom were more excited about the images they were viewing than the students in the other two classrooms. The fact that they could watch a living organism for a sustained period of time, and discuss what they were viewing with the member of their group, seemed to foster their enthusiasm and their level of engagement. The enthusiasm was especially evident when the students were viewing protists.

When I interviewed the three teachers, I asked each one, "How would you rate the students' engagement in their learning when the hand-held magnifiers and CD-ROM images/regular microscopes/digital microscopes were used in your classroom in the unit on cells?" Ms. Nu said that "almost 100% of students were on task." She added, "I learned that if we are going to spend time on a topic, we should enjoy it. We can make the learning fun and meaningful. This is the first time that students have not asked when we are going to be finished with a unit."

When I asked Ms. Alpha about the engagement of the students in her classroom, she replied, “The majority of the students were very engaged in the lessons. You always have a few, regardless of what you do, who are not engaged. I would say that 95% of the students were very engaged and on-task. Compare this to teaching without the microscopes. I could see a big improvement with the microscopes. Usually, there are only four or five students of each class who actually participate in the lessons. This time most wanted to talk about what was happening and participate in the class time. Also, students wanted to take it a step further – to add their own ideas. Like when we set up our mini-ponds. Some of my kids chased down worms one weekend and brought to school to add to their mini-ponds. They said that every pond has to have worms. I let them add worms to their ponds because they were so interested in this environment. They had their own ideas of things to do. Then again, adding the worms to the ponds didn't work. The worms died. The students asked questions, like ‘Why don't you think it worked? What could we do different next time?’ They had fun and learned a lot at the same time.” Ms. Alpha concluded her answer with this response, “This has been so much fun. This is exactly what the kids need. I cannot believe how interested my students are in the lessons. They want to learn!”

In response to my question concerning student engagement, Ms. Delta stated, “I think that the students were very engaged in their learning. In fact, for this unit, the engagement was far above any other unit that I taught this year. I think that the long-term results will be far greater than it would have been without the digital microscopes. What I mean is that I think that these students will remember more about cells in future years, and as they take high school courses, because of the way they were engaged in this unit.” Ms. Delta also stated, “I noticed that competition developed between the groups to see who could have the

best pictures. With the exception of maybe five students, everybody found something really interesting. Those five students were in trouble in other classes and missed so much class that it was difficult for them to be interested in what we were doing. They missed the continuity of the class."

I mentioned to Ms. Delta that each teacher had stated that she thought that the students were more engaged in this unit than other units taught this year. She shared a thought that I found interesting. She said, "I think that the students were excited about using the handheld magnifiers because they had not used them in the elementary grades – or at had not used them very much. By seventh grade, the magnifiers should not be such an exciting visual tool if they had been used all along in earlier grades. This shows that our teachers have not been using the tools all along." These statements fit with the observations that I made and the student interviews. I agree with Ms. Nu and with Ms. Alpha that their students did show a high level of engagement in the learning activities. However, I had the advantage of being able to compare them to Ms. Delta's class, where I could witness an even higher level of student engagement. Also, the student interviews provided evidence that students from each class were engaged in the learning process. However, the fact that Ms. Delta's students provided more elaboration about the learning experience and about the content that they learned suggested that her students had maintained a higher level of engagement during the unit.

In conclusion, I think that Ms. Delta's students were the most engaged in the work. I think that the other students were very interested in the tools that were provided to them because they realized that these tools helped to make science interesting to them and helped them to understand the concepts related to cell theory that are the learning goals of the

Diversity of Life kit. Perhaps if Ms. Nu's students had the opportunity to use the digital microscopes, they may have found the handheld magnifiers to be a poor substitute for the digital microscopes. However, they did not have the opportunity to make that comparison during this study. Therefore, they enjoyed and appreciated the tools that they used. Also, their response to the digital images that were provided from the CD-ROM and from the digital microscopes suggest that images taken from digital microscopes can be very effective in helping to engage middle grades students in learning about cells. From observing the students, and from comments in the students' interviews indicating that they liked to be able to have their hands on the magnification devices, I think the data suggest that the students are more engaged when they are using the digital microscopes than when using the analog microscopes or the handheld magnifiers. However, if digital microscopes are not available, then analog microscopes, handheld magnifiers, and digital images can serve as tools that help middle school students to be more engaged in learning about science than they would be from reading texts and having class discussions without the additional hands-on and visual experiences.

Research Question Two

How might the selected middle grade students in this rural school perceive the use of images (in text and on a CD-ROM), or the use of analog microscopes, or the use of digital computer microscopes (with corresponding multimedia applications) in their study of cells?

The students in all three classrooms indicated that the use of images was very important to them in understanding the concepts presented in this unit on cells. From Ms. Nu's class, Kendrick stated that the CD-ROM images matched up with the handouts that the teacher used from the Diversity of Life kit. Seeing the pictures and video clips on the screen

helped him to be able to answer the questions on the handouts. He also said that because he was viewing the CD-ROM images, it helped him to picture what he was reading in the supplementary textbook that was supplied with the Diversity of Life kit. Scott expressed a similar thought when he said, "When you read the book, you could understand it. We read and looked at pictures and answered questions. Reading made more sense because we had seen the pictures from the computer." When I asked him what he would like for Ms. Nu to know about teaching this unit, he replied, "I would tell her that working with magnifying glasses and images helps you know what you are looking for." Tanisha said that the images from the computer "show details about plant cells. You could see the details of the plant and animal cells. It helped us to learn about cells." I asked her which visualization tool she thought was more helpful to her in studying about cells – the images projected from the computer or the viewing of objects with handheld magnifiers. She replied, "Both. We needed both." Alyssa also stated that both means of visualization were helpful to her in learning about cells. She enjoyed looking at the brine shrimp and at algae with the handheld magnifiers, and she thought that the digital images projected from the computer, such as the video of paramecia, were helpful to her in learning about cells..

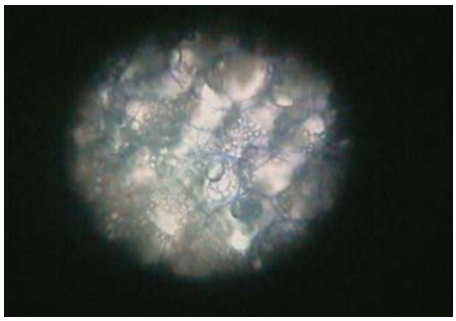
Ms. Nu's comments echoed what her students had told me. She thought that the use of the handheld magnifiers and the digital images "added a lot to their learning. They looked forward to seeing what they could see. They liked the applications they could see to the real world. I think it made them feel more like a real scientist as the watched the movement of the brine shrimp and saw their reaction to the environment, as they swam away from the light. In fact, I was surprised at how much they could see with the handheld magnifiers. I had never thought they were worth messing with before. It surprised me to see that they could see more

details than I had expected." Ms. Nu was also surprised at how well the students responded to the images projected from the computer and at how easily she could use the technology. She said, "I was so afraid of the technology, but Dr. Jones showed us how to use it and it wasn't hard. Nothing about it was hard. The students liked it so much, too, that I was really motivated to use it. Plus, I could tell that they could learn more about protists by watching those Quicktime videos of them. They could really see them moving – and responding to their environment."

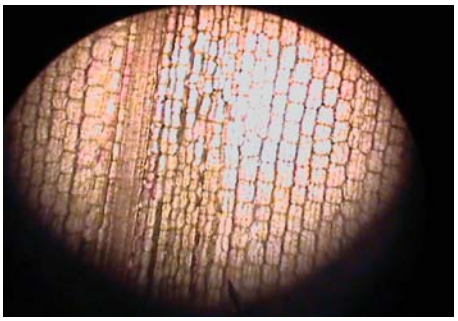
Interviews with Ms. Alpha's students provided information regarding how they perceived the use of analog microscopes in their study of cells. Quanda said, "Using the microscopes has been fun but informative at the same time. You can learn a lot more by looking through the microscope than with your normal eye." She also told me, "Drawing the paramecium helped me to form it in my own mind and to understand what I had seen in the microscope." Rashad said, "I think looking in the microscope and writing down what you saw - that helped me the most. Actually seeing it in real life helped me to understand it. It's better than looking in a book. I really didn't like the book part. I can't see how the cells really look and how they move. To me, it's really better using microscopes than anything else." William stated, "Using the microscopes was most helpful to me. We saw what was really going on with the cells." When I asked Kayla about her perceptions of the microscope use, she replied, "I liked it a lot. It was better than reading the books all the time. I liked the whole hands-on kind of thing. You got to actually like look at them instead of just reading about them. You could see how they behaved or whatever. Using the microscope helps you understand better." She added, "I wish they [microscopes] were in all science classrooms. I think they would give you a better understanding of what you were doing."

Ms. Alpha's comments indicated that she agreed with her students that the analog microscopes were very beneficial to them in this unit of study on cells. She said, "I have found that the students learn so much more this way. I know that they were taught these objectives last year, and I know that the teachers did their best, but these students had very little concept about cells. It's the way we have been teaching it. I was teaching that way, too – the old-fashioned way. I thought that the kids had to be under control and organized. Well, with this new way – we are organized and structured. I learned that we could use the microscopes in an organized and structured way – and that their use would be beneficial to the students." (To clarify her comments, I add this note. As was explained in chapter 3, the objectives related to cell theory are currently in the seventh grade North Carolina Standard Course of Study. Next year, those objectives will move to the eighth grade. Thus, in this study, teachers and students from both the seventh and eighth grades were participants.)

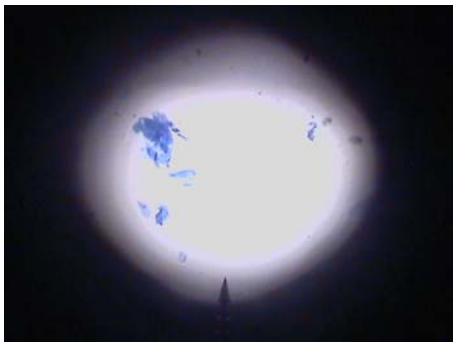
The analog microscopes did not offer a means for the students to capture still pictures or videos of the images that they were viewing through the lenses. However, I managed to hold a digital camera to the eyepiece of an analog microscope and take pictures of some of the slides. A sample of those pictures is shown in Figure 2 to provide examples of what Ms. Alpha's students were able to see with the use of the analog microscopes.



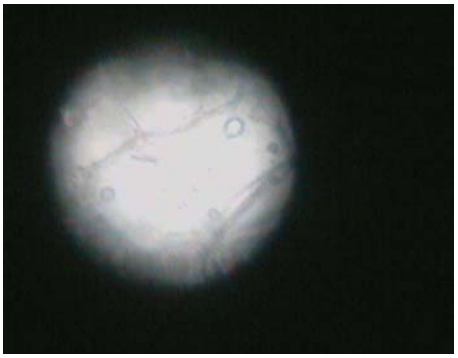
Potato cells



Elodea leaf cells



Cheek cells



Paramecia

Figure 2: Pictures taken using a digital camera held to the eyepiece of an Analog Microscope

An overview of classroom observations and student interviews from Ms. Delta's class, presented earlier in this chapter, provided information on how her students viewed the use of digital computer microscopes (with corresponding multimedia applications) in their study of cells. A review of some of the highlights from those interviews with Ms. Delta's students, as well as some additional comments they offered during our conversation, provide insights on this topic. Robert indicated that he really enjoyed using the digital microscope and thought that it was very helpful to him in understanding and learning the content presented in the unit on cells. He added, "I found out interesting things like the paramecium and the amoebae can be found in a river - in fresh water, and I didn't know amoebae existed. I learned that there are many different cells - like protists - that have a nuclei, and prokaryotic that don't have nuclei, and they are called bacteria. We were able to look at the cheek cells. I

didn't know what they looked like. We got to look at cells I didn't know were there – too small to see with the naked eye – like paramecium and euglena swimming around. We observed things up close in their natural habitat." Robert also told me that he had used a regular microscope in the past, and he noted that he preferred using the digital microscopes to the analog microscopes. He said, "You could look at it on a monitor on the computer instead of having to put your eye on the sight piece of a regular microscope. You could enlarge and adjust the picture. You can change the light quality." Robert also told me that it was much easier to see images on a computer screen than it is to see them through the eyepiece of an analog microscope when one is wearing eyeglasses. Ike indicated that he, too, had used analog microscopes and that he preferred the digital microscopes to the analog microscopes. He thought that the digital microscopes had made the unit interesting and had helped him to understand the concepts presented. He explained, "I like the digital better than regular microscopes. I liked using them because it's more better than the old ones. You get more closer up. You could really see the stuff moving. We could all see it." He also pointed out the advantage of being able to take pictures with the digital microscopes. He added, "It gave you pictures. What you see, you can magnify it larger. If you can't hardly see it, you can make it larger." Ike said that Ms. Delta definitely should use the digital microscopes next year when she teaches this unit. He emphasized to me that using the digital microscopes made the science unit fun.

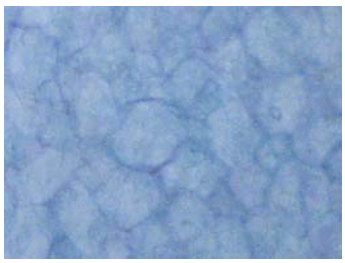
A female student from Ms. Delta's class, DeAndrea, told me that she really liked using the digital microscopes in this unit of study on cells and that she thought they were very helpful to her in understanding the content. She said, "I would want you to know that it's a good learning experience and you'll learn more about cells. It's interesting, and you

wouldn't think it would be – to get a higher education. When you get to a higher grade, you would know more. Each of us saw stimulating things about science." She paused a few seconds, smiled, and added, "I liked it. It was fun. It was a good experience for me because I got to learn about new things I didn't think I would learn about. It was fun from beginning to end!" DeAndrea stated that she had used analog microscopes in the past and that she preferred the digital microscopes. The other female student, Laqueta, said that she had never used a traditional microscope, but she did not think she would like it as well as the digital microscopes. She said, "I liked seeing the screen with the others my group. And, it helped me to see what other groups were working with." She also stated, "I liked how you could take pictures with the digital microscopes. I liked it, and it helped me learn." When I asked DeAndrea what she would like to tell Ms. Delta about this unit and the digital microscopes, she replied, "I want to tell her that it's interesting and thanks for letting us do this and these microscopes helped us learn more about science." Thus, all four of Ms. Delta's students perceived that the digital microscopes made this unit on cells more interesting to them. They also thought that the use of the digital microscopes helped them to understand the concepts, and their perception was that the digital microscopes would be a better tool for this middle grades unit than the analog microscopes.

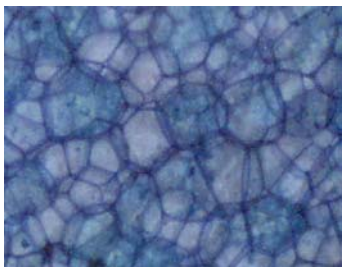
My interview with Ms. Delta provided insights into how she thought the students viewed the use of the digital microscopes. She said, "The students loved working with the digital microscopes." She added, "I noticed that competition developed between the groups to see who could have the best pictures. With the exception of maybe five students, everybody found something really interesting. Those five students were in trouble in other classes and missed so much class that it was difficult for them to be interested in what we

were doing. They missed the continuity of the class." Ms. Delta told me that not only did the students enjoy using the digital microscopes, but she really enjoyed the experience as well. She said, "You know I've been thrilled the whole time. I can sit here for hours in the afternoon playing with the digital microscopes. Also, when I know that my students are enjoying the unit and that they perceive they are learning more than usual, then I'm really happy to be using them in my class." Ms. Delta also discussed the fact that before this unit of study began, she had been a little apprehensive about the students' behavior as they worked in groups using computers and digital microscopes. What she learned was that the students' behavior actually improved when they used the digital microscopes, compared to their behavior during other units taught this year. More details regarding how Ms. Delta viewed the digital microscopes as learning tools for her students are presented in the examination of research question five.

In an earlier section of this chapter, I inserted some digital pictures that the students took of the substances that were in the vials used to introduce the unit. In Figure 3, I have placed pictures that the students made of cells. The students used the Digital Blue™ QX5 to record these pictures.

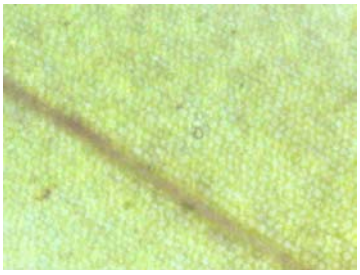


Potato cells



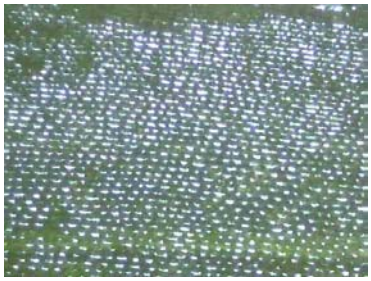
Potato cells

Celery stem

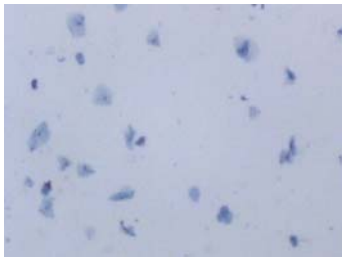


Elodea leaf

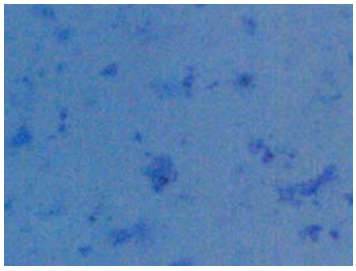
Elodea leaf



Elodea leaf



Cheek cells



Cheek cells

Paramecia

Paramecia

Euglena

Stentor

Figure 3: Pictures taken with the Digital Microscopes

Research Question Three

When the selected middle grade students in this rural school are taught about cell theory, how do students perceive science instruction in classrooms that include the use of digital microscopes (and corresponding multimedia applications) and in classrooms that do not?

Details of the students' and the teachers' reactions to the use of digital microscopes in Ms. Delta's classroom were provided in the overall presentation of information earlier in this chapter and in the information presented in the analysis of research question two. Details were also provided regarding the two classrooms that did not use digital microscopes – Ms. Nu's and Ms. Alpha's classrooms – in these same two sections. Thus, I will not repeat those details here. Instead, I offer an analysis of these data and a few additional comments that the teachers offered that add insight to this research question.

All of the students interviewed were interested in using whatever visualization tools were provided to them. Observations of Ms. Nu's classroom provided data that indicated that her students enjoyed using the handheld magnifiers, and they found them to be helpful in learning the content presented in this unit. Her students also were very engaged in learning when she showed them digital images from the CD-ROM provided in the Diversity of Life kit and from the pictures that Ms. Delta's students had made using the digital microscopes. They perceived the use of these materials, along with more traditional materials including the supplementary textbook and the class discussions, as beneficial to them. Students in Ms. Alpha's classes enjoyed using the analog microscopes, and they enjoyed viewing the digital images provided on the Diversity of Life CD-ROM. Like Ms. Nu's students, they viewed the tools that were provided to them as beneficial to their learning in this unit, and they noted

that the supplementary textbook was beneficial. They also indicated that the analog microscopes and the digital images they viewed helped to foster interest in this unit. Ms. Delta's students enjoyed using the digital microscopes. The three students that I interviewed from her classroom who had also used analog microscopes stated that they preferred the use of the digital microscopes for this unit of study. The fourth student had not used an analog microscope, but she stated that she thought that she would prefer the digital over the analog microscope. Ms. Delta's students provided elaborate descriptions of what they had learned and how they had enjoyed learning the content. They also explained why they thought the digital microscopes were effective learning tools for them during this unit of study. Thus, each group of students perceived the use of magnifying devices provided to them and the presence of digital images to be beneficial to them. They thought that these items fostered their interest in this unit of study and their understanding of the concepts presented in this unit.

This unit was the last one taught by the teachers in the school year. Each teacher reported that the students in her classroom were more engaged in learning during this unit than during any other unit she taught this year. Observations show that students in each of the three classrooms were involved in the learning activities. However, when the data are compared and contrasted, a pattern emerges that suggests that the students in Ms. Alpha's classroom were more engaged than the students in Ms. Nu's classroom, and the students in Ms. Delta's classroom were more engaged than the students in Ms. Alpha's classroom. (More details regarding the engagement of the students is provided in the analysis of research question one.) In summary, the data suggest that handheld magnifiers, digital images from the Diversity of Life CD-ROM, analog microscopes, and digital microscopes served as

visualization tools that enhanced the study of cells for these middle school students. However, the use of digital microscopes provided the most conducive learning environment of the three magnification tools.

As noted in the analysis of research question one, Ms. Delta had shared her thoughts regarding why she thought that the students in Ms. Nu's class were excited about the use of handheld magnifiers, even though the devices could not be used for viewing cells. Ms. Delta said, "I think that the students were excited about using the handheld magnifiers because they had not used them in the elementary grades – or at had not used them very much. By seventh grade, the magnifiers should not be such an exciting visual tool if they had been used all along in earlier grades. This shows that our teachers have not been using the tools available to them." These statements fit with the observations that I made and with the student interviews. A statement made by Ms. Nu regarding the use of handheld magnifiers adds support to Ms. Delta's observation. Ms. Nu said, "I was surprised at how much they could see with the hand magnifiers. I had never thought they were worth messing with before. It surprised me to see that they could see more details than I had expected." Of course, Ms. Nu noted that the handheld magnifiers could not be used for viewing for cells, but she was surprised at how helpful they were to the students in viewing other specimens, such as the red sand and the brine shrimp that were used in the introduction of this unit. Over the years, Ms. Delta has used handheld magnifiers and analog microscopes with her students. She stated that the digital microscopes were the best tools that she has used with students in the study of cells. She noted that students were more engaged when using the digital microscopes than when using the analog microscopes because they could view the screen as a group and because they could take pictures to use for future reference. She also stated that

the fact that students could draw pictures while continuing to glance between the computer screen and the notebook paper was an advantage afforded by the use of the digital microscopes over the analog microscopes. She noted that obviously both microscopes held an advantage over the handheld magnifiers since no specimens could be viewed on the cellular level with the handheld magnifiers.

In summary, the students interviewed in each of the three classrooms reported that they enjoyed using the magnification devices to view the specimens provided to them. Also, all of them were very interested in the digital images that were provided for them, from the digital microscopes in Ms. Delta's classroom and from the CD-ROM in all three classrooms. The students expressed surprise and interest in what they saw. I asked each student what he/she did not like about the unit of study. Each student interviewed indicated that he/she liked everything about the unit. I think that each group of students perceived the use of magnifying devices and the viewing of digital images to be tools that helped to engage them in the unit of study. However, the data from the observations and interviews suggest that the digital microscopes provided the most conducive learning environment for these middle school students in this unit on cells. I think that if each group of students had received the opportunity to use the digital microscopes, they would likely have selected them to be the magnification device that was best suited for their study of this unit on cells.

Research Question Four

How do selected middle grade students who have access to the use of digital computer microscopes, during the unit on cell theory, make use of the multimedia options that are available with these microscopes?

Both the ProScope™ and Digital Blue™ digital microscopes have software that the user operates to view the images captured by the digital microscopes and viewed on the computer screen. The software includes options that allow the user to take still pictures and video clips of the images being projected onto the computer screen. The students in Ms. Delta's room enjoyed using this option. As Robert stated, "When we found colonies of brine shrimp or euglena or paramecium, we took pictures. Then, we could show them to the teacher. We took movies of the paramecium eating. We could see them moving to the yeast, and we used it to show the teacher what we'd been looking at." As I observed Ms. Delta's classroom, I noticed that her students frequently took pictures and videos. As the teacher circulated from one group to another, she would discuss with the group of students what they were viewing on the screen. If the students had a question regarding an image they had recorded, they would show the picture or video to the teacher and discuss it with her. They also would show her images that they found interesting or that they thought provided a good view of the specimen. In addition, the students often used a picture when making a sketch of the specimen. They realized that in the picture, the specimen was not moving. It was easier for them to make a sketch from a still picture than from a moving organism.

Robert also told me that sometimes his group of students would view pictures or videos that another group had captured. Another of Ms. Delta's students, DeAndrea, stated, "I liked taking the pictures because you could see them bigger, and I liked making movies. You could play them back on the computer. It gave you things you might have missed or something." Like DeAndrea, Robert told me, "You could enlarge and adjust the picture." Laqueta told me, "I liked how you could take pictures with the digital microscopes. I liked it, and it helped me learn." Thus, Ms. Delta's students valued the opportunity to take pictures

and videos using the software that accompanies the digital microscopes. They also realized that they could enlarge a picture that they had saved in order to see more details of the specimen. In addition, they appreciated being able to see the pictures later, when they were no longer viewing the specimen.

Ms. Delta chose not to show the students how to use the software to make multimedia presentations. I had thought that some of the students might find the options on their own and make a multimedia presentation from their own initiative. However, the students followed the teacher's directions and did not venture into areas of the software that the teacher did not directly tell them to access. Although the students used the computers every available free minute, they always sought Ms. Delta's permission, and they used only the parts of the program that they had been directed to use. Therefore, none of the students used the software to make multimedia presentations.

Ms. Delta realized that she missed an opportunity to use the pictures in large group discussions with the students. She had a discussion at the end of the unit where she used pictures they had captured to help the students review some of the concepts they were learning. At that time, she realized that she should have used this strategy at frequent intervals throughout the unit. She told me that next year, she plans to hold a large group discussion with her students about every three days. During this time, she intends to use the pictures and videos as a means for discussing what the students have viewed. She also plans to help them make connections from what they have viewed and captured in images to the pictures and the information presented in the supplementary books supplied with the Diversity of Life Kit.

While Ms. Delta did not allow the students to make multimedia presentations, she did make a paper presentation of her own. She printed some of the pictures that the students had taken with the digital microscopes. She laminated the pictures and displayed them on a bulletin board in the hall. Two of the students in her class mentioned this bulletin board and their pride in it when I interviewed them. Other students in her classroom also showed me the bulletin board and told me about some of the pictures on display. Robert said that he sometimes used those pictures to explain to students in other classes about what they were doing and learning in Ms. Delta's class. However, Ms. Delta never took her students into the hall to discuss the pictures with her students. She used the pictures as a display, but she missed the opportunity to use them as a presentation tool to discuss with the students concepts they were learning. (Before Ms. Delta placed the pictures on the bulletin board, she spread the pictures on some of the tables in her classroom. I used a digital camera to record some of the display as it was being prepared. Those pictures are presented in Figure 4.)

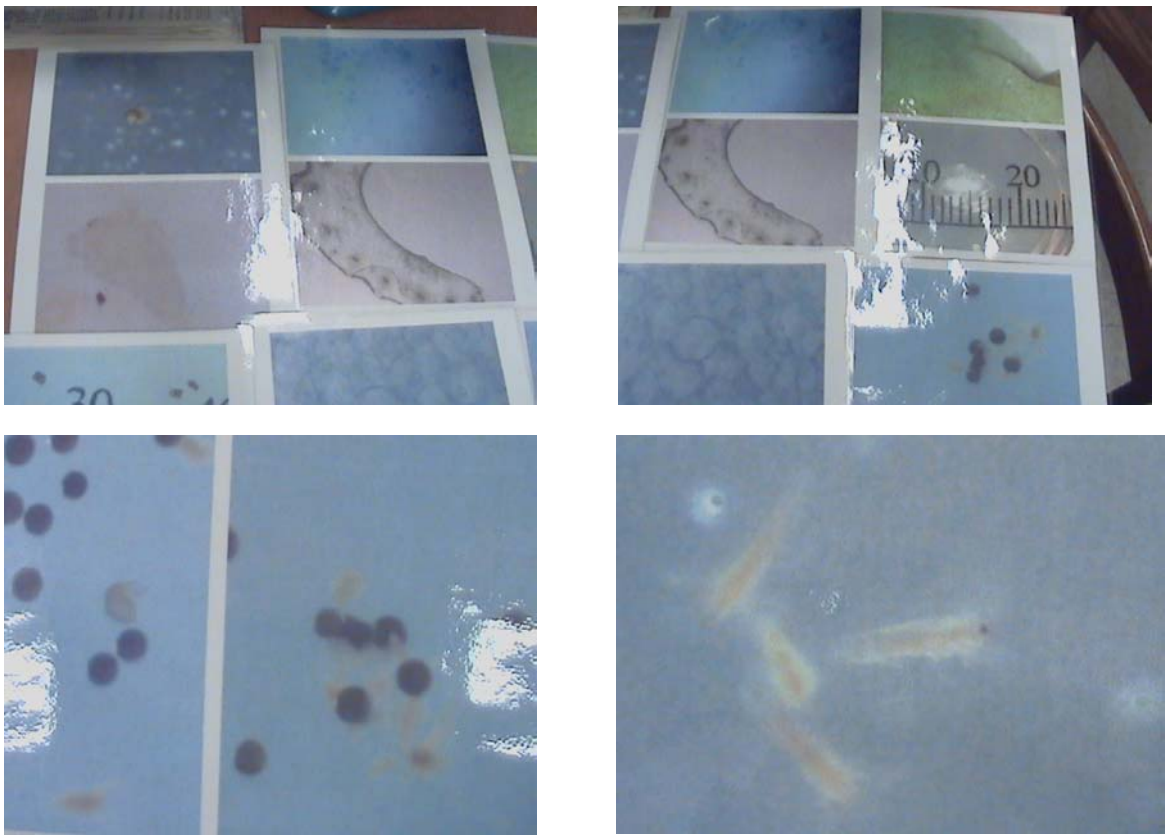


Figure 4: Pictures from Digital Microscopes for bulletin board display

Research Question Five

How do selected middle grade students who have access to the use of digital computer microscopes, during the unit on cell theory, use digital microscopes as mindtools in their learning about cells?

I was interested in learning how the students might use the digital microscopes as constructivist mindtools to help them construct meaning during this unit on cells. I used a constructivist learning model created by Gagnon and Collay (2001) to provide a structure for examining the digital microscopes a constructivist mindtool. Gagnon and Collay labeled their model the Constructivist Learning Design (CLD). Their CLD model consists of six parts,

which they say flow back and forth into each other. The first part is labeled as "situation," and it is defined as the frame for student engagement. The situation provides the overall goals and tasks for the learning situation. The second element is "groupings," the social structures that will are during the learning experience. Third, "bridge" refers to the scaffolding that is provided to help the students connect the new learning to the knowledge they have already formed in their minds. Fourth, "questions" are used to help inspire students to analyze, synthesize, extend, and integrate what they are learning. The fifth element, "exhibit," refers to having the students share what they are learning with others. The authors also refer to the exhibits as "artifacts of learning" (p. *xi*). "Reflections" allow students to think critically about what they are learning, to apply their learning to other areas of the curriculum and to their lives, and to think about future opportunities for learning. This model provided a framework for me as I analyzed the data for this research question. The situation was the unit of study on cells that occurred in Ms. Delta's classroom in the spring semester of 2005.

The first part in this model, the situation, provides the frame for student engagement. The situation provides the overall goals and tasks for the learning situation. The goals and objectives for this unit were in alignment with the North Carolina Standard Course of Study, 2004 Version for Eighth Grade, Competency Goal 6. A copy of these goals and objectives can be found in Appendix F. The goals and objectives were also outlined in Diversity of Life kit from Full Option Science System (FOSS), a research based science system, designed by the Lawrence Hall of Science, UC Berkeley (2003a) with support from the National Science Foundation, for grades K-8 and published by Delta Education. This material was designed to be in alignment with the national science standards (AAAS, 1993; National Research Council, 1996). The FOSS Diversity of Life Course (Lawrence Hall of Science, UC

Berkeley, 2003a) was recommended by the North Carolina Department of Public Instruction for use in teaching the North Carolina Standard Course of Study middle grades objective on cell theory. This kit is designed to help students construct the following main concepts:

- Life happens in cells.
- Cells are aquatic, even in terrestrial organisms.
- Cells all have the same basic requirements for survival.
- Life is diverse.
- Most life is single-celled.
- All organisms are adapted to live where they live. (Lawrence Hall of Science, UC Berkeley, 2003b, p.7).

These goals provided the framework for the unit of study that was occurring in Ms. Delta's eighth grade classroom.

The second element in the CLD model is "groupings," the social structures that are employed during the learning experience. Using the digital microscopes was conducive to the use of groups. Ms. Delta used six digital microscopes. She placed her students in groups of three to five students, depending on the size of the class and the number of students present. She made sure that the groups rotated computer stations so that all of her students had the opportunity to work with both the ProScope™ and the Digital Blue™ QX5™ computer microscopes. There was no observed difference in how the students responded to their groups based on the brand of digital microscope they were using. The use of the digital microscopes not only fostered group behavior in that students had to share the resource, but it also provided a means for the students to view the images as a group, rather than seeing an image individually. From the beginning, the students tended to operate the digital microscopes as a group. One of the first organisms that they viewed was brine shrimp. I noticed that the students tended to operate the microscopes in groups. One student would hold the mouse to operate the software and to take pictures and videos, another would move the slide around to

locate brine shrimp as they moved out of view. Still another student in the group would adjust the focus. Since they could all see the picture together, they could work together on adjusting the picture, offering suggestions to each other about what combinations made the best pictures and providing suggestions on when images should be captured. I heard comments such as, “Move down a little - a little more - that's it! That's it!” “I see it!” “Me too!” “Ooooh, oooh, oooh, did you see that?” “Look at it.” “See that!” I also heard, “Get a picture! Get a picture! Ohhh, that's a good one.” “Look at what it shows.” “We got some good pictures!” These comments suggest that the students were working together as a group to achieve a common goal.

The third element, “bridge” refers to the scaffolding that is provided to help the students connect the new learning to the knowledge they have already formed in their minds. With the digital microscopes, the digital images, including still pictures and video clips, served as a bridge that helped the students connect the new learning to what they already knew. One way that the pictures provided this scaffolding was that the pictures on the screen provided a representation that bridged the concrete to the abstract. The students were operating in a concrete manner as they placed the specimens on the slides and placed them under the digital microscopes. They had a concrete connection to the specimen. The Diversity of Life kit intentionally planned for students to examine specimens that could be seen with the naked eye before introducing them to samples that could be seen only with a microscope. The first specimens that they viewed with digital microscopes were the “mystery items” in the five vials – red sand, dry yeast, polyacrylate crystals, radish seeds, and brine shrimp eggs. All of the items could be viewed with the naked eye and could be seen in more detail with the handheld magnifiers. Then, they looked at these materials with the digital

microscopes. Thus, when a picture appeared on the screen, they could easily relate it to the objects that they had already seen in a direct manner. Then, they viewed brine shrimp that had been placed in a salt water solution. Using the digital microscopes allowed them to see that what had appeared to be floating specks were actually organisms hatching from eggs. This provided a second level of the bridge for these students. They were learning to think more abstractly about what they had seen concretely. They were also connecting this new information to ideas they already held, as evidenced by the student who exclaimed, "Oh man, I just saw one hatch. That is so neat. Just like watching a dog have babies. Look, that one just attacked another one. Can you believe it?"

As the students moved to working with specimens at the cellular level, they were able to build a bridge from their concrete interaction with the materials to the abstract concepts, again using the images on the computer screen as a bridge. For example, they could see and recognize a slice of potato as a specimen that was very familiar to them. They used methylene blue to dye the potato cells. Since they were preparing the slides themselves, they knew what they were viewing on the computer screen. The students expressed surprise at the presence of the potato cells. A female student said, "I didn't think a potato would look like this." A male in her group added, "I can't explain it." Some of the students commented that the potato slice looked like ice crystals. Another group of students said that the digital image of the potato slice looked fish scales. Again, the students were using the images from the digital microscopes to build bridges between what they already knew and what they were learning. They were also using the digital microscopes to build abstract concepts from their concrete experiences.

Later, when they viewed cheek cells, they knew that the matter they had rubbed on the slides had come from inside the cheek of one of their group members. The image of the cheek cells that was displayed on the screen introduced them to another concept that was new to them. They had not realized that the inside of the human cheek was composed of cells. The image on the computer screen made a bridge between the concrete activity of rubbing a toothpick against the interior of a human cheek and the abstract notion that the cheek tissue is composed of cells that have nuclei. The students could see the nuclei of some of the cells, so they had another abstract concept that was bridged to their concrete experience.

After viewing "mystery items" in the vials, plant cells, and animal cells (human cheek cells), they were introduced to the concept of single-celled organisms that live in a drop of water. By this time, the students comprehended that the images they were viewing on the computer screen were of real organisms that existed in the drop of water. They also related this concept to the one they had already formed of tiny brine shrimp that lived in a drop of water. Viewing the digital images helped them to form abstract concepts related to protists. The students recognized the value of the digital microscopes as tools that helped them to learn the concepts presented in this unit. Laqueta expressed this thought when she told me, "Well, we looked through the microscope at paramecium and amoebae and some other things. You get to see different things. You get to see what's inside of them – like inside the paramecium and stuff. It helped me to learn about cells and helped us grow up to be scientists." Rashad said, "I think looking in the microscope and writing down what you saw - that helped me the most. Actually seeing it in real life helped me to understand it. It's better than looking in a book. I really didn't like the book part. I can't see how the cells really look and how they move. To me, it's really better using microscopes than anything else." William

stated, “Using the microscopes was most helpful to me. We saw what was really going on with the cells.” When I asked Kayla about her perceptions of the microscope use, she replied, “I liked it a lot. It was better than reading the books all the time. I liked the whole hands-on kind of thing. You got to actually like look at them instead of just reading about them. You could see how they behaved or whatever. Using the microscope helps you understand better.” She added, “I wish they [digital microscopes] were in all science classrooms. I think they would give you a better understanding of what you were doing.”

The students in Ms. Delta’s class appreciated the fact that they could use the digital microscopes to take still pictures and video clips of the digital images they were viewing on the computer screen. Robert’s comments regarding this capability included, “I think it was a good feature. We could find stuff and be able to take a picture and groups who couldn’t find amoebae could come over and look at our pictures and movies.” Then he added, “When we found colonies of brine shrimp or euglena or paramecium, we took pictures. Then, we could show them to the teacher. We took movies of the paramecium eating. We could see them moving to the yeast, and we used it to show the teacher what we'd been looking at.” Videos allowed the students to review the actions of the specimens. They could also view the interactions repeatedly and analyze them. Sometimes one student would say that a specimen was acting a certain way that the others had not observed. The students would watch the video as a small group and look for the behavior one of the members had claimed to see. Then, they would discuss the behavior and make speculations regarding what they thought was occurring. Robert also found printed pictures from the digital microscopes to be useful to him in learning the objectives of this unit. He stated, “She printed out pictures and put on the

bulletin board. People who came down hall would look to see what we were learning. It helped me to look at the pictures and see them again."

The fourth element in the CLD model is called "questions." In this model, questions are used to help inspire students to analyze, synthesize, extend, and integrate what they are learning. At the beginning of this unit, I heard Ms. Delta frequently asking questions that helped the students to process what they were viewing. Some of the questions I heard her ask were the following.

> "In Vial A, did you think it was living or nonliving? What was your reason?"
> "Do you see any signs of life in Vial C?"
> "What evidence did you find that made you think that the mystery substance in Vial D is a seed?"

As the unit progressed from the investigation of the "mystery substances" in the vials to the examination of plant cells, animal cells, and protists, I noticed that Ms. Delta asked these types of questions much less frequently. She continued to provide directions for the students, and she continued to ask them to make sketches and written records of their observations. She circulated among the groups and looked at what they were viewing. However, she told me that she had thought that the most effective approach would be to allow the students to work as scientists, without much input from her. Her goal was to provide the directions and the supplies and to allow them to discover concepts for themselves.

The fact that they could see the computer screen as a group fostered their communication with their group members. The students shared thoughts and observations with members of their groups. They also asked each other questions and offered answers to questions asked by their group mates. Some of the questions that I heard them ask their group members are listed below.

> "What is that red spot? It looks like his eye, but it's dark on all the others? I wonder why this one is red."
> "What's that?"
> "Why do you think those paramecium keep bumping into each other?"
> "Is that the food he just ate?" (The students viewed the paramecia as they ate red-dyed yeast.)

As one group looked at an elodea leaf, a female student asked, "What do you think that white place is?" The students in her group could see exactly what white spot she was questioning as she pointed to the area on the screen. Another female student in her group replied, "It must be a tear in the leaf." The first student said, "Yeah, but look at the leaf. I don't see a tear." The second student said, "Maybe it's too small to see without the microscope."

Students also used the images that they captured with the digital microscopes to analyze data. The students expressed thoughts to their group mates as they watched the specimens on the computer screen. By making observations on different days, and then being able to compare the images taken from more than one day, the students began to clarify their assumptions. They decided that some of their initial speculations were inaccurate as they continued to observe and to compare the images. They refined their original statements regarding what they thought they were observing. I heard students making statements that began with "I thought" and then later included "but now I think" as they reviewed the images and continued to make observations. Ms. Delta reminded the students that they were working like real scientists as they refined their conjectures.

The fifth element of the CLD model, "exhibit," refers to having the students share what they are learning with others. The authors also refer to the exhibits as "artifacts of learning" (Gagnon & Collay, 2001, p. *xi*). As already explained, the students shared what they were learning with their group members as they used the digital microscopes. They also shared information with the teacher and with other groups as they compared still pictures and

video clips that they had captured. I had hoped that the students would also share their learning through a multimedia project made with the software that accompanies the digital microscopes. However, the teacher did not want the students to spend time creating a multimedia presentation, so none was created. In addition to the pictures captured by the digital microscopes, the students also recorded sketches and written observations in a notebook. The notebook also contained written activities from the Diversity of Life kit that related to the observations they were making. Ms. Delta checked their notebooks twice during the unit of study. A copy of the checksheet that she used has been placed in Appendix O. The checksheet lists the artifacts of learning that each student was expected to complete. The content test designed for this research study also provided an artifact of learning for each student. The results of how well the students performed on this test were presented in chapter 4.

The final element in the CLD model, "reflections," allows students to think critically about what they are learning, to apply their learning to other areas of the curriculum and to their lives, and to think about future opportunities for learning. One way that Ms. Delta used the digital microscopes to help the students reflect was to have them compare pictures that they had taken with those taken by other groups of students. However, I think that she missed some opportunities to help the students reflect on what they were learning. She did not emphasize to them that all organisms are made of cells, that the cell is the basic unit of life, or that all cells carry out similar processes. She wanted the students to discover these concepts for themselves, but I think that the unit would have been more effective if this final step had been more thoroughly utilized. Ms. Delta did not help her students to see how plant and animal cells were different and alike. The pictures that they captured with the digital

microscopes could have provided a means of helping the students to reflect on these concepts. After the unit ended, Ms. Delta realized that she had neglected this opportunity. When I interviewed her regarding what she had learned from teaching this unit, she told me that she had learned that she needed to spend more time helping the students to reflect on what they were seeing and helping them make connections from what they were viewing to the concepts that she wanted them to learn. When she examined the results of their content tests, she realized that some of the students had not developed some of the concepts that she thought they were discovering for themselves.

In conclusion, the digital microscope served as a mindtool for the students in Ms. Delta's classroom. Students used this tool to bridge concepts they had previously learned to those that were presented in this unit on cells. The digital microscope also served as a means for the students to make connections from the concrete learning activities to the abstract concepts presented in this unit. After the unit ended, Ms. Delta realized that she might have used the microscopes more effectively as mindtools if she had spent more time helping the students to reflect on their activities and the concepts and helping them to process the abstract concepts.

Research Question Six

What comparison information can we learn from the selected middle grade students who have access to the use of digital computer microscopes, during the unit on cell theory, regarding the use of two types of digital microscopes, the Digital Blue™ QX5™ microscope and the ProScope™ digital microscope, in their study of cell theory?

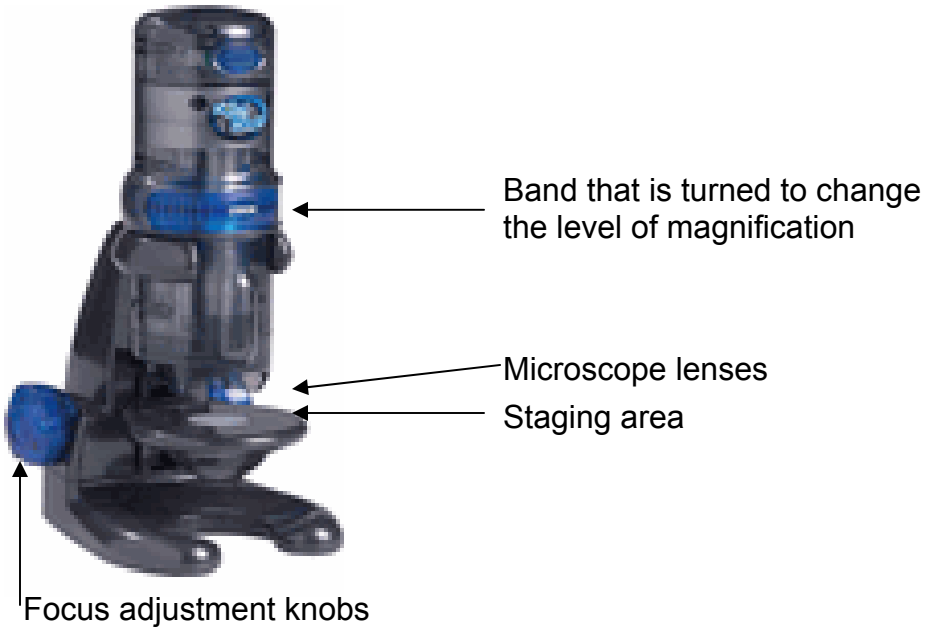
Two types of digital microscopes were used in this study. One brand of microscope is more expensive than the other one. I wanted the teacher and the students to have the

opportunity to try both types of microscopes. If the more expensive microscope provided an appropriate learning opportunity, but the less expensive one were inadequate for the students' needs, then teachers would not want to waste valuable funds for instructional materials on the less expensive microscopes. They might decide that it is worthwhile to purchase a few of the more expensive microscopes. Conversely, if the less expensive one should meet the students' needs in a manner similar to the more expensive one, then that information could be very helpful to classroom teachers, especially those in rural school systems where local funding for digital microscopes may be limited. Therefore, Ms. Delta's students had access to three microscopes of each model. Ms. Delta ensured that all students had the opportunity to use both of types of microscopes. I observed the students as they worked with both types, and as I interviewed the four students from her classroom, I asked them to compare the use of the two types. I also asked Ms. Delta to share her insights regarding the use of the two types of microscopes.

Ms. Delta and her students used three Digital Blue™ QX5™ (Prime Entertainment, 2005) computer microscopes and three ProScope™ (Bodelin Technologies, 2004) computer microscopes. A Digital Blue™ QX5™ computer microscope can be purchased for about $80.00 and is connected to the computer by a USB port. Each microscope comes with three lenses to allow magnification at 10X, 60X, and 200X. The microscope is accompanied by software that allows the students to view digital microscope images, capture and edit still pictures, make and edit digital video clips, and create time-lapse movies. The ProScope™ computer microscope costs about $745.00 for a set that includes the microscope and stand, and 10X, 50X, 100X, and 200X lenses, and a c-mount adaptor that allows it to be used with an analog microscope, converting the analog pictures to digital pictures. Like the Digital

Blue™ QX5™ computer microscope, the ProScope™ is also accompanied by software that allows the user to view digital microscope images, capture and edit still pictures, make and edit digital video clips, and create time-lapse movies. This product also allows the user to capture images from an analog microscope that can be attached to the ProScope™. Thus, the ProScope™ can capture pictures from an analog microscope and save those images in a digital format. Detailed descriptions of the Digital Blue™ QX5™ computer microscope and the ProScope™ computer microscope were provided in chapter 1 of this document.

One difference in the types of microscopes is the manner in which the magnification is changed. The Digital Blue™ QX5™ looks similar to a traditional analog microscope. The slide is placed on the staging area, similar to a traditional microscope. The user can change the magnification power by turning the middle area of the microscope. In addition to using this microscope in a manner similar to the way a traditional microscope is used, the microscope can also be removed from the stand and used as a handheld microscope. The students in Ms. Delta's class found that using it as a handheld device required a steady hand. If the specimen fit on the staging area, they preferred to use the microscope on the stand. However, they found that if the specimen were too large to fit on the staging area, the microscope could be removed and held near the specimen. A picture of the microscope is shown in Figure 5.

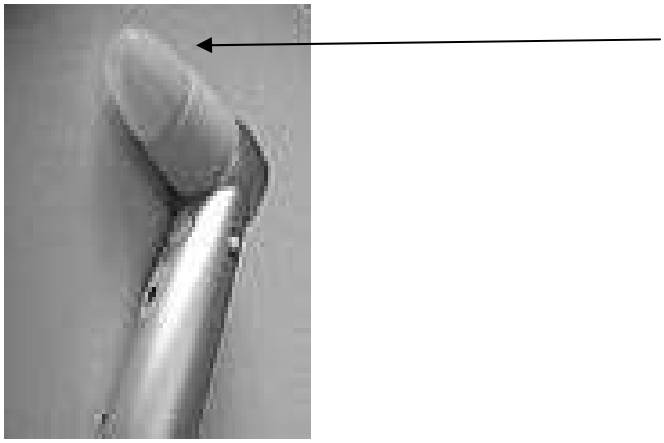


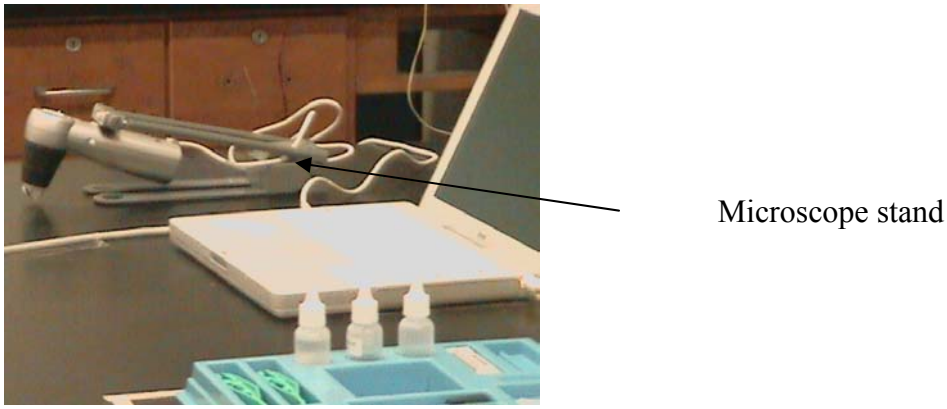
Picture of Digital Blue™ QX5™ attached to computer in Ms. Delta's classroom

Figure 5: Pictures of Digital Blue™ QX5™ Computer Microscope

The ProScope™ computer microscope has separate lenses. To change the magnification, one must remove the lens and replace it with another lens. There is no focus adjustment knob. The microscope can be used as a handheld device. When it is held, the focus is adjusted by manually moving it closer to or farther from the specimen. Like the Digital Blue™ QX5™, a steady hand is necessary to produce a quality image on the computer screen. Ms. Delta's students discovered that this model produced better results when they used the microscope stand. In order to focus the microscope, they had to move it

closer to or farther from the specimen. They found it more difficult to get this microscope focused because small movements were difficult to produce with the stand. They also did not like the fact that the lens had to be removed and replaced to change the magnification. This process also required the students to focus the image after each lens change. As I observed the students, I noticed that most of the time the students used the 100X magnification. When I asked students why they were not changing the lens, the answers were always similar. The students indicated that it was too much trouble and that the 100X lens usually gave the most satisfactory results to them. Although the ProScope™ set that was used in Ms. Delta's room had a c-mount adapter to use the ProScope™ with an analog microscope, we could not make the adapter fit the student microscopes that belonged to the school. We tried holding the ProScope™ to the analog microscope, but that did not give satisfactory results. The pictures in Figure 6 show the ProScope™ computer microscope.



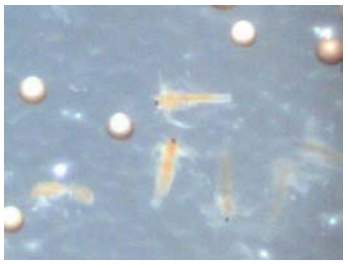


ProScope™ on stand in Ms. Delta's classroom

Figure 6: Pictures of ProScope™ Digital Microscope

When I interviewed the four students in Ms. Delta's classroom, I asked them, "If you worked with both brands of microscopes, which one did you think was better? What did you like better about that microscope than the other one?" All four students stated that they had used both models of computer microscopes. One student, DeAndrea, indicated that she liked both microscopes. Her preference depended on the size of the specimen that she was viewing. She said, "The ProScope™ was better for the vials, and the Digital Blue™ was better on slides." The other three students stated that they preferred using the Digital Blue™ QX5™ computer microscope. Robert told me, "The ProScope™ was hard to focus. Most of

the time when we tried to focus it, we ended up putting it in the water - the solution. You could not change the focus easily. You had to leave it on the same magnification because it was more difficult to change the magnifying piece. Ms. Delta pointed out that it's good to use in the field, but I found a problem. None of us had a good steady hand. We had to stick the paper under it to get a better view. Whereas on the Digital Blue™, we had a top light and a bottom light. We also had a good place to put the slide. It just worked better." Ike said, "I think the Digital Blue™ was a little bit better than the ProScope™. You don't have to put no paper under the Digital Blue™. You don't have to keep moving it around to see what's going on. It's easier to use." He also stated, "The Digital Blue™ is just better. They have a bottom light and a top light. You can magnify from 60 to 200. You can make the light bright or dim. You can move it up or down." Laqueta shared her insights as she said, "I used them both. I liked the Digital Blue™ better because you could find stuff quicker on it. The ProScope™ – you had to search for it and stuff. The Digital Blue™ seemed clearer. The Digital Blue™ is better." Ms. Delta's comments were similar to DeAndrea's. She thought that the ProScope™ was fine for viewing larger items. She enjoyed holding it as she examined some of the larger specimens, such as the yeast and red sand. Although she noted that the Digital Blue™ also worked well for viewing these items, she preferred the ProScope™ as a handheld microscope. However, she preferred the Digital Blue™ for viewing the slides. She especially noticed how much more easily the students were able to adjust the focus when using the Digital Blue™. She said that if she had a budget to spend on digital microscopes to be used in the middle school unit on cells, she would use the money to purchase a set of Digital Blue™ microscopes rather than buying a ProScope™ microscope. Pictures from both types of microscopes are shown in Figure 7.

Pictures captured with the Digital Blue™ QX5™ computer microscope	Pictures captured with the ProScope™ computer microscope
	
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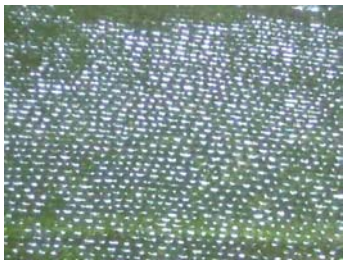
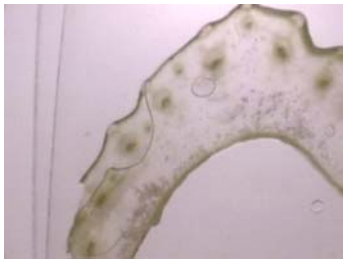
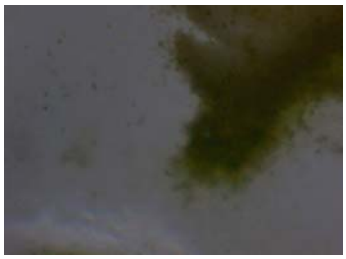
	
Elodea Leaf	
	
Slice of Celery Stalk	

Figure 7: Comparison of pictures taken with Digital Blue™ QX5 Digital Microscope and ProScope™ Digital Microscope

Paramecia



Euglena

Figure 7: (continued)

SUMMARY

Reform in science education has been an American concern for about a century. National events have played a role in refueling the interest in this area. The launching of the Soviet spacecraft Sputnik on October 5, 1957, was one of those defining moments. The national sense of fear that the United States was lagging behind the Soviet Union in the exploration of the space frontier led to a sense of urgency in improving science education. For approximately the next 15 years, there was a national emphasis on reforming science education. However, these reform efforts lacked the establishment of policies at the state and local levels needed to sustain the innovative processes, and momentum for these programs was lost (Bybee, 1997; Rutherford, 1997).

In recent years, a new national emphasis on improving science education has occurred. Rutherford (1997) proposed that the current national events that have rekindled American interest in science education reform are the rivalry for international trade and the competition for high scores in international education tests. Bybee (1997) and Rutherford agree that systemic change is important for lasting, effective educational reform in science education. Both also agree on the importance of this reform including an emphasis on improving science education for all students, not just for those labeled as the brightest students.

Project 2061 was begun by the American Association for the Advancement of Science (AAAS) in 1985. The goal of this project was to help all Americans attain science literacy. In 1989, this project published *Science for All Americans*. This publication outlined the need for all Americans to become literate in science, and it provided recommendations on how this goal might be achieved. The authors acknowledged that changing people, and

changing a huge enterprise such as the American education system, is a very slow process. Thus, they recommended systemic change that would support long-term efforts at reform (AAAS, 1989). In 1993, the AAAS published *Benchmarks for Science Literacy*, which provided content guidelines for clusters of grade levels.

In North Carolina, state standards were developed that were based on the national benchmarks (NCDPI, 2004a). These standards call for changes in the content and skills that students are taught. Practices such as inquiry-based teaching, learning that is grounded in concrete activities, and active engagement in learning activities are encouraged. While progress has been made in implementing these standards, much work remains to be done in implementing the principles and reforms in science teaching that accompany these standards (Anderson & Helms, 2001; Edelson, 2001; Roseman, 1997; Sarason, 1996; Songer et al., 2002).

A review of the literature suggested a need for improvement in middle school science education. Data from the 1995 Third International Mathematics and Science Study (TIMSS) suggest that the longer the student stays in an American school, the worse his/her progress is, when compared to the test results of students in other nations. Research examining National Assessment of Educational Progress (NAEP) scores showed that during the middle school years, students' interest in learning about science declined (Simpson & Oliver, 1985; Yager & Penick, 1986). Simpson and Oliver (1990) found that student attitudes toward science are positively correlated with student motivation and achievement in science courses. They also noticed that the students' attitude toward science is a strong predictor of achievement in future science courses. Singh et al. (2002) found that the success students experience in

science courses in middle school is related to whether they choose to take science electives in high school and whether they choose to pursue careers in the field of science.

Research studies on teaching and learning in middle schools have shown a need for the curriculum to be relevant, challenging, and exploratory. Studies also show a need for multiple approaches to teaching and learning, to which a diversity of students can respond, to be implemented in middle school classrooms (National Middle School Association [NMSA], 2003a). The need for improvement in middle school teaching methods that promote the success of a diversity of students in science courses is evidenced in the results of national testing scores. Data from the 1995, 1999, and 2003 TIMSS (U.S. Department of Education, National Center for Education Statistics, n.d.) administrations show a persistent gap between males and females in the eighth grade. While the gap between African American and White students in the eighth grade has narrowed from 122 score points in 1995 to 89 score points in 2003, a troubling difference remains (Gonzales et al., 2004).

Studies regarding the use of technology in the classroom have shown promise in improving some areas of education (Apple Computer, 1995, 2002, 2005; Christmann & Badgett, 1999; James et al., 2000; Kulik, 2002; Mann et al., 1999; Roschelle et al., 2000; Sandholtz et al., 1994; Sivin-Kachala & Bialo, 2000; Waxman et al., 2002), but more needs to be learned. A specific area of need is the use of technology to improve middle school students' attitudes and achievement in middle school science. This researcher was interested in the use of technology as a mindtool. Jonassen and Carr (2000) define a mindtool as a device, such as computer, that can be used to help students build a bridge from a concrete experience to an abstract concept. Linn (2003) specifically noted the need for research into the use of computer technology specifically as a mindtool that could foster visualization.

The purpose of this study was to investigate the use of microscopes in the study of cell theory at the middle grades level. The researcher examined the use of technology in the teaching of cell theory at the middle school level. The researcher proposed that the presence of technology, in the form of microscopes – especially digital microscopes attached to computers – may foster constructivist learning and student engagement, facilitate understanding of content related to middle grades cell theory, and encourage positive attitudes toward the learning of science. Situated in the classrooms of three middle school teachers in a rural school system in North Carolina, this study examined the variable of microscope use on three levels – no microscopes, analog microscopes, and digital microscopes – during the middle school unit on cells. While the focus of the study was to examine the use of technology in teaching cell theory, this study also compared the use of digital microscopes to a more traditional type of technology – analog microscopes – and to a control situation where no microscopes were provided to the students.

The teachers were the three teachers from the selected school district who were licensed in middle grades science and who were planning to teach a unit on cell theory during the 2004-2005 school year. All three teachers used the textbook *Integrated Science: Interactions and Limits* (Parke, Stanford & Stiffler, 2000) and the Full Option Science System (FOSS) Diversity of Life kit (Lawrence Hall of Science, UC Berkeley, 2003a) to teach the North Carolina Standard Course of Study Goal Six (see Appendix G) on cell theory. In addition to the kit materials, one teacher, Ms. Alpha, used six analog microscopes. Another teacher, Ms. Delta, used six digital microscopes. The third teacher, Ms. Nu, did not use any microscopes. Thus, she and her participating students formed the comparison group.

Following the recommendations of Brewer and Hunter (1989), this study consisted of two complementary components – a quantitative part and a qualitative part. The quantitative part of this study employed a quasi-experimental pretest-posttest comparison-group design. The design was considered to be quasi-experimental because the students were not assigned randomly to groups. Rather, the groups of students were selected based on their membership in one of the three teachers' classes. The quantitative component examined changes in student attitudes toward science as measured by pretests and posttests using the Scientific Attitude Inventory II (Moore & Foy, 1997; see Appendix A). The quantitative component of the study also investigated changes in the students' content attainment as measured by pretests and posttests using a content test (see Appendix B) developed for this unit of study. The results of these tests were analyzed using Microsoft Excel to provide descriptive statistics and SAS 9.1.3 for Windows to conduct an Analysis of Covariance.

The qualitative portion was an instrumental case study, as defined by Stake (1995). The purpose of the qualitative component was to provide insights into how the students and teachers viewed the teaching of this unit when no microscopes were used, and with the addition of the analog and digital microscopes into the unit on cell theory. The researcher proposed that when students used digital microscopes to observe cells and to capture images of them, they may become more engaged in their learning than when technology is not present. Thus, she observed students in all three teachers' classes to see how they responded to the unit of study when no microscopes were used (in Ms. Nu's room) and with addition of microscopes (analog microscopes in Ms. Alpha's room and digital microscopes in Ms. Delta's room). She was particularly interested in observing the students' engagement in learning in each of the three classroom situations. Student interviews provided insights into

the students' attitudes toward the unit on cell theory in each of the three classroom environments. Interviews with the teachers provided additional data regarding how the teachers viewed the addition of analog and digital microscopes into the middle school unit on cell theory.

Discussion of the Findings

This chapter presents a discussion of the findings of this study. The results of the quantitative part were provided in chapter 4 and the analysis of the qualitative data were detailed in chapter 5. The purpose of this chapter is to provide a discussion of the quantitative data analysis, a summary of the qualitative results, and a discussion of how the two types of data complement each other.

Discussion of Quantitative Data – Descriptive Statistics Related to the Content Test

In chapter 4, Table 4.2 provided the content pretest and posttest data disaggregated by racial identity and by gender for each teacher's students who participated in this study. The researcher was interested in noting the differences in gains from the pretest mean to the posttest mean scores on the content test for male and females and for African American students and White students. These data were examined for each of the three learning environments – with no microscopes, with analog microscopes, and with digital microscopes.

In Ms. Nu's class, where no microscopes were used, the African American males made a gain of 5.45 points from the mean pretest to the mean posttest scores on the content pretest as compared to the White males who made a gain of 2.97 points. Thus, the African American males made a larger gain than the White males. However, the sample, especially for the White males, was too small for this difference to be meaningful for generalizations. The African American females made a gain of 5.60 points from the mean pretest to the mean

posttest scores versus the White females who made a gain of 7.00 points on the content test. Thus, the White females made a slightly larger gain than the African American females from the pretest mean to the posttest mean score on content test. However, the sample, especially for the White females, was very small, and the difference between the number of points gained by these two groups was very small.

In Ms. Alpha's class, where analog microscopes were used, the African American males made a gain of 4.48 points from the mean pretest to the mean posttest scores on the content test as compared to the White males who made a gain of 4.5 points. While the sample was small, especially for the White males, it is interesting to note that the two groups had very similar gains from the mean content pretest score to the mean content posttest score. The African American females made a gain of 6.84 points from the mean pretest to the mean posttest scores on the content test versus the White females who made a gain of 4.8 points. The gain made by the African American females was larger than the gain made by the White females. However, the samples were small, especially for the White females, and the difference between the number of points gained by each of the two groups was also small.

In Ms. Delta's class, where digital microscopes were used, the African American males made a gain of 5.08 points from the mean pretest to the mean posttest scores on the content test as compared to the White males who made a gain of 4.32 points. Thus, the African American males made a larger gain than the White males. However, the difference between the gains of these two groups was very small, as there was less than one point difference between the two numbers. The African American females made a gain of 6.05 points from the mean pretest to the mean posttest scores, while the White females made a gain of 5.13 points. Thus, the African American females made a slightly larger gain than the

White females. However, the sample, especially for the White females, was very small, and the difference between the numbers of points gained by these two groups was less than one point.

This researcher was interested in examining the data disaggregated by racial groups due to the results of a national testing program in science. The National Center for Education Statistics of the U.S. Department of Education (2003) released a report card on science education in the United States. A summary of the 2000 National Assessment of Educational Progress (NAEP) and a comparison to this assessment in 1996 were provided in that report. The report noted a gap in the scores when the scores were disaggregated by race. Among the eighth grade students tested in 2000, the average scale score was 162 for White students, compared to an average scale score of 122 for Black students. The report also noted that eighth-grade students whose science teachers reported that their students used the computer data analysis, simulations, modeling, and other applications had a higher average score than those students whose teachers did not report these types of activities. Thus, this researcher was interested in reporting the scores of the students by racial groups. The data discussed above showed that there was very little difference in the gains made from the mean pretest to the mean posttest scores on the content test by the students participating in this study of each racial group in each of the three learning environments – with no microscopes, with analog microscopes, and with digital microscopes.

The researcher was also interested in noting the gains from the pretest mean to the posttest mean scores on the content test for male and female students in each of the three learning environments. In Ms. Nu's class, where no microscopes were used, the African American males made a gain of 5.45 points from the mean pretest to the mean posttest scores

on the content test, while the African American females made a gain of 5.60 points. Thus, there was very little difference between the gains made by these two groups. The White males made a gain of 2.97 points from the mean pretest to the mean posttest scores on the content test as compared to the White females who made a gain of 7.00 points. Although the White females made a larger gain than the White males, the samples for these two groups were very small, making generalizations impossible.

In Ms. Alpha's class, where analog microscopes were used, the African American males made a gain of 4.48 points from the mean pretest to the mean posttest scores on the content test as compared to the African American females who made a gain of 6.84 points. The White males made a gain of 4.5 points from the mean pretest to the mean posttest scores on the content test versus the White females who made a gain of 4.8 points. The data from this class showed that the female students in Ms. Alpha's class made slightly larger gains than the male students. However, the samples were small, especially for the White students, and the difference between the gains of the White males and White females was less than half a point.

In Ms. Delta's class, where digital microscopes were used, the African American males made a gain of 5.08 points from the mean pretest to the mean posttest scores compared to the African American females who made a gain of 6.05 points. The White males made a gain of 4.32 points from the mean pretest to the mean posttest scores versus the White females who made a gain of 5.13 points. The data from this class showed that the female students made slightly larger gains than the male students in this class. However, the samples were small, and the differences between the groups was also were also very small.

In this study, an examination of test scores by gender was an important component. The report released by The National Center for Education Statistics of the U. S. Department of Education (2003), provided a summary of the 2000 National Assessment of Educational Progress (NAEP) and a comparison to this assessment data in 1996. These data showed that among eighth grade students, the mean scores of the male students was significantly higher than the mean scores of the eighth grade female students, with a mean scale score of 154 for males and for 147 females. In addition, an analysis of the TIMSS data from 1995, 1999, and 2003 also showed a persistent gap between males and females in the eighth grade. While both groups made progress, the gap between their mean scores has remained fairly steady. In the last three administrations of this study, the males scored an average of 15 points higher than the females in 1995, 19 points higher in 1999, and 17 points higher in 2003.

In light of the data presented on national testing programs in the preceding paragraph, it was important to examine the data from this current study to see if there were large discrepancies between the gains made by groups of students, based on gender, from the pretest mean to the posttest mean scores on the content test. In all three learning environments presented in this study, the female students in each racial group made slightly larger gains from the mean pretest to the mean posttest scores on the content test than the male students in each racial group. However, the samples for the groups in these classes were small, so generalizations should be made with caution.

Discussion of Quantitative Data – Hypothesis One

Hypothesis One: There will be a significant difference ($p<.05$) among the population mean posttest scores on the content test for the three groups (Digital, Analog, None) after

adjusting for the effects of the pretest scores. The Digital group will be significantly higher than the Analog group and the None group.

The statistical analysis showed that the mean scores on the content test for each of the three teachers' classes were very similar. In Ms. Nu's class, where no microscopes were used, the mean pretest score (n=79) was 8.20, the mean posttest score (n=83) was 13.72, and the difference between the pretest and posttest mean scores was 5.52 points. In Ms. Alpha's class, where analog microscopes were used, the mean pretest score (n=60) was 9.15, the mean posttest score (n=60) was 14.37, and the difference between the pretest and posttest mean scores was 5.22 points. In Ms. Delta's class, where digital microscopes were used, the mean pretest score (n=86) was 8.95, the mean posttest score (n=93) was 14.39, and the difference between the pretest and posttest mean scores was 5.44 points. Thus, these data show that the mean scores and the difference in the mean pretest and posttest scores on the content test were very similar for all three groups of students.

An analysis of covariance (ANCOVA) was conducted to compare the means of the posttest scores of the content test for each of the three teachers (one who used digital microscopes, one who used analog microscopes, and one who used no microscopes) while controlling for the covariate, the pretest scores. The results of the ANCOVA showed that there was no statistically significant difference between any of the three groups for the variable of "Teacher" when controlling for the pretest as a variable. (The variable "Teacher" referred to whether the student was in Ms. Nu's classroom where no microscopes were used, Ms. Alpha's room, where analog microscopes were used, or in Ms. Delta's room, where digital microscopes were used.) The hypothesis was not supported. There was not a significant difference ($p<.05$) among the population mean posttest scores on the content test

for the three groups (Digital, Analog, None) after adjusting for the effects of the pretest scores. The Digital group was not significantly higher than the Analog group or the None group.

While generalizations should be made with caution, the results of this study showed that the students who participated in this study performed equally well in all three learning environments on the content test. When the content posttest scores were adjusted for the effects of the pretest, the students who used no microscopes performed as well on the content posttest as the students in the classroom where analog microscopes were used and in the classroom where digital microscopes were used.

Discussion of Quantitative Data – Descriptive Statistics Related to the SAI II

In chapter 4, Table 4.11 provided the SAI II pretest and posttest data disaggregated by racial identity and by gender for each teacher's students who participated in this study. In Ms. Nu's class, where no microscopes were used, the African American males made a gain of 0.42 points from the mean pretest to the mean posttest scores on the SAI II compared to the White males who made a gain of 6.92 points. Thus, the White males made a larger gain from the pretest mean score to the posttest mean score than the African American males. However, the sample, especially for the White males, was too small for this difference to be meaningful for generalizations. The African American females made a gain of 1.57 points from the mean pretest to the mean posttest scores versus the White females who made a gain of 5.89 points. Thus, the White females made a larger gain than the African American females. However, the sample, especially for the White females, was very small.

In Ms. Alpha's class, where analog microscopes were used, the African American males had a negative change in points from the mean pretest to the mean posttest scores on

the SAI II. The mean posttest score was 8.23 points lower than the mean pretest score. The White males also had a negative change from the mean pretest to the mean posttest scores. However, their change of 0.25 points was a smaller difference than the change for the African American males. The African American females had a loss of 2.59 points from the mean pretest to the mean posttest scores on the SAI II as compared to the White females who made a gain of 3.2 points. The White females were the only subgroup of students in Ms. Alpha's class who exhibited a positive change from the pretest to the posttest mean score on the SAI II. However, the samples, particularly of the White students, were very small.

In Ms. Delta's class, where digital microscopes were used, the African American males made a gain of 1.77 points from the mean pretest to the mean posttest scores on the SAI II compared to the White males who made a gain of 7.37 points. Thus, the White males made a larger gain than the African American males. The samples were small, so generalizations should be made with caution. The African American females made a gain of 2.32 points from the mean pretest to the mean posttest scores on the SAI II as compared to the White females who made a gain of 8.5 points. Thus, the White females made a larger gain than the African American females. However, the samples, especially for the White females, were very small.

This researcher was interested in comparing the results of the SAI II of males to females, as well as comparing the gain in scores of the two racial groups. In Ms. Nu's class, where no microscopes were used, the African American males made a gain of 0.42 points from the mean pretest to the mean posttest scores on the SAI II compared to the African American females who made a gain of 1.57 points. The White males made a gain of 6.92 points from the mean pretest to the mean posttest scores on the SAI II, while the White

females made a gain of 5.89 points. Thus, the African American females made a slightly larger gain than the African American males, and the White males made a slightly larger gain than the White females. The differences between gains for males and females in each racial group were very small. Also, the samples, especially for the White students, were very small.

In Ms. Alpha's class, where analog microscopes were used, the African American males showed a loss of 8.23 points from the mean pretest to the mean posttest scores on the SAI II as compared to the African American females who had a loss of 2.59 points. The White males had a loss of 0.25 points from the mean pretest to the mean posttest scores on the SAI II versus the White females who made a gain of 3.2 points. The data from this class showed that African American male students made the largest drop in scores from the mean pretest to the meant posttest scores of the SAI II. Only the White females had a positive difference from the pretest to the posttest on this instrument. However, samples, especially for the White students, were very small.

In Ms. Delta's class, where digital microscopes were used, the African American males made a gain of 1.77 points from the mean pretest to the mean posttest scores on the SAI II as compared to the African American females who made a gain of 2.32 points. The White males made a gain of 7.37 points, while the White females made a gain of 8.5 points. The data from this class showed that the female students made slightly larger gains than the male students. However, the samples were small, and the differences in gains between the male and the female students were very small.

The samples for the groups in these classes were small, so generalizations should be made with caution. However, it was important to examine the data to see if there were large discrepancies between the gains made by groups of students from the mean pretest to the

mean posttest scores on the SAI II. While there were some differences in the scores between the groups, the differences were small. In two of the learning environments – where no microscopes were used and where digital microscopes were used – all of the groups of students showed a positive gain from the mean pretest to the mean posttest score of the SAI II. In the classroom where analog microscopes were used, three of the four groups of students showed a decline in scores from the mean pretest to the mean posttest scores. In this classroom, only the White females, which were a very small sample, showed a gain from the pretest mean to the posttest mean scores on the SAI II.

Discussion of Quantitative Data – Hypothesis Two

Hypothesis 2: There will be a significant difference ($p<.05$) among the population mean posttest scores on the Scientific Attitude Inventory II for the three groups (Digital, Analog, None) after adjusting for the effects of the pretest scores. The Digital group will be significantly higher than the Analog group and the None group.

The statistical analysis showed some differences among the scores on the SAI II of students in the three teachers' classrooms. In Ms. Nu's class, where no microscopes were used, the mean pretest score (n=77) was 132.61, the mean posttest score (n=84) was 133.85, and the difference between the mean pretest and the mean posttest scores was 1.24 points. In Ms. Alpha's class, where analog microscopes were used, the mean pretest score (n=60) was 136.87, the mean posttest score (n=54) was 132.09, and the difference between the mean pretest and mean posttest scores was -4.78 points. In Ms. Delta's class, where digital microscopes were used, the mean pretest score (n=90) was 133.51, the mean posttest score (n=88) was 136.56, and the difference between the mean pretest and mean posttest scores on the SAI II was 3.05 points. Thus, these data showed positive difference for the students in

Ms. Nu and Ms. Delta's classrooms, but there was a negative difference from the mean pretest to the mean posttest scores of the SAI II for students in Ms. Alpha's classroom.

An analysis of covariance (ANCOVA) was conducted to compare the means of the posttest scores of the SAI II for each of the three teachers (one who used digital microscopes, one who used analog microscopes, and one who used no microscopes) while controlling for the covariate, the pretest scores. The results of the ANCOVA showed that there was a statistically significant difference between the three groups for the variable of "Teacher" when controlling for the pretest as a variable. (The variable "Teacher" referred to whether the student was in Ms. Nu's classroom where no microscopes were used, Ms. Alpha's room, where analog microscopes were used, or in Ms. Delta's room, where digital microscopes were used.) Thus, Scheffe's multiple comparisons test was run to test for significant differences between each group of students. Although the data from the ANCOVA showed that overall the variable of teacher contributed significantly to the posttest score when controlling for the variable pretest, when the more conservative Scheffe test was run to test for multiple comparisons, no significant differences were found among the levels of the variable teacher.

The hypothesis was not supported. There was not a significant difference ($p<.05$) among the population mean posttest scores on the SAI II for the three groups (Digital, Analog, None) after adjusting for the effects of the pretest scores. The Digital group was not significantly higher than the Analog group or the None group.

While no statistically significant difference was found when using the Scheffe test, this test did show that the largest difference was between Ms. Alpha's class (which used analog microscopes) and Ms. Delta's class (which used digital microscopes). It is interesting

that the use of analog microscopes was associated with a decline of mean score from pretest to posttest on the SAI II. The use of no microscopes and the use digital microscopes were associated with an increase in mean SAI II scores, and the largest increase was in the classroom where digital microscopes were used. However, the reader is reminded that none of these differences were found to be statistically significant, so generalizations are not warranted from this test.

Connection of SAI II Data to the Research

Simpson and Oliver (1985) noted some interesting patterns regarding attitudes toward science in middle school students. They found that for their large sample of about 4000 students, attitudes toward science declined steadily from grade six to grade eight. The steepest decline was from the seventh grade to the eighth grade. They also noted that at each grade level, the male students had more positive attitudes toward science than the female students did.

In addition to comparing the attitude changes across grade levels, Simpson and Oliver (1985) also examined the attitude changes that occurred within each grade level. Attitudes were assessed at the beginning, middle, and end of the year for each grade level. In each grade level, the attitudes declined sharply from the beginning of the year to the middle of the year. They also declined somewhat from the middle to the end of the year, but this change was not statistically different.

Yager and Penick (1986) examined data collected from the National Assessments of Educational Progress (NAEP) for three separate studies in three different years – 1977, 1982, and 1984. They found a pattern similar to the one identified by Simpson and Oliver (1985).

In their study, Yager and Penick found that as the students got older, they were less likely to describe science classes as fun, interesting, or exciting.

In this study, only the students in Ms. Alpha's classroom, where analog microscopes were used, had a pattern which matched those reported by Simpson and Oliver (1985) and Yager and Penick (1986). Ms. Alpha's students showed a decline from the mean pretest to the mean posttest scores on the SAI II. However, the students in Ms. Nu's class, where no microscopes were used, and the students in Ms. Delta's classroom, where digital microscopes were used, did not fit this pattern. Rather than showing a decline in SAI II scores, the students in these two classrooms showed an increase from the mean pretest to the mean posttest scores on the SAI II.

Summary of the Qualitative Data

A detailed analysis of the qualitative data was presented in chapter 5. In this chapter, a summary of that analysis for each qualitative research question will be presented.

Research Question One

How might the selected middle grade students be engaged/disengaged in the study of cells when digital microscopes are available for their use compared with the availability of traditional microscopes or the lack of availability of any microscopes?

The data showed that students in all three learning environments – with no microscopes, with analog microscopes, or with digital microscopes – were engaged in the study of cells. However, the classroom observations provided evidence that the students in Ms. Delta's classroom, which included the use of digital microscopes, were more engaged than the students in the other two classrooms. The students in Ms. Delta's classroom could view the images with a group of students and were able to communicate with their group

members and with the teacher about the slide that they were viewing as a group. The observations also provided evidence that Ms. Nu's students, where no microscopes were used, were more engaged when viewing digital images of slides than when reading and discussing content from the textbook. The students in Ms. Alpha's room, where analog microscopes were used, spent more time waiting for the opportunity to view a slide than actually viewing an image through the microscope. They also exhibited off-task behaviors as they waited their turns to view the slide.

In the teacher interviews, each of the three teachers reported that she thought that her students were more engaged in this unit than they have usually are. Thus, a reasonable conclusion seems to be that students in all three classes were engaged in this unit of study, but the students in Ms. Delta's classroom exhibited higher levels of engagement than the students in the other two classrooms.

Research Question Two

How might the selected middle grade students in this rural school perceive the use of images (in text and on a CD-ROM), or the use of analog microscopes, or the use of digital computer microscopes (with corresponding multimedia applications) in their study of cells?

The interviews showed that the students in all three classes were interested in using the visualization tools provided to them. Ms. Nu's students were excited about using handheld magnifiers and viewing pictures projected from a computer. Her students noted that being able to see specimens and pictures helped them to understand the content they were reading. However, they did not have the opportunity to compare this experience to the use of analog or digital microscopes. Ms. Alpha's students indicated that they enjoyed using the analog microscopes and found them to be helpful in learning about cells. However, one

student did express frustration in having to wait her turn to view the slides. Observations of Ms. Alpha's class also showed that students would lose interest and sometimes become frustrated as they took turns viewing the slides under the microscopes. Observations also indicated that the students had more difficulty discussing what they were viewing, especially when looking at protists, than students did in Ms. Delta's classroom. The fact that they could not verify that what one student was seeing was the same view that another student had seen hampered their interaction and their ability to process what they thought they had seen. In addition, the teacher was not able to verify what they were viewing because the image in the viewfinder may change from the time the student was viewing the slide until the teacher was able to view the slide. Students in this class often exhibited off-task behaviors as they waited for their next opportunity to use the analog microscope.

The students in Ms. Delta's room enthusiastically described the use of digital microscopes. The student interviews from her classroom provided more details regarding what they learned than the interviews of students from the other two classes. This distinction was an indicator that the digital microscope served as a better tool than the analog microscope or combination of handheld magnifiers and digital images. The students interviewed from Ms. Delta's class noted the advantage of being able to see the image on the screen at the same time as others in the group. Classroom observations provided evidence that this feature of the digital microscopes offered an advantage for student engagement over the analog microscopes. Three of the four students interviewed from Ms. Delta's class stated that they had used analog microscopes in the past and they preferred using the digital microscopes to the analog microscopes. One of her students wore eyeglasses, and he explained that viewing the computer screen was especially preferable to viewing an analog

microscope eyepiece when wearing glasses. Another advantage of using digital microscopes that Ms. Delta's students discovered was that they could take pictures and videos to view later with their group, with students from other groups, and with the teacher. They also realized that they could enlarge the digital photographs to see more detail than they had originally viewed on the computer screen. Finally, Ms. Delta noted that the students' behavior was better during this unit of study than at any other time during the school year. She attributed that improvement to the interest generated from the use of the digital microscopes.

Research Question Three

When the selected middle grade students in this rural school are taught about cell theory, how do students perceive science instruction in classrooms that include the use of digital microscopes (and corresponding multimedia applications) and in classrooms that do not?

The students in all three classrooms perceived the instruction to be fun and interesting. A student in Ms. Nu's class summed up the students' comments from all three classes when he said that the images helped the students to understand what they were learning. However, another comment from one her students showed that the students using the handheld magnifiers and the digital images from the CD-ROM were at a disadvantage compared to the other two groups when the students were viewing a CD-ROM image of a protist. The student asked, "Ms. Nu, have you ever seen one of those things?" That comment showed that the students in this learning environment were missing the concrete connection of being able to view a slide that the student him/herself had prepared, as contrasted to viewing an image of a slide with no direct, concrete connection to the specimen. In summary,

the data suggest that handheld magnifiers, digital images from the Diversity of Life CD-ROM, analog microscopes, and digital microscopes served as visualization tools that enhanced the study of cells for these middle school students. However, the data from the observations and interviews suggest that the digital microscopes provided the most conducive learning environment for these middle school students in this unit on cells. If each group of students had received the opportunity to use the digital microscopes, they would likely have selected them to be the magnification device that was best suited for their study of this unit on cells.

Research Question Four

How do selected middle grade students who have access to the use of digital computer microscopes, during the unit on cell theory, make use of the multimedia options that are available with these microscopes?

The students in Ms. Delta's class enjoyed taking still pictures and video clips of images viewed with the digital microscopes. They also found it beneficial to review the pictures with their group members and with the teacher. If one group had trouble viewing a specimen, they learned that they could view a picture or video from another group. Ms. Delta's students also learned that they could enlarge images captured with a digital microscope to view the picture in more detail than they had originally seen. The students also found using a captured image to be helpful to them as they sketched a picture of the image from the slide.

The software included with each of the two types of digital microscopes allowed the user to create a multimedia presentation from pictures and videos captured and saved on the computer. However, Ms. Delta decided that she did not want her students to spend time

creating a multimedia presentation. She was focused on having her students use the microscope as a tool to view the specimens, but she did not value having them create multimedia projects to express what they had learned. Therefore, none of the students created multimedia presentations. Ms. Delta did make printed copies of some of the still photographs to display on a bulletin board in the hall. She used the pictures as a display, but she missed the opportunity to use them as a presentation tool to discuss with the students concepts they were learning.

Research Question Five

How do selected middle grade students who have access to the use of digital computer microscopes, during the unit on cell theory, use digital microscopes as mindtools in their learning about cells?

A constructivist learning model created by Gagnon and Collay (2001) provided a structure for examining the digital microscopes as a constructivist mindtool. Gagnon and Collay labeled their six-part model the Constructivist Learning Design (CLD). In Ms. Delta's class, the first part, the situation, was goal six, and its related objectives, from the North Carolina Standard Course of Study, 2004 Version for Eighth Grade, (see Appendix F). Goal Six and the related objectives were aligned with national science standards (AAAS, 1993; National Research Council, 1996). The goals of the FOSS Diversity of Life Course (UC Berkeley, 2003b) were also aligned with the state goal and with the national standards.

The second element, "groupings," referred to the use of groups of three to five students who worked together at a digital microscope station. The digital microscopes served as a tool that fostered the collaboration of students as they worked in teams to view the images and to discuss what they were seeing. The digital microscopes also promoted student

interaction with the teacher, who could view the same images that the students were viewing and discuss the concepts with them.

The third element, "bridge" refers to the scaffolding that is provided to help the students connect the new learning to the knowledge they have already formed in their minds. One way that the digital microscopes provided this scaffolding was that the pictures on the screen provided a representation that bridged the concrete activities to the abstract concepts that were being taught in this unit. The students found the digital microscopes to be a valuable tool that helped them to connect what they were seeing to the concepts they were discussing.

Ms. Delta allowed the students to have concrete experiences, and she used the digital microscopes as tools to help them connect those concrete experiences to the images they were viewing. However, she missed some opportunities to help the students use those images as a vehicle to process the content on an abstract level. If she had projected some of the images that the students captured onto a screen to view as a class, she could have helped them to form more abstract concepts related to what they were viewing. For example, she could have pointed out the visible parts of the elodea leaf cells, such as the cell wall, to the students. She could have had them compare and contrast pictures of plant cells (elodea leaf) to pictures of animal cells (cheek cells.) She might also have helped the students to understand how the cells of the elodea leaf function together to make a more complex structure. She also could have used video clips of protists to show the students how each protist was a complete living organism. The students used the digital microscopes to view the paramecia ingesting Congo red dye stained yeast, but Ms. Delta did not use the videos they captured to lead a discussion regarding how they were watching the paramecia as theses

organisms exhibited one of the processes of life. Thus, Ms. Delta used the digital microscopes and the images produced from them to help the students form a bridge from the concrete experience to an abstract concept, but she missed opportunities to help the students build a more complete abstract understanding of concepts related to cells that were outlined in the state and national standards developed for middle school students.

The fourth element in the CLD model is called "questions." In this model, questions are used to help inspire students to analyze, synthesize, extend, and integrate what they are learning. At the beginning of this unit, I heard Ms. Delta frequently asking questions that helped the students to process what they were viewing. As the unit progressed from the investigation of the "mystery substances" in the vials to the examination of plant cells, animal cells, and protists, I noticed that Ms. Delta asked these types of questions much less frequently. The fact that students could see the computer screen as a group fostered their communication with their group members. The students shared thoughts and observations with members of their groups. They also asked each other questions and offered answers to questions asked by their group mates. Thus, the students asked each other questions, even though I heard Ms. Delta ask questions less frequently. The students also reviewed some of their pictures on their own and revised their thinking about some of the observations they had made. I heard students making statements that began with "I thought" and then later included "but now I think" as they reviewed the images and continued to make observations. Although Ms. Delta might have used questioning more effectively, the use of digital microscopes in groups of students tended to foster that type of questioning even without much teacher prompting.

The fifth element of the CLD model, "exhibit," refers to having the students share

what they are learning with others. The students shared what they were learning with their group members as they used the digital microscopes. They also shared information with the teacher and with other groups as they compared still pictures and video clips that they had captured. This communication was very helpful to the students as they processed the images they were viewing. I had hoped that the students would also share their learning through a multimedia project made with the software that accompanies the digital microscopes. However, the teacher did not want the students to spend time creating a multimedia presentation, so none was created. In addition to the pictures captured by the digital microscopes, the students also recorded sketches and written observations in a notebook. However, the teacher did not help the students to understand the connection between what they had drawn and the concepts related to cells. For example, she did not point out to them that the dot each was drawing inside the picture of the cheek cell was a representation of the cell's nucleus. In summary, the students created and shared artifacts of learning, but Ms. Delta also missed some opportunities to help them create ways, (such as multimedia presentations and labeling of pictures they sketched,) that may have been more meaningful to them as they shared what they were learning.

In conclusion, the digital microscope served as a mindtool for the students in Ms. Delta's classroom. Students used this tool to bridge concepts they had previously learned to those that were presented in this unit on cells. The digital microscope also served as a means for the students to make connections from the concrete learning activities to the abstract concepts presented in this unit. However, Ms. Delta might have used the microscopes more effectively as mindtools if she had spent more time helping the students to reflect on their activities and helping them to process the abstract concepts.

Research Question Six

What comparison information can we learn from the selected middle grade students who have access to the use of digital computer microscopes, during the unit on cell theory, regarding the use of two types of digital microscopes, the Digital Blue™ QX5™ microscope and the ProScope™ digital microscope, in their study of cell theory?

Two types of digital microscopes were used in this study. One brand of microscope is more expensive than the other one. Ms. Delta and her students used three Digital Blue™ QX5™ (Prime Entertainment, 2005) computer microscopes and three ProScope™ (Bodelin Technologies, 2004) computer microscopes. A Digital Blue™ QX5™ computer microscope can be purchased for about $80.00 and is connected to the computer by a USB port. The microscope comes with three lenses to allow magnification at 10X, 60X, and 200X. It is accompanied by software that allows the students to view digital microscope images, capture and edit still pictures, make and edit digital video clips, and create time-lapse movies. The ProScope™ computer microscope costs about $745.00 for a set that includes the microscope and stand, and 10X, 50X, 100X, and 200X lenses, and a c-mount adaptor that allows it to be used with an analog microscope, converting the analog pictures to digital pictures. Like the Digital Blue™ QX5™ computer microscope, the ProScope™ is also accompanied by software that allows the user to view digital microscope images, capture and edit still pictures, make and edit digital video clips, and create time-lapse movies. This product also allows the user to capture images from an analog microscope that can be attached to the ProScope™.

Ms. Delta ensured that all of her students used both types of digital microscope. The students were not aware of the price differences of the two microscopes. When I interviewed

students from her classroom, three of the four students stated that they preferred using the Digital Blue™ QX5™ computer microscope over the ProScope™ digital microscope. The fourth student said that she preferred the ProScope™ for viewing the specimens that were not placed on a slide, such as the red sand and dry yeast. She preferred using the Digital Blue™ QX5™ for viewing the specimens placed on slides. Although each microscope could be used as a handheld tool, she found it a little easier to use the ProScope™ in a handheld manner.

The students found it easier to use the Digital Blue™ QX5™ model when using the microscope in a stand. They found that changing the level of magnification was easier with the Digital Blue™ QX5™ than with the ProScope™ model. The level of magnification could be changed on the Digital Blue™ QX5™ by turning the lens in a manner similar to how the magnification is adjusted on a traditional analog microscope. Changing the magnification on the ProScope™ model involved removing and replacing the lens. The students also found adjusting the focus on the Digital Blue™ QX5™ to be easier than adjusting the focus on the ProScope™. The stand for the Digital Blue™ QX5™ has a control similar to the adjustment knob on a traditional analog microscope. Adjusting the stand and the lens on the ProScope™ is more difficult. The students had to loosen the stand, move and adjust the stand, then tighten the stand. They tried using the ProScope™ as a handheld device when viewing slides, but as one student noted, none of the students was able to hold the microscope steady enough to achieve the focus and image quality desired. Ms. Delta agreed with the students that she preferred the Digital Blue™ QX5™ as a middle school classroom microscope. Like one of her students, she preferred the ProScope™ as a handheld microscope for looking at large objects, but she liked the Digital Blue™ QX5™ for viewing slides. She also said that she

would prefer to spend money designated for microscopes on nine Digital Blue™ QX5™ microscopes rather than on one ProScope™ microscope.

The fact that the students and the teacher preferred the Digital Blue™ QX5™ microscope over the ProScope™ model is important for school personnel who may be considering the purchase of a digital microscope for a middle school classroom. This instrumental case study provided support for the idea that the digital microscopes were appropriate tools for the middle school students in this school system in their study of cells. This study also suggested that digital microscopes were conducive to learning when students used them while working in small groups. School systems would be much more likely to afford the purchase of a set of Digital Blue™ QX5™ microscopes than a set of ProScope™ microscopes. Knowing that in this study, the Digital Blue™ QX5™ served the purpose at least as well as the ProScope™ digital microscope can be very useful information.

Analyzing the Quantitative and Qualitative Data as Complementary Forms of Research

Brewer and Hunter (1989) suggested that quantitative and qualitative research can be used as complementary forms of investigation. This study employed the method of combining two forms of research techniques that Tashakkori and Teddlie (1998) referred to as an equivalent status design. The specific design they defined that applied to the type employed in this study was the Parallel/Simultaneous design, in which quantitative and qualitative data are collected and analyzed from parallel situations during the same time frame.

Analyzing the Quantitative and Qualitative Data in Terms of Content Attainment

The results of the content test, as reported in chapter 4, showed that the students in all three classrooms had very similar scores. The students in Ms. Nu's class, where no

microscopes were used, made a gain of 5.52 points from the mean pretest score to the mean posttest score. In Ms. Alpha's class, where analog microscopes were used, students made a gain of 5.22 points from the mean pretest score to the mean posttest score. Ms. Delta's students, who used digital microscopes, made a gain of 5.44 points from the mean pretest score to the mean posttest score. The Analysis of Covariance (ANCOVA) showed no significant difference among the content test posttest scores for these groups when testing for the main effect of teacher (who used no microscopes, or analog microscopes, or digital microscopes) and controlling for the effect of the pretest.

The qualitative data contributed information that added insight into what the quantitative data provided. From the observations of the three classrooms, I concluded that all three groups of students were engaged in the learning activities provided for them. Yet, I also concluded that the students in Ms. Delta's classroom were more engaged than the students in the other two classrooms. The students interviewed in Ms. Nu's class indicated that the use of handheld magnifiers and digital images helped them to comprehend the material that they were reading and discussing. Observations revealed that a large part of the class time was devoted to reading text, answering questions, and participating in teacher-led discussion. While the student engagement levels were very high when handheld magnifiers were used and when digital images were projected onto a screen, the students appeared to be less engaged during the times that they were assigned to read the text and answer questions from the text. The interviewed students in Ms. Alpha's room reported that they found the analog microscopes helpful to them in learning about cells, but classroom observations and one student interview revealed frustration and boredom as students waited their turns to view slides under the analog microscopes. Observations of Ms. Delta's students showed that they

were the most engaged of any of the three classes as these students worked together in groups to view slides and to discuss what they were seeing and thinking as they observed the specimens. The details that they provided in their interviews added evidence of their engagement with the content. Yet, the quantitative data showed that there was no statistically significant difference between the mean content posttest scores for each teacher's group when controlling for the pretest score as a variable.

A comment that Ms. Delta made in her interview provides insight into one possible reason that the students' content posttest scores may have been very similar for all three groups. The students were very interested in using whatever visualization tools were provided to them. Ms. Delta stated that she thought the reason the students in Ms. Nu's class were excited about using handheld magnifiers was that they had not used these tools in the past. Ms. Nu made a similar comment when she stated that she had not thought that handheld magnifiers had been worth using in the past. Now, after using them in this study, she viewed them as tools that were helpful to her students. A reasonable conclusion may be that since none of these students were accustomed to using visualization tools, they found each of the tools that were provided to be helpful to them in learning about cells. For these three groups of students, each set of tools seemed to be equally effective in helping them to learn the middle school level content related to cell theory.

Another factor that may have contributed to the students' similar results was the fact that this unit was the first time that their teachers had used science kits as the primary resource, rather than a traditional textbook, to teach a science unit this year. Houston et al. (2003) conducted a study comparing the use of traditional science textbooks to packaged science kits. Their sample consisted of 588 students in grades three through five. The

quantitative instrument used was the My Class Inventory (MCI) (Fraser & Fisher, 1983). The students were given a pre-test and a post-test. An analysis of covariance (ANCOVA) showed a significant difference for two variables: Cohesiveness and Satisfaction. The groups of students who used the kits showed considerably larger changes in scores from the other two groups, those who used only the textbook and those who used a combination of the textbook and a science kit. That study provides data that might help to explain why all three groups of students made similar gains on the content test. The fact that this was the first time for the students to use this type of kit may have helped to explain why all of the students, regardless of which visualization tool they used, showed evidence of engagement in the lessons. Nonetheless, the qualitative data lends support to the claim that the students who used the digital microscopes were more engaged in the lessons than the students in the other two environments were.

A third factor noticed from the analysis of the qualitative data that is helpful in examining the content test data was the observation that Ms. Delta spent less time helping her students to process what they were seeing. From the observations and from Ms. Delta's interview, data were provided that showed that Ms. Delta did not spend as much time and effort trying to help her students relate their visual experiences to the concepts that she was trying to teach them as the other two teachers did. As noted in the summary of qualitative research question five (presented in an earlier section of this chapter), Ms. Delta allowed the students to have concrete experiences. She used the digital microscopes as tools to help them connect those concrete experiences to the images they were viewing. However, she missed opportunities to help the students process the content on an abstract level. She could have used the pictures that they captured from the digital microscopes to help them connect the

images they viewed to concepts related to cells. Thus, Ms. Delta might have used the microscopes more effectively as mindtools for helping her students learn the content if she had spent more time helping the students to reflect on their activities and the concepts she was hoping they would learn and more time helping them to process the abstract concepts. Observation data showed that the other two teachers placed a larger emphasis on helping the students to form concepts related to cells than Ms. Delta did. Thus, the digital microscopes may have served as more effective mindtools if she had helped the students build more concepts based on the activities they were doing and the images they were viewing. This omission in Ms. Delta's teaching might help to explain why her students appeared to be more engaged in the learning activities than the students in the other two classrooms, but their content test scores were not different from the test scores of the other two groups.

Analyzing the Quantitative and Qualitative Data in Terms of Attitudes Toward Science

The results of the Scientific Attitude Inventory II (SAI II), as reported in chapter 4, showed some differences among the scores of the students in the three classrooms. The possible scores on this attitude inventory ranged from 40 to 200 points The students in Ms. Nu's class, where no microscopes were used, made a gain of 1.24 points from a mean pretest score of 132.61 to a mean posttest score of 133.85. In Ms. Alpha's class, where analog microscopes were used, students showed a loss of 4.78 points from a mean pretest score of 136.87 to a mean posttest score of 132.09. Ms. Delta's students, who used digital microscopes, made a gain of 3.05 points from a mean pretest score of 133.51 to a mean posttest score of 136.56. The Analysis of Covariance (ANCOVA) showed that there was a significant difference among the SAI II posttest scores for these groups when testing for the main effect of teacher and controlling for the effect of the SAI II pretest. However, when the

more conservative Scheffe's method was run to test for multiple comparisons, no significant difference was among the posttest scores of the three groups of students for the variable of teacher (who used no microscopes, analog microscopes, or digital microscopes) when controlling for the pretest as a variable.

The qualitative data provide some insights into the results of the SAI II. Four students from each teacher's class were interviewed. All twelve of the students expressed interest in the unit on cells. Observations of Ms. Nu's class showed that the students were engaged in most of the lessons, but the engagement was at the highest levels when the students were using handheld magnifiers or viewing projected digital images. More class time, however, was devoted to using reading and discussions than using the handheld magnifiers or viewing the digital images. In accordance with their expression of interest in the lesson and the observations of how class time was spent, their SAI II scores made a small gain (1.24 points) from the mean pretest to the mean posttest score.

The students in Ms. Alpha's class were the only group of students whose SAI II scores showed a loss, rather than a gain, from the mean pretest to the mean posttest scores. One interesting note is that the students' mean pretest score in her class was higher than the mean pretest score of each of the other two groups. In fact, this mean pretest score was a little higher than the mean posttest score of any of the three groups. Observations of Ms. Alpha's class indicated that at the beginning of this unit, her students were excited about the prospect of using microscopes as they studied about cells. When they used the microscopes, they showed frustration and lower levels of engagement as they waited their turns to view the slides. They also expressed frustration related to the lack of ability to discuss what they were viewing with someone else who was viewing the image at the same time. Their levels of

frustration were most evident at the end of the unit as they viewed protists. They found that the specimens they were trying to observe and sketch had often moved from view by the time they could get the opportunity to view the slide a second time. Perhaps the difference between their expectations of the experience of using microscopes to view cells and the reality of using analog microscopes in a classroom setting to see cells partially accounted for their decrease from the mean pretest to the mean posttest scores on the SAI II.

However, this observation should be tempered by the fact that the four students interviewed in Ms. Alpha's class indicated that they liked using the analog microscopes, and they found the use of the microscopes to be beneficial to them in learning about cells. The four students indicated that they preferred using the microscopes to the use of textbooks alone. One interviewed student expressed frustration in having to wait her turn to view slides, but she also indicated that found the use of the microscopes to be helpful to her learning experience.

Ms. Delta's students, who used the digital microscopes, made the largest gain (3.05 points) from the mean pretest to the mean posttest scores on the SAI II. The observation data indicated that her students enjoyed using the digital microscopes. The fact that students asked to remain in her classroom after the period ended is one example of their interest in using the digital microscopes. Observation data showed that the student's desire to use the digital microscopes to view cells did not wane as the unit progressed. The students' elaboration in their interviews was further evidence of their enthusiasm regarding the use of the digital microscopes. The fact that Ms. Delta used the loss of privilege of participating in class learning activities as a means of classroom management was another indicator of the students' interest in being involved in science learning activities when digital microscopes

were used. While no statistically significant differences between any of the three groups of students were found when Scheffe's method of multiple comparisons was used, the largest difference between mean SAI II posttest scores, when controlling for mean SAI II pretest scores, was found between the scores of Ms. Alpha's class and Ms. Delta's class. Generalizations need to be made with caution since the difference was not statistically significant, but the difference in scores does fit with the fact that the classroom observations showed higher levels of engagement and interest in Ms. Delta's classroom than in Ms. Alpha's classroom or in Ms. Nu's classroom.

Conclusions from the Study

Project 2061, begun by the American Association for the Advancement of Science (AAAS) in 1985, promoted the goal of all Americans attaining science literacy. They recommended systemic change that would support long-term efforts at reform. In 1989, the AAAS published *Science for All Americans*, in which they recommended that students develop a deep understanding of a few concepts, rather than a surface level knowledge of many topics. The authors promoted the idea of helping students to construct their own knowledge. Another recommendation was that science teaching should strive to counteract anxieties that students possess regarding the learning of science. Specifically, the authors recommended that teachers provide abundant experiences for the students in using the tools of science. They also suggested that the role of girls and minorities be supported. Finally, they suggested that an emphasis on group learning might help to reduce the learning anxieties associated with science education.

In 1993, the AAAS published *Benchmarks for Science Literacy* (AAAS, 1993), which provided content guidelines for clusters of grade levels. The National Committee on Science

Education Standards and Assessment, of the National Research Council (1996), made similar recommendations for science education reform, published as the *National Science Education Standards*. North Carolina state standards for science education were developed (NCDPI, 2004a), based on the national benchmarks developed by the AAAS (1993) and the National Research Council. Progress has been made in implementing the national standards, but much work remains to be done in implementing the principles and reforms in science teaching that accompany these standards (Anderson & Helms, 2001; Edelson, 2001; Roseman, 1997; Sarason, 1996; Songer, et al., 2002). In addition to the recommendations specifically addressing science education, research studies on teaching and learning in middle schools have shown a need for the curriculum to be relevant, challenging, and exploratory. Studies also show a need for multiple approaches to teaching and learning, to which a diversity of students can respond, to be implemented in middle school classrooms (National Middle School Association, 2003a).

This study used the middle school goals and objectives related to cell theory from the North Carolina Standard Course of Study (NCDPI, 2004a), which are based on the *Benchmarks for Science Literacy* (AAAS, 1993) and the *National Science Education Standards* (National Research Council, 1996). The purpose of this study was to investigate the use of microscopes in the study of cell theory at the middle grades level. Situated in the classrooms of three teachers in a rural school system in North Carolina, this study examined the variable of microscope use on three levels – with no microscopes, with analog microscopes, and with digital microscopes – during the middle school unit on cells. Since one of the recommendations from *Science for All Americans* (AAAS, 1989) was for teachers to provide experiences for the students in using the tools of science, two of the teachers, Ms.

Alpha and Ms. Delta, used microscopes as tools of science to help students construct knowledge. (Ms. Alpha used analog microscopes, and Ms. Delta used digital microscopes.) A third teacher, whose classroom formed a comparison group, used handheld magnifiers and digital images, rather than microscopes, as tools to help her students construct knowledge related to cell theory.

The theory of constructivism served as the conceptual framework for this study. One goal was for students participating in this study to construct knowledge of cell theory. The use of the digital microscopes seemed to serve as a tool for constructivist learning, a concept based on the works of educational theorists including Bruner (1966, 1977), Dewey (1933), Piaget (1963), Papert (1993), and Vygotsky (1978). Constructivism proposes that individuals interacting with their environment construct knowledge or meaning. The interaction takes place within a context that includes both the physical setting and the social engagement (Honebein et al., 1993). Social constructivist principles (Vygotsky) support the engagement of students in collaborative group projects in which knowledge and skills are taught in context, rather than as isolated sequential facts.

Jonassen (2000) built upon the constructivist concept as he encouraged educators to use computers as "mindtools," a term he used to refer to the use of the computer as a tool that can help the user construct knowledge. Jonassen et al. (2003) suggested that technology could be used to provide a social context which could support learning by student interaction with the environment and with other students. As such, technology could become an intellectual partner that allows students to learn with technology, rather than from it. One type of mindtool for which Jonassan and Carr (2000) stated that the computer is well suited is a visualization tool. Linn (2003), Jonassen, Mathewson (1999), and Wollsey and Bellamy

(1997) referenced studies that explored the idea of mindtools as visualization tools. None of these sources mentioned the use of technology as a visualization tool in the life sciences, which suggested a need for studies to be conducted in this area. Bruce et al. (1997), Crouch et al. (1996), Dodson et al. (1999), Edelson (2001), Edelson et al. (1999), and Gordin, et al. (1996) provided studies on the use of visualization tools in science. Only the Chickscope Project (Bruce et al.; Hogan, 2000) referenced the use of visualization tools in the area of life science. Thus, the current study helped to fill a need for research on using technology as a visualization tool in the area of life science.

Research based on the Apple Classrooms of Tomorrow (ACOT) (Apple Computer, Inc., 2005) found that the presence of computers seemed to serve as a catalyst for change in the classroom, facilitating a move to a more constructivist style classroom. The constructivist environment created in Ms. Delta's classroom particularly fit with Bruner's (1966) recommendations that students first work concretely, directly, and actively with the learning materials. Then, they should develop an iconic or pictorial representation of the concept. Finally, they should develop the abstract concepts. The students in Ms. Delta's classroom used the digital microscopes as they worked directly with specimens, then viewed magnified images of the specimens, and formed abstract concepts related to the images and the specimens.

The research on the ACOT classrooms (Apple Computer, Inc., 2005) suggested that another way that technology can provide support for a constructivist style classroom is through its ability to provide students with multiple representations of ideas. This current study fits with that finding. The students in Ms. Delta's classroom were able to use the digital microscopes to view magnifications of the specimens. The students really appreciated the

fact that they could view the specimens with a group of students and with their teacher. They also found it helpful to capture images to view later. The students realized that they could enlarge the digital photographs to get a more detailed view of the specimen. They could also make video recordings of the specimens. The video clips allowed the students to view the organisms from different angles as they moved and changed positions. In contrast, the analog microscopes did not foster the viewing of specimens as a group activity. They also did not offer a means for the students to capture still pictures or videos of the images that they were viewing through the lenses.

Thus, the digital microscopes provided an appropriate visualization tool for Ms. Delta's students as they learned abstract concepts related to cells that they could not view without magnification. However, as Ms. Delta noted and as the observation data confirmed, she missed some opportunities to help her students use the images as a means to form abstract concepts related to cell theory. Although Ms. Delta and the researcher wondered if the students would have learned more content if those opportunities had been provided, a conclusion from this study was that the digital microscopes served as visualization mindtools to help the students in Ms. Delta's classroom in their study of cell theory.

Another finding from the research on the ACOT classrooms (Apple Computer, Inc., 2005) was that these classrooms moved from being teacher-centered and didactic to becoming more learner-centered and interactive. The digital microscopes contributed to the constructivist learning environment as their use helped to transform how the teacher used groups and how the groups functioned in Ms. Delta's classroom. All three teachers used groups in their classrooms. However, the students in Ms. Nu's class (where no microscopes were used) were often observed to be off-task when their groups were assigned to read and

discuss the text. The students in Ms. Alpha's classroom were often bored and frustrated and exhibited off-task behaviors as they waited their turns to view slides under the analog microscopes. The group behaviors in Ms. Delta's classroom were in contrast to the behaviors observed in the other two classrooms. In Ms. Delta's room, the students were working in groups, discussing what they were viewing and what they were thinking about the images. They also discussed their thoughts with the teacher, as she viewed their screens and their pictures. The students' interest in using these tools to study cells did not wane as the unit of study progressed and even as it concluded.

Despite the success of the digital microscopes in transforming Ms. Delta's classroom into a constructivist learning environment, the results of the content tests showed that there were no statistically significant differences among the posttest scores of the three groups of on the content test when controlling for the pretest scores. One possible reason for this fact was that all three groups were using science kits for the first time. Another possible factor was that the students in each classroom were using visualization tools for the first time, so each group seemed interested in using whatever tool – handheld magnifier, analog microscope, or digital microscope – was provided to them. A third possible explanatory factor was that Ms. Delta missed opportunities to help the students process the content on an abstract level. Although she used the digital microscopes as tools to help them connect those concrete experiences to the images they were viewing, she failed to help them make many of the connections to the abstract concepts she was hoping they would develop. She indicated that she had become so interested in having them use the digital microscopes to explore the specimens that she neglected to help them process what they were seeing and discovering. Classroom observations confirmed her statement.

Anderson and Helms (2001) noted barriers that made it difficult for teachers to implement the use of scientific inquiry. One obstacle they found was that of changing roles. They noted that the roles that students and teachers assume in a classroom are deeply rooted in traditional school culture. Making changes in the roles that they play and the type of work that students produce is a difficult transition. Thus, their study fit with the difficulty that Ms. Delta experienced as she tried to change roles from a traditional teacher model to a constructivist teaching role. While she was willing to make a change in her role, she realized that creating that new role was more difficult and complex than she had anticipated.

A recommendation from the AAAS (1989) was that the role of girls and minorities be supported in the learning of science. Results of national tests provided support for this recommendation. The National Center for Education Statistics of the U.S. Department of Education (2003) released a report card on science education in the United States. A summary of the 2000 National Assessment of Educational Progress (NAEP) and a comparison to this assessment in 1996 were provided in this national report. The data showed that, for eighth grade students tested, the average score of the male students in 2000 was seven points higher than the average score of the female students. There was also a gap in scores when the scores were disaggregated by race. Among the eighth grade students, the average scale score was 162 for White students, compared to an average scale score of 122 for African American students.

While there were not particular strategies employed in the current study with the goal of specifically encouraging girls and minorities, this study examined the data disaggregated by race and by gender to determine if the use of microscopes in this study was associated with positive or negative gains on the content assessment for each group of students. The

mean content pretest and posttest scores were provided for each group of students by gender and by racial group. There were very little differences in gains made on the content test from the mean pretest to the mean posttest scores by any group of students, regardless of gender or racial identity. Thus, these data do not provide any evidence of one of these three environments providing an advantage for any racial or gender group. Likewise, the data do not indicate that any of the three treatments was a hindrance for any racial or gender group in learning about cells. While the reader is reminded that the samples for each of these groups was small, making generalizations inappropriate, the researcher thought it was important to notice if any of the treatments had been associated with a lack of student success for any of the groups of students.

Research studies have suggested that the use of technology in education could improve students' attitudes toward learning (Schiefele, 1991; Simpson & Oliver, 1985, 1990; Singh et al., 2002), which is an important goal in science education (AAAS, 1989). Simpson and Oliver (1990) found that student attitudes toward science are positively correlated with student motivation and achievement in science courses, thus providing another rationale for encouraging positive attitudes toward the learning of science. Likewise, Singh et al. concluded that attitudes toward science are predictive of academic performance in this subject. Research examining National Assessment of Educational Progress (NAEP) scores showed that during the middle school years, students' interest in learning about science declined (Simpson & Oliver, 1985; Yager & Penick, 1986). In this current study, the only students whose attitudes declined, as measured by the change from the mean pretest to the mean posttest scores on the Scientific Attitude Inventory II (SAI II), were the students in Ms. Alpha's classroom, where the analog microscopes were used. The students in Ms. Nu's

classroom, where no microscopes were used, made a small positive gain, and the students in Ms. Delta's classroom, who used the digital microscopes, made the largest positive gains. Although there were differences among the gains made by the students in the three classrooms, the reader is reminded that when Scheffe's Method of Multiple Comparisons was used to compare the mean posttest scores, while controlling for the pretest scores, there was no statistically significant difference found among the three groups of students. However, the qualitative data supported the conclusion that Ms. Delta's students, who used technology in the form of digital microscopes, exhibited enthusiasm for learning about cells throughout the unit of study.

The mean pretest and posttest scores for the Scientific Attitude Inventory II (SAI II) were also provided for each group of students by gender and by racial group. While some differences were noted between the groups of students, there were no large discrepancies between the gains made by groups of students from the mean pretest to the mean posttest scores on the SAI II. In addition, the samples for the groups of students, especially the White students, were too small for these differences to provide any meaningful interpretations. However, an examination of the groups revealed that in two of the learning environments – where no microscopes were used and where digital microscopes were used – all of the groups of students showed a positive gain from the mean pretest to the mean posttest score of the SAI II. In the classroom where analog microscopes were used, three of the four groups of students showed a decline in scores from the mean pretest to the mean posttest scores. In this classroom, only the White females, who were a very small sample, showed a gain from the pretest mean to the posttest mean scores on the SAI II.

One particular ACOT study focused on student engagement. Sandholtz et al. (1994) examined student engagement when technology was available in the classroom and found some trends. They reported positive changes in student attitude. In fact, they documented a sustained level of enthusiasm from both the teachers and the students. Another trend noted was changes in the use of time. Teachers found that the students tended to work longer on a project if they used the computer. Students also frequently chose to use the computers during their free time. A third trend that the researchers noted was that the teachers reported that the students were enthusiastic about learning and as a whole were spending more time on task than they had in the past A fourth trend was the increase in student initiative. Teachers noted that many students not only completed the assignments, but they exceeded the expectations. They also noted that some students independently sought to learn about new applications and developed skills that were not part of the regular lesson. A fifth trend was that of increased student experimentation and risk-taking. The teachers and researchers noticed that the students' desire to experiment on their own often led to increased interest and engagement in learning.

The current study found trends similar to the ones noted in the ACOT study (Sandholtz et al., 1994). The qualitative data showed that the students who used the digital microscopes had higher levels of engagement than the students in the other two classrooms. These data also indicated that the students exhibited sustained positive attitudes toward learning science when technology, in the form of digital microscopes, was utilized. The students who used the digital microscopes spent more time on task than the other two groups did. Similar to the students in the ACOT study, Ms. Delta's students often asked to use the digital microscopes during their lunch time or after school. They also took initiative to bring

items from home that they wished to view under the digital microscopes. Students in the other two classrooms did not ask to use the analog microscopes or the handheld magnifiers outside of class time. They also did not bring samples to view.

A review of over 80 studies conducted in grades K-12 on the effectiveness of computer-based technology concluded that computer-based technology can serve as tools that support effective educational environments, by promoting active engagement and collaborative learning (Roschelle et al., 2000). The current study provides support for this finding. Fredricks et al. (2004) noted studies that have documented a correlation between behavioral engagement and achievement. Yet, they found only a few studies that addressed achievement and motivation in specific contexts, such as the middle school science classroom. They called for more qualitative research regarding engagement in specific contexts. They noted a particular need to learn more about the engagement of minority students in learning contexts. This current study addressed that need.

Other studies examined in chapter 2 of this document showed a correlation between student achievement and the use of technology. One study examined the relationship between the Basic Skills/Computer Education (BS/CE) program implemented in West Virginia public schools and statewide assessment scores over an eight-year period. The researchers concluded that as a whole, 11% of the students' achievement gains were considered to be accounted for by the BS/CE program (Mann et al., 1999). Contrary to that report, this current study found no statistically significant difference between any of the three classroom learning environments on the results of the content posttests, when controlling for the content pretests. However, as noted earlier, the qualitative data did loan some support to the idea that the

digital microscopes served as an appropriate learning tool for the students in Ms. Delta's classroom.

Kulik (2002) reviewed 36 evaluation studies on instructional technology in mathematics and science programs and concluded that instructional technology can benefit programs in these subject areas. A conclusion from this current study is that students made similar gains on the content test in each of the three learning environments. However, the qualitative data indicated that the students were more engaged in the classroom that used digital microscopes than in the other two classrooms. Thus, this current study suggests that students in Ms. Delta's science class benefited from the presence of instructional technology, in the form of digital microscopes, in their study of cell theory, even though their content posttest scores were not statistically significantly different from the other two groups of students.

The National Science Foundation (NSF) has recognized the important need of providing science education for all students and has launched a program, Systemic Initiatives, to help achieve this goal. One of the programs funded by this grant is the Rural Systemic Initiatives, intended to promote improvement in mathematics and science education in rural schools, (National Science Foundation, 2003). At a conference sponsored by the National Science Foundation (NSF) and conducted by the Appalachian Rural Systemic Initiative, a research agenda was established for examining factors that have an impact on learning and achievement in science and mathematics among students in rural schools. Two researchable questions that they proposed were the following:

> What is the accessibility, availability, use, and effectiveness of advanced digital technology to teach mathematics and science in rural schools?
> How can the teaching and learning of science and mathematics in rural schools be improved with the effective integration of technology? (Harmon et al., 2003, p. 54)

This current study was situated in a rural school system in North Carolina. Interviews with the three teachers indicated that digital technologies for teaching science at J. H. Strum Middle School prior to this study on teaching cell theory were very limited. However, the qualitative data collected during this study suggested that the digital microscopes were effective tools for engaging the students in Ms. Delta's classroom in learning about cells. The data also showed that Ms. Delta and her students preferred using the Digital Blue™ QX5™ microscope over the ProScope™ digital microscope in the study of cells. Ms. Delta and the four students interviewed from her classroom indicated that they thought the Digital Blue™ QX5™ microscopes were a valuable resource in learning about cell theory at the middle grades level. Ms. Delta recommended to the principal that a classroom set of six Digital Blue™ QX5™ microscopes be purchased for the next school year. At a price of approximately $80.00 each, the principal indicated that these microscopes would be affordable for the school. Based on what Ms. Delta told her about the students' learning experiences with the digital microscopes, as well as her own observations of Ms. Delta's students as they used the Digital Blue™ QX5™ microscopes, the principal thought that the purchase of a classroom set would be a wise investment for the school. She also planned to relocate five computers so that they could be shared by the science teachers to use with the microscopes. Each teacher could teach the unit at a different time during the school year so that the computers and the microscopes could be used at alternating time periods. (Each teacher already has one computer available in the classroom.) Thus, a conclusion from the qualitative data was that the teaching and learning of science in this rural middle school could be improved with the effective integration of technology by the use of digital microscopes in the study of cell theory. This use of digital microscopes may also help to

bridge the "digital divide" by the use of technology in the form an affordable tool that possibly provides the potential for transforming learning in a middle grades science class during the unit on cell theory.

In conclusion, this study provided information regarding the use of microscopes on three levels – no microscopes, analog microscopes, and digital microscopes – during the unit on cell theory in a rural middle school. Students' attitudes toward learning science, in each of these three learning environments, were studied. Also, the attainment of content knowledge by groups of students in each of these three learning environments, during the unit on cell theory, was examined. In addition, this study investigated the use of technology, in the form of digital microscopes, as a tool for knowledge construction. The use of technology as a mindtool, and specifically as a visualization tool, in which students learn with the technology, rather than learn from the technology, was explored. Information regarding the use of technology as a means to foster student interaction in a constructivist learning environment was presented. Student engagement in each of the three learning environments was studied. Finally, the use of images in each of the three learning environments was explored as a means for helping students to construct knowledge related to cell theory. The information presented in this study may be of interest to teachers and administrators in middle school classrooms, especially in rural areas. The North Carolina middle grades teachers and administrators may be particularly interested in the findings of this study because end of grade field testing in eighth grade science will begin in the spring of 2006.

Limitations of the Study

One limitation of this study was that it was a quasi-experimental study. The groups were selected based on classes of students that had already been assigned to each of the three

teachers. Although the three groups of students were similar, and the pretest scores on the content test and on the SAI II were used as control variables, the students were not randomly assigned to each treatment group. Another limitation was the fact that the teacher who used the digital microscopes missed opportunities to help her students process the abstract concepts that she was hoping they would form from their interactions with the learning materials and through the use of the digital microscopes. A third limitation of this study was that the samples were small, especially when the groups of students were examined. The number of white students in each teacher's classroom was especially small, which made generalizations to a larger population impossible. Finally, a limitation in this study resulted from the fact that the three teachers failed to read the content test aloud to the students when they administered it as a posttest.

Recommendations for Future Research

One recommendation is for a similar study to be conducted using students assigned randomly to the groups, if that is possible. More staff development should be provided to the teachers on using tools to help students use images to make connections from the concrete activities to the abstract concepts that are being taught. Another interesting facet to this study would be to teach the unit early in the school year and then give a follow-up content posttest at the end of the school year to compare the retention levels of the students over a period of time. In this current study, the eighth grade students had been taught about cells as part of the seventh grade curriculum the preceding school year. Yet, there was very little difference between the mean pretest scores on the content test for these students and for the seventh grade students who had not received instruction on this topic the preceding year (or during the current school year prior to the study.) The similarity in pretest scores could be an

indication that the traditional methods used to teach the unit to the eighth graders when they were seventh graders had not been effective for long-term retention of the content. Adding a content posttest months later would provide some data on how well the students retained the concepts over a period of time.

A second recommendation would be to conduct research on using the digital microscopes as visualization tools in other areas of the middle school science curriculum. One area that might fit well with their use would be the study of rocks and minerals in the sixth grade North Carolina Standard Course of Study. Another topic from the sixth grade that might benefit from the use of the digital microscopes as visualization mindtools is the study of soil (color, consistency, texture, particle size) in the sixth grade curriculum. In the North Carolina Standard Course of Study for the seventh grade, an objective involves studying about the use of technology as a way of investigating particulate matter in the atmosphere. Digital microscopes could be considered as a tool for examining particulate matter that is collected from the atmosphere. In the eighth grade curriculum, the digital microscopes might be examined as a tool in the study of rocks and fossils, as well as in the study of cell theory.

An interesting thought gleaned from the study that was conducted was that perhaps if the students had used handheld magnifiers more frequently in the elementary schools, then they might not have been as excited about their use in the seventh grade unit on cells. This observation could be an indicator that more research should be conducted on how elementary science is taught. In particular, there may be a need to learn more about the use of visualization tools, including handheld magnifiers, in elementary classrooms, especially in rural school systems.

Research focused on staff development might provide insights into how to prepare teachers to use digital microscopes, and other forms of technology, as mindtools in the study of science. In the current study, Ms. Delta was willing to use the digital microscopes and was excited about allowing the students to use them to investigate. Yet, she found the tasks of helping the students to process what they were doing and facilitating their creation of abstract concepts related to cell theory to be more difficult and more complex than she had anticipated. Research that focused on how to help teachers learn to use technology as visualization mindtools may be helpful.

A conference (Center for Research on Education, 2002) focused on applying the recommendations of Heath (1983) in her book *Ways with Words: Language, Life and Work in Communities and Classrooms* to the teaching and learning of science and mathematics. The conference organizers and participants were concerned about the under-representation of minority students in advanced science and mathematics courses. They noted the goals of science reform include the mandate for science education for all students (AAAS, 1993; National Research Council, 1996). They stated that in spite of this goal, students of minority groups and students living in poverty were enrolled in fewer advanced science courses than students from other groups. They proposed that science education reform should include specific attempts to provide appropriate instruction for poor students and for those belonging to minority groups. A question that the group attending this conference suggested should be studied was, "What forms of learning in science and mathematics will help beginning and experienced teachers see the deep connections between disciplinary ideas and practices and children's understandings and sense-making?" (Center for Research on Education, 2002). This question could be considered in light of the need for teachers to learn to use technology

as a mindtool. Perhaps if Ms. Delta, an experienced teacher, had been able to see the deep connections between the concepts she was attempting to teach in the unit on cell theory and the ways that her students were attempting to make meaning from the images seen with the digital microscopes, she might have been more successful in helping them to learn the content on an abstract level and to form deeper, long-lasting meanings related to the content. Thus, research on this topic could provide insight that might be helpful to teachers, especially when working with students who are poor or who belong to minority groups.

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APPENDICES

APPENDIX A: SCIENTIFIC ATTITUDE INVENTORY II (SAI II)

WHAT IS YOUR ATTITUDE TOWARD SCIENCE?
(A Scientific Attitude Inventory)

SAI II

By R. W Moore & R. L. H Foy

There are some statements about science on the next two pages. Some statements are about the nature of science. Some are about how scientists work. Some of these statements describe how you might feel about science. You may agree with some of the statements and you may disagree with others. That is exactly what you are asked to do. By doing this, you will show your attitudes toward science.

After you have carefully read a statement, decide whether or not you agree with it. If you agree, decide whether you agree mildly or strongly. If you disagree, decide whether you disagree mildly or strongly. You may decide that you are uncertain or cannot decide. Then, find the number of that statement on the answer sheet, and blacken the:

Ⓐ if you agree strongly

Ⓑ if you agree mildly

Ⓒ if you are uncertain or cannot decide

Ⓓ if you disagree mildly

Ⓔ if you disagree strongly

EXAMPLE:

I would like to have a lot of money.

Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ

The person who marked this example agrees strongly with the statement, "I would like to have a lot of money."

Please respond to each statement and blacken only ONE space for each statement.

1. I would enjoy studying science.
2. Anything we need to know can be found out through science.
3. It is useless to listen to a new idea unless everybody agrees with it.
4. Scientists are always interested in better explanations of things.
5. If one scientist says an idea is true, all other scientists will believe it.
6. Only highly trained scientists can understand science.
7. We can always get answers to our questions by asking a scientist.
8. Most people are not able to understand science.
9. Electronics are examples of the really valuable products of science.
10. Scientists cannot always find the answers to their questions.
11. When scientists have a good explanation, they do not try to make it better.
12. Most people can understand science.
13. The search for scientific knowledge would be boring.
14. Scientific work would be too hard for me.
15. Scientists discover laws which tell us exactly what is going on in nature.
16. Scientific ideas can be changed.
17. Scientific questions are answered by observing things.
18. Good scientists are willing to change their ideas.
19. Some questions cannot be answered by science.
20. A scientist must have a good imagination to create new ideas.
21. Ideas are the most important result of science.
22. I do not want to be a scientist.

23. People must understand science because it affects their lives.
24. A major purpose of science is to produce new drugs and save lives.
25. Scientists must report exactly what they observe.
26. If a scientist cannot answer a question, another scientist can.
27. I would like to work with other scientists to solve scientific problems.
28. Science tries to explain how things happen.
29. Every citizen should understand science.
30. I may not make great discoveries, but working in science would be fun.
31. A major purpose of science is to help people live better.
32. Scientists should not criticize each other's work.
33. The senses are one of the most important tools a scientist has.
34. Scientists believe that nothing is known to be true for sure.
35. Scientific laws have been proven beyond all possible doubt.
36. I would like to be a scientist.
37. Scientists do not have enough time for their families or for fun.
38. Scientific work is useful only to scientists.
39. Scientists have to study too much.
40. Working in a science laboratory would be fun.

APPENDIX B: SCIENCE CONTENT TEST– FINAL

Science Content Test – Diversity of Life Unit – Study of Cells
Identifying number: _____

Directions:

1. There is an identifying number listed above. Please write that number in the blank that asks for your name on the scan-tron sheet. **Do not write your name** on the scan-tron sheet.
2. There are 25 multiple choice questions in this assessment. Choose the **best** answer for each question. Then, use a number 2 pencil to mark the appropriate answer choice on the scan-tron sheet that you teacher will provide you.

Multiple Choice Questions:

1. The thick outer covering around the cell membrane of a plant cell is the:
   A. chloroplast.
   B. plant wall.
   C. cell wall.
   D. nuclear membrane.

2. The basic unit of structure in all living things is the:
   A. cell.
   B. tissue.
   C. organ.
   D. organelle.

3. The green structures, which allow the production of food (energy,) and that are found in plant cells (and in some protists, such as the euglena) are called:
   A. cytoplasm.
   B. chloroform.
   C. chloroplasts.
   D. Golgi bodies.

4. The liquid material that is flowing inside cells is called:
   A. ribosomes.
   B. cytoplasm.
   C. mitochondria.
   D. chloroplasts.

5. Which of the following structures are used by the paramecium to take food (a source of energy) into the organism?
   A. ribosomes
   A. nucleus
   B. oral groove
   C. cytoplasm

6. The nuclear material in a cell is separated from the rest of the cell by the:
    A. cell wall.
    B. nuclear membrane.
    C. cell membrane.
    D. endoplasmic reticulum.

7. An organism that is made of a single cell is classified in which group:
    A. protists
    B. animalia
    C. plants
    D. elodea

8. The smallest unit capable of carrying out all functions of life is called the:
    A. endoplasmic reticulum.
    B. cell.
    C. organelle.
    D. vacuole.

9. All cells have:
    A. a cell nucleus.
    B. a cell membrane.
    C. a cell wall.
    D. chlorophyll.

10. Protists have nuclei; therefore, they can be considered to be a part of which group of cells:
    A. prokaryotic
    B. eukaryotic
    C. symbiotic
    D. many-celled

11. Which of the following lists is organized from the least complex to the most complex organization?
    A. organelles, cells, animals, organs, tissues
    B. organelles, cells, organs, tissues, animals
    C. tissues, cells, organs, organelles, animals
    D. animals, cells, organelles, tissues, organs

12. An independent living thing is known as a(n):
    A. organ.
    B. organelle.
    C. organism.
    D. nucleus.

13. Euglena use a whiplike structure for propulsion. This structure is called a:
    A. cilia.
    B. chloroplast.
    C. flagellum.
    D. paramecium.

14. A paramecium:
    A. is a single-celled organism.
    B. is capable of carrying out life processes.
    C. uses hair-like structures called cilia to move.
    D. All of the choices above are true of the paramecium.

15. In cell functions, osmosis is most frequently utilized in:
    A. excretion of waste.
    B. protein production.
    C. mitotic division.
    D. photosynthesis.

16. _____ are openings on leaves that let gases in and out the plant.
    A. Stomates (or Stomata)
    B. Guard cells
    C. Cuticle cells
    D. Xylem cells

17. Which cell part makes it possible for green plants to make their own food (thus supplying energy)?
    A. chloroplast
    B. chromosome
    C. cytoplasm
    D. mitochondria

18. _____ are specialized leaf cells which control the size of the openings on the leaves.
    A. Guard cells
    B. Xylem
    C. Root hairs
    D. Stomates (or Stomata)

19. Once a paramecium takes in food, the food is enclosed in a packet called a :
    A. digestive enzyme.
    B. water-expelling vesicle.
    C. food vacuole.
    D. pseudopod.

20. Which statement about plant cells and animal cells is the **most** correct?
    A. Both plant and animal cells have cell membranes and chloroplasts, but animal cells also have a cell wall.
    B. A plant cell has chloroplasts, a cell membrane, and a cell wall; an animal cell has a cell membrane but no chloroplasts or cell wall.
    C. Both plant and animal cells have chloroplasts, but an animal cell has a cell membrane and a plant cell has a cell wall.
    D. An animal cell has chloroplasts and a cell wall; a plant cell only has a cell membrane.

21. Paramecia usually reproduce by:
    A. budding, in which a paramecium gives birth to a smaller paramecium.
    B. germination, which occurs when a paramecium seed is planted.
    C. photosynthesis, which takes place in the presence of sunlight.
    D. cell division, in which the cell duplicates the organelles in the cell and splits into two daughter cells.

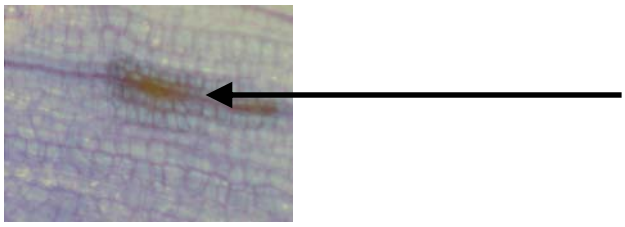
22. An amoeba takes in food by:
    A. surrounding and engulfing the food
    B. sending out a false foot to retrieve the food and bring it to the amoeba.
    C. using cilia to brush the food into the organism.
    D. using a flagellum to whip the food into its mouth.

23. Certain processes are required of all living organisms, whether single-celled or multi-cellular (such as animals and plants.) Which of the following items is not one of these processes?
    A. reproduction
    B. response to the environment
    C. use chloroplasts to produce food
    D. elimination of wastes

24. The following picture shows a paramecium as it is undergoing which life process?

    A. reproduction
    B. photosynthesis
    C. elimination of wastes
    D. capture and release of energy

25. The following picture shows cells from a stalk of celery. The arrow points to some specialized cells. These cells are:



A. xylem cells that carry water
B. reproductive cells
C. food vacuoles
D. none of these

APPENDIX C: SCHEDULE OF LESSONS TO BE TAUGHT

Note:
This document provides a detailed schedule for the teachers to follow during the unit on cell theory. The dates that are highlighted in gray are the days that I am planning to observe the classes.

Note: All activities referenced in this unit outline are from the materials that have been purchased for use in these classrooms. The textbook that is used is *Integrated Science: Interactions and Limits* from Carolina Academic Press (2000), and the kit is the FOSS Diversity of Life kit (Lawrence Hall of Science, UC Berkeley, 2003a). In this outline, materials from *Integrated Science: Interactions and Limits* will be abbreviated ISIL, and materials from the Diversity of Life kit will be abbreviated DL. Also, this outline refers to students using magnification devices. The students of Ms. Nu used handheld magnifiers (furnished with the Diversity of Life kit) and pictures in the Diversity of Life resource book and on the Diversity of Life CD-ROM. Since those items are part of the kit, the students in the other classes also had access to them. However, the students in Ms. Alpha's classes also used analog microscopes to view the materials referenced in these lessons, and the students in Ms. Delta's classes used digital microscopes and computers.

Before unit begins:
March 14 - Monday:

- Teachers will administer the content pre-test.
- Teachers will help the students to set up the notebooks that they will use for the unit on cells.
    - A notebook will be prepared in advance for each student. The notebook will contain reproducible information and recording sheets from the DL materials and from the ISIL materials.
    - Students will use the notebooks to store and organize their notes and learning materials for the unit.

Unit of Study:
March 15 - Tuesday

- Teachers will administer the Scientific Attitude Inventory II.
- Teachers will begin Investigation 1: What is life? (DL)
    - Students will group pictures into the categories of "living" and "non-living."
    - The students will realize that some pictures do not easily fall into one category or the other. The teachers will lead the students through a discussion on this "problem" and help them to realize that they will need to develop more categories and that some items will belong in more than one category.
- Students will complete a "quick write" activity (as describe in the DL teacher's manual on page 46) in their notebooks in which they write what they have learned from the activity. Then, each student will write a definition of a living organism.

March 16 - Wednesday

- Teachers will use materials from ISIL and from DL to teach concepts about safety in the science classroom.
- Students will take a safety quiz.
- Students will be issued science safety contracts to sign.
- Teachers and students will set up "miniponds," which they will use later with the DL materials.
    - Each group of four students will set up a minipond.
    - In containers supplied in the DL kit, students will place a spoon of soil.
    - Students will add a small quantity of dry leaves, dead grass, and twigs.
    - They will add water from a pond or from bottled water.
    - Students will put a lid on the container and will label it with their number, class period, and date.
    - Miniponds will be stored in the classroom for future investigations.
- After school, the teacher will prepare materials for the next day. (Directions are on pages 54-55 of the DL teacher's manual.) Teachers will prepare a set of 5 vials for each team. (Vials, vial holders, and materials to go in the vials are included with the DL kit.) A small amount of the following materials will be placed into the vials. (Each vial will have one material.) Each vial will be labeled with a letter corresponding to the material it contains.
    - A. Red sand
    - B. Dry yeast
    - C. Polyacrylate crystals
    - D. Radish seeds
    - E. Brine shrimp eggs

March 17 - Thursday

- Teachers and students will continue Investigation 1: What is Life from DL.
- The students will use the vials prepared by the teacher (as described above.)
- Students will observe each of the vials and the materials in it. They will try to determine which materials are alive and which are not.
- Each group will add a water solution to the vials. Some groups will receive Solution A, some will use Solution B, and some will have Solution C.
    - Solution A – salt water
    - Solution B – sugar water
    - Solution C – water
- The group of students will pour some of the solution that was provided for their group into each of the vials that belong to their group.
- Students will observe the vials, again trying to determine which items are living and which are not.
- Students will complete the "Is Anything Alive in Here?" sheet from the DL materials in their notebooks.
- Students will place the vials in the proper storage area.

March 18 - Friday

- Students will again observe the materials in the vials, noticing any changes that have occurred.
- Students will compare the results of their vials and the solution they used with two other groups who used the other two solutions.
- Students will add notes to the "Is Anything Alive in Here?" sheet from the DL materials in their notebooks.
- The students will prepare a new vial (one vial per group) of brine shrimp eggs and salt water.
- Students will view the brief video from the DL CD-ROM on using the microscopes. (There is also a virtual microscope that the students in Teacher A's classes will use.)
- Students will view the brief video from the DL CD-ROM on preparing slides.
- Students will complete the Mid-summative Assessment 1 from DL.
- Students will use the magnifying devices to view the new batch of brine shrimp eggs. They should be able to view the eggs in the egg stage and as the brine shrimp are hatching. (Students in Teacher A's class should be able to see them with hand magnifiers, but there will not be much detail. They will also view CD-ROM pictures and video clips of brine shrimp on the CD-ROM.)

March 21 – Monday – Teacher Workday. No schools are in session.

March 22 - Tuesday

- Students will again view materials in the vials and will answer the following questions in their notebooks:
    - How many of the materials appeared to be alive when you first observed them?
    - How many appear to be alive now, 2 days after they were placed in the vials with the liquid?
    - How does the environment affect organisms?
- Students will learn what the materials in the vials are.
- Students will continue to work with the vial of brine shrimp that they created the previous day.
- Each group of students will use magnifying devices to observe the brine shrimp.
- Students will use flash lights to observe the brine shrimps' response to light. (The students using the handheld magnifiers will be able to see the response to light.)
- The teachers will prepare a suspension of yeast dyed with Congo red stain.
- Each group of students will prepare a slide of brine shrimp and yeast and observe the yeast with the magnifying devices as they feed. (Students in Teacher A's room will observe with handheld magnifiers and will view images on the CD-ROM.)
- Students will record their observations in their notebooks.

March 23 - Wednesday

- Students will use the magnifying devices to view:
    - Potato cells
    - Root cells (from a plant in the room)

- Students will draw & label cells in notebook
- Students will take the mid-summative assessment 2 from the Diversity of Life materials. This item includes a short quiz on the parts of a microscope and on using a microscope.

March 24 – Thursday - Early release day for this school system. Class periods will be shorter than usual.

- Students will participate in a class competition using the Diversity of Life game on the CD-ROM (projected onto a screen for class viewing.)

School System's Spring Break – March 25 – April 1

April 4 – Monday

- Review day – Teachers will help students to review material that was taught before the spring break. They will use a game show format to have students review content.
- Teachers will review the parts of the microscopes with the students. They will also use the virtual microscope from the CD-ROM to review microscope use and focusing with the students.

April 5 - Tuesday

- Investigation 4 from DL
  - Students will read from the resource book about cells.
  - Students will view animal cells by doing cheek scrapings.
- Students will view images of animal cells from the CD-ROM in the DL materials.

April 6 – Wednesday

- Ribbon of Life activity
  - Students will use the multimedia activity on the CD-ROM to become familiar with the concepts presented in this activity.
  - Students will be presented information regarding eukaryote and prokaryote cells.
  - Students will learn that cells have defining structures, such as cell membranes, cell wall, nuclei, chloroplasts, and cytoplasm.
  - Students will be presented information regarding how cells are the basic unit of life and how all life is aquatic at the cellular level.
- Students will complete the "Ribbon of Life" activity sheets in their notebooks.
- Students will complete Mid-summative assessment 4 from the DL materials. The assessment is correlated with the concepts presented in the "Ribbon of Life" activity.

April 7 – Thursday

- Students will view plant cells by examining leaf cells (from the water plant furnished with the DL kit and other samples of leaves.)
- Students will record their observations in their notebooks
- Teachers will lead discussions regarding the similarities and differences in plant and animal cells.

April 8 - Friday and April 11 – Monday

- Begin Investigation 3 on protists.
- Observe Paramecia under the microscopes (or view the CD-ROM images and video clips.) (A culture of paramecia is provided with the DL materials.)
- Students record observations in notebooks. (Use "Response Sheet – Microscopic Life.")
- Teachers lead a discussion about paramecia and the students' observations. They will be sure to include the word "protists," and will discuss how a single living cell can be an organism and how all cells carry out the processes of life. Teachers will again reinforce the concept of "organism."

April 12 – Tuesday and April 13 - Wednesday

- Teachers and students will continue Investigation 3.
- Students will use magnifying devices to observe amoeba. (A culture of amoeba is provided with the DL materials.)
- Students will use magnifying devices to observe euglena. (A culture of euglena is provided with the DL materials.)
- Teacher will lead a discussion on the variety of protists. They will be certain to include a discussion on their various means of locomotion and on how euglena have chloroplasts like plant cells and have other characteristics of animal cells.)
- Students will place rye grass and radish seeds in minisprouters.

April 14 – Thursday: The teachers will be in Raleigh the second day of notebook training. The substitute teachers will have the students read materials from the DL and the ISIL materials on cells. Students will complete the sheets in their notebooks that address protists.

April 15 – Friday: Teacher work day. No schools are in session.

April 18 – Monday

- Students will participate in a Minipond safari.
    - Students will use the magnifying devices explore the miniponds that they created at the beginning of the unit of study.
        - They will likely find multicellular organisms, such as Daphnia and nematodes.
        - Students will use the Microorganism Guide in the Diversity of Life Resource book to identify organisms that they find in their miniponds.
        - Students will record their observations complete the "Minipond Safari" sheets in their notebooks.
- Teachers will lead discussions about what they found in their miniponds and how they think that the living organisms got in there. They will also discuss how these organisms compare to others they have viewed.

April 19 – Tuesday

- Students will work on Investigation 5: Seeds of Life from the DL materials.
- Students will examine lima bean & radish seeds then will use the magnifying devices to examine them more closely.
- Students will examine rye grass (monocot) and radish sprouts (dicot) sprouts and will compare and contrast monocotyledons & dicotyledons.
- Students will dissect lima beans that have been soaked in water for a few minutes.
- Students will record their observations in their notebooks.
- Students will watch the video "Secret Garden" from the DL materials.
- Teachers will lead discussions about seed germination and will help students to compare and contrast the dicots and monocots.

April 20 – Wednesday

- Students will examine root cells.
    - They will stain root tips of the radish and rye grass sprouts with methylene blue and use the magnifying devices to study the root structures.
    - They will describe the regions of differentiation in a growing root.
    - Students will record their observations in their notebooks.
    - Teachers will lead discussions regarding the parts of the root, including the root tip, the zone of elongation, and the zone of maturation (where the root hairs form.)
- Students will examine slices of a celery stalk.
    - Students will find xylem tissue.
    - Students will record their observations.
    - Teachers will help students discover how water is moved from the roots, through the xylem tissue, to the leaves of the plant. Teachers will also help students continue to form the concepts of a variety of types of cells carrying out the functions of life and working together for the sake of the organism in a multicellular organism. They will also help students to form a definition of transpiration.

April 21 – Thursday

- Teachers will administer the posttest of Scientific Attitude Inventory II.
- Students will watch the brief video "The Unknown World" from the DL materials.
- Teachers will show the video clips of bacteria from the CD-ROM provided with the DL materials.
- Teachers will review the content from the unit on cell theory.

April 22 – Friday

- Teachers will administer posttest of content test.
- Teachers will use the computer and a projector to allow the students to view the game questions on the CD-ROM from the DL materials. Students will form two teams and compete against each other in answering the questions that are presented in a game format.

APPENDIX D: REVISED SCHEDULE OF LESSONS TO BE TAUGHT

This document shows the revised basic schedule that the three teachers followed. Each teacher found it necessary to make adjustments to the schedule, but the teachers used it as a guideline. The testing dates were the same for all three teachers.

Note: All activities referenced in this unit outline are from the materials that have been purchased for use in these classrooms. The textbook that is used is *Integrated Science: Interactions and Limits* from Carolina Academic Press (2000), and the kit is the Diversity of Life kit from FOSS (2003). (A full reference for each of these materials can be found in the reference section of this document). In this outline, materials from *Integrated Science: Interactions and Limits* will be abbreviated ISIL, and materials from the Diversity of Life kit will be abbreviated DL. Also, this outline refers to students using magnification devices. The students of Ms. Nu used handheld magnifiers (furnished with the Diversity of Life kit) and pictures in the Diversity of Life resource book and on the Diversity of Life CD-ROM. Since those items are part of the kit, the students in the other classes also had access to them. However, the students in Ms. Alpha's classes also used analog microscopes to view the materials referenced in these lessons, and the students in Ms. Delta's classes used digital microscopes and computers.

Revised Schedule

Schedule for Unit on Cell Theory

Prior to Unit of Study:
March 14 - Monday:
Teachers administer the content pre-test

Unit of Study:
March 15 - Tuesday
Teachers administer the Scientific Attitude Inventory II.
Teachers have students to sort picture cards to determine which are "Living" and "Not Living"

March 16 - Wednesday
Teachers use materials from ISIL and from DL to teach concepts about safety in the science classroom.
Teachers and students set up "miniponds," which they use later with the DL materials.
After school, teachers prepare vials of "mystery substances": red sand, dry yeast, polyacrylate crystals, radish seeds, brine shrimp eggs.

March 17* - Thursday

Teachers and students begin Investigation 1: What is Life from DL.

The students use the vials prepared by the teacher.

Students add a water solution and observe each of the vials and the materials in it. They try to determine which materials are alive and which are not.

March 18* – Friday

Students again observe the materials in the vials, noticing any changes that have occurred.

The students prepare a new vial (one vial per group) of brine shrimp eggs and salt water.

Students use the magnifying devices to view the new batch of brine shrimp eggs. They should be able to view the eggs in the egg stage and as the brine shrimp are hatching.

March 21 – Monday – Teacher Workday. No schools are in session.

March 22* – Tuesday

Students again view materials in the vials and answer questions in their notebooks:

Students continue to work with the vial of brine shrimp that they created the previous day.

March 23* – Wednesday

Students continue to examine vials, draw what they see, and discuss the characteristics of life.
Students continue to examine brine shrimp, drawing what they see, and noticing the changes that have occurred.

March 24 – Thursday - Early release day for this school system. Class periods be shorter than usual.

Students participate in a class competition using the Diversity of Life game on the CD-ROM (projected onto a screen for class viewing.)

March 25 – April 1 – School System's Spring Break

April 4 – Monday

Review day – Teachers help students to review material that was taught before the spring break.

April 5* – Tuesday

Students use the magnifying devices to view potato cells.

April 6* – Wednesday

Students view animal cells by doing cheek scrapings.

Students view images of other plant and animal cells form the CD-ROM in the DL materials.

April 7* – Thursday
Students view plant cells by examining leaf cells (from the water plant furnished with the DL kit)

April 8 - Friday and April 11* – Monday

Students observe paramecia under the microscopes (or view the CD-ROM images and video clips.) (A culture of paramecia is provided with the DL materials.)

April 12* – Tuesday and April 13 - Wednesday

Students continue to observe paramecia and also look at euglena. (A culture of euglena is provided with the DL materials.)

March 14 – Thursday

The teachers will be in Raleigh the second day of notebook training. The substitute teachers will have the students read materials on cells.

March 15 – Friday – Teacher work day. No schools are in session.

April 18* – Monday
Students use magnifying devices to observe amoeba. (A culture of amoeba is provided with the DL materials.)

April 19 – Tuesday
Students use magnifying devices to observe protists, making drawings in notebooks.

April 20* – Wednesday
Shortened instructional day due to state assessment field testing
Teachers use the shortened class time to catch up on lessons or to allow students to explore freely with the materials.

April 21 – Thursday

Students participate in a Minipond safari by using the magnifying devices to explore the miniponds that they created at the beginning of the unit of study.

April 22* – Friday
Prom is scheduled for this night. Classes are disrupted due to teacher and student involvement in the preparations.
Teachers use the disrupted class time to catch up on lessons or to allow students to explore freely with the materials.

April 25* – Monday
Ribbon of Life activity

April 26 – Tuesday
Students watch the brief video "The Unknown World" from the DL materials.
Teachers check student notebooks and review the material covered in this unit.

April 27 – Wednesday
Administration of SAI II

April 28 – Thursday
Administration of SAI II (allows for interruptions of schedule on April 27 and for some make-up testing)

April 29 – Friday
Teacher workday

May 2 – Monday
Teachers administer posttest of the content test.

May 3 and 4 – Tuesday and Wednesday
Make-up testing for content test and SAI II

* Researcher observed a class of each teacher on this date.

APPENDIX E: SCIENCE CONTENT TEST VERSION 1

Generic Content Test on the Study of Cells – Version One
Multiple choice items – Please choose the best answer for each question.

1. The thick outer covering around the cell membrane of a plant cell is the:
    A. chloroplast
    B. plant wall
    C. cell wall
    D. nuclear membrane

2. The movement of material from an area of greater to an area of lesser concentration is called:
    A. photosynthesis
    B. death
    C. diffusion
    D. none of these

3. The basic unit of structure in living things is the:
    A. cell
    B. tissue
    C. organ
    D. none of these

4. The green structures found in plant cells are called:
    A. chlorophyll
    B. chloroform
    C. chloroplasts
    D. none of these

5. The pathways found in the cytoplasm are called the:
    A. ribosomes
    B. endoplasmic reticuli
    C. mitochondria
    D. none of these

6. The areas of the cell where energy is produced are called:
    A. ribosomes
    B. nucleus
    C. mitochondria
    D. none of these

7. The nuclear material is separated from the rest of the cell by the
    A. cell wall
    B. nuclear membrane
    C. cell membrane
    D. none of these

8. DNA is found in the nucleus located on structures called:
    A. chromosomes
    B. nuclear membranes
    C. vacuoles
    D. none of these

9. The smallest unit capable of carrying out all functions of life are called:
    A. DNA
    B. cells
    C. organelles
    D. Golgi bodies

10. Animal cells have:
    A. cell walls
    B. chloroplasts
    C. nuclear membrane
    D. chlorophyll

11. Photosynthesis takes place in the:
    A. lysosomes
    B. chloroplasts
    C. vacuoles
    D. endoplasmic reticulum

12. All cells have:
    A. a cell nucleus
    B. a cell membrane
    C. a cell wall
    D. chlorophyll

13. What structure forms the outer boundary of the cell and allows only certain materials to move into and out of the cell?
    A. cell membrane
    B. Golgi bodies
    C. endoplasmic reticulum
    D. lysosome

14. Which of the following is a form of hereditary material?
    A. cytoplasm
    B. chromatin
    C. chloroplasts
    D. mitochondria

15. What does a virus require to reproduce?
    A. mitochondria
    B. vaccine
    C. vacuole
    D. host cell

16. Which of the following is found in plant cells, but not in animal cells?
    A. chromatin
    B. cell wall
    C. cytoplasm
    D. nucleus

17. Which of the following is found in animal, but not in plant cell?
    A. mitochondria
    B. ribosomes
    C. lysosomes
    D. nuclear membrane

18. What can protists, which have nuclei, be considered?
    A. prokaryotic
    B. eukaryotic
    C. symbiotic
    D. many-celled

19. Which of the following lists is organized from the least complex to the most complex organization?
    A. organelles, cells, animals, organs, tissues
    B. organelles, cells, organs, tissues, animals
    C. tissues, cells, organs, organelles, animals
    D. animals, cells, organelles, tissues, organs

20. Which of the following is NOT a structure found in eukaryotic cells?
    A. nucleus
    B. ribosome
    C. mitochondrion
    D. stomata

21. An independent living thing is a(n):
    A. organ
    B. organelle
    C. organism
    D. nucleus

22. Euglena use a whiplike structure for propulsion. This structure is called a:
    A. cilia
    B. chloroplast
    C. flagellum
    D. paramecium

23. A paramecium:
    A. is a single-celled organism
    B. is capable of carrying out life processes
    C. uses hair-like structures called cilia to move
    D. all of the above are true of the paramecium

24. Osmosis is most frequently utilized in:
    A. excretion of waste
    B. protein production
    C. mitotic division
    D. photosynthesis

25. The cells that line the stomata in a leaf are called:
    A. phloem cells
    B. guard cells
    C. cuticle cells
    D. xylem cells

APPENDIX F: NORTH CAROLINA STANDARD COURSE OF STUDY GOAL 6

2004 Version
Eighth Grade
Competency Goal 6

COMPETENCY GOAL 6: The learner will conduct investigations, use models, simulations, and appropriate technologies and information systems to build an understanding of cell theory.

Objectives:

6.01 Describe cell theory:

- All living things are composed of cells.
- Cells provide structure and carry on major functions to sustain life.
- Some organisms are single cell; other organisms, including humans, are multi-cellular.
- Cell function is similar in all living things.

6.02 Analyze structures, functions, and processes within animal cells for:

- Capture and release of energy.
- Feedback information.
- Dispose of wastes.
- Reproduction.
- Movement.
- Specialized needs.

6.03 Compare life functions of protists:

- Euglena.
- Amoeba.
- Paramecium.
- Volvox.

6.04 Conclude that animal cells carry on complex chemical processes to balance the needs of the organism.

- Cells grow and divide to produce more cells.
- Cells take in nutrients to make the energy for the work cells do.
- Cells take in materials that a cell or an organism needs.

(Objectives were quoted from the North Carolina Department of Public Instruction (2004). *North Carolina Standard Course of Study and Grade Competencies*.

Retrieved November 4, 2004, from
http://www.ncpublicschools.org/curriculum/science/standard/toc.html.)

APPENDIX G: PROJECT 2061 MIDDLE GRADES CELL THEORY

By the end of the 8th grade, students should know that

- All living things are composed of cells, from just one to many millions, whose details usually are visible only through a microscope. Different body tissues and organs are made up of different kinds of cells. The cells in similar tissues and organs in other animals are similar to those in human beings but differ somewhat from cells found in plants.
- Cells repeatedly divide to make more cells for growth and repair. Various organs and tissues function to serve the needs of cells for food, air, and waste removal.
- Within cells, many of the basic functions of organisms-such as extracting energy from food and getting rid of waste-are carried out. The way in which cells function is similar in all living organisms.
- About two thirds of the weight of cells is accounted for by water, which gives cells many of their properties.

(Objectives were quoted from American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press. Available online at http://www.project2061.org/tools/benchol/ch5/ch5.htm#Cells_6_8.)

APPENDIX H: SCIENCE CONTENT TEST – VERSION 2

Content Test on the Study of Cells
Multiple choice items – Please circle the answer choice that you think is the best one.

1. The thick outer covering around the cell membrane of a plant cell is the:
   a. chloroplast
   b. plant wall
   c. nuclear membrane
   d. cell wall

2. The movement of material from an area of greater to an area of lesser concentration is called:
   a. photosynthesis
   b. diffusion
   c. death
   d. none of these

3. The basic unit of structure in living things is the:
   a. cell
   b. organ
   c. tissue
   d. none of these

4. The green structures, which allow the production of energy, and that are found in plant cells are called:
   a. cytoplasm
   b. chloroform
   c. chloroplasts
   d. none of these

5. The liquid material that is flowing inside cells is called:
   a. ribosomes
   b. cytoplasm
   c. mitochondria
   d. none of these

6. Which of the following structures are used by the paramecium to take food (a source of energy) into the organism?
   a. ribosomes
   b. oral groove
   c. nucleus
   d. cytoplasm

7. The nuclear material is separated from the rest of the cell by the
   a. cell wall
   b. cell membrane
   c. nuclear membrane
   d. none of these

8. An organism is that is made of a single cell is classified in which group:
   a. protests
   b. plants
   c. animalia
   d. elodea

9. The smallest units capable of carrying out all functions of life are called:
    a. DNA
    b. organelles
    c. cells
    d. Golgi bodies

10. Photosynthesis takes place in the:
    a. lysosomes
    b. vacuoles
    c. chloroplasts
    d. endoplasmic reticulum

11. All cells have:
    a. a cell nucleus
    b. a cell wall
    c. a cell membrane
    d. chlorophyll

12. What structure forms the outer boundary of the cell and allows only certain materials to move into and out of the cell?
    a. cell membrane
    b. endoplasmic reticulum
    c. Golgi bodies
    d. lysosome

13. What can protists, which have nuclei, be considered?
    a. Prokaryotic
    b. Symbiotic
    c. eukaryotic
    d. many-celled

14. Which of the following lists is organized from the least complex to the most complex organization?
    a. organelles, cells, animals, organs, tissues
    b. organelles, cells, organs, tissues, animals
    c. tissues, cells, organs, organelles, animals
    d. animals, cells, organelles, tissues, organs

15. Which of the following is NOT a structure found in eukaryotic cells?
    a. Nucleus
    b. Mitochondrion
    c. ribosome
    d. stomata

16. An independent living thing is a(n):
    a. organ
    b. organelle
    c. organism
    d. nucleus

17. Euglena use a whiplike structure for propulsion. This structure is called a:
    a. cilia
    b. flagellum
    c. chloroplast
    d. paramecium

18. A paramecium:
    a. is a single-celled organism
    b. is capable of carrying out life processes
    c. uses hair-like structures called cilia to move
    d. all of the above are true of the paramecium

19. Osmosis is most frequently utilized in:
    a. excretion of waste
    b. mitotic division
    c. protein production
    d. photosynthesis

20. The cells that line the stomata (or stomates) in a leaf are called:
    a. phloem cells
    b. cuticle cells
    c. guard cells
    d. xylem cells

21. Which cell part makes it possible for green plants and euglenas to produce make their own food (thus supplying energy)?
    a. chloroplast
    b. cytoplasm
    c. chromosome
    d. mitochondria

22. Which statement about plant cells and animal cells is the **most** correct?
    a. Both plant and animal cells have cell membranes and chloroplasts, but animal cells also have a cell wall.
    b. A plant cell has chloroplasts and a cell wall; an animal cell has a cell membrane but no chloroplasts or cell wall.
    c. Both plant and animal cells have chloroplasts, but an animal cell has a cell membrane and a plant cell has a cell wall.
    d. An animal cell has chloroplasts and a cell wall; a plant cell only has a cell membrane.

23. _____ are specialized leaf cells which control the size of the openings on the leaves.
    a. Guard cells
    b. Root hairs
    c. Xylem
    d. Stomates (or stomata)

24. Once a paramecium takes in food, it is enclosed in a packet called a :
    a. digestive enzyme
    b. food vacuole
    c. water-expelling vesicle
    d. pseudopod

25. Paramecia usually reproduce by:
    a. budding, in which a paramecium gives birth to a smaller paramecium.
    b. germination, which occurs when a paramecium seed is planted.
    c. photosynthesis, which takes place in the presence of sunlight.
    d. cell division, in which the cell duplicates the organelles in the cell and splits into two identical daughter cells.

26. An amoeba takes in food by:
    a. Surrounding and engulfing the food
    b. Sending out a false foot to retrieve the food and bring it to the amoeba.
    c. Using cilia to brush the food into the organism.
    d. Absorbing the food by diffusion.

27. Certain processes are required of all living organisms, whether single-celled or multi-cellular (such as animals and plants.) Which of the following items is not one of these processes?
    a. Exchange of gases
    b. Response to the environment
    c. Elimination of wastes
    d. Reproduction
    e. Use chloroplasts to produce food

APPENDIX I: STUDENT INTERVIEW QUESTIONS

I plan to interview four students from one class of each teacher. The questions below refer generically to the use of CD-ROM images, analog (regular) microscopes, and digital microscopes. However, I will ask each student specifically about the item that is being used in his/her classroom. (One teacher's classes will use the CD-ROM images, another teacher's classes will use analog microscopes, and the third teacher's classes will use digital microscopes.) Also, I want to make it clear to the students that I am not there to evaluate their learning or their behavior. Instead, I am looking for their help in learning about teaching cells. Their input will be valuable to me in understanding how these tools are useful or are not useful to middle school students as they learn about cells. These are the questions that I plan to ask each student.

1. What are you learning?
2. What about this unit on cells do you find interesting?
3. What about this unit on cells is not interesting to you?
4. What do you like about using the hand-held magnifiers and CD-ROM images/regular microscopes/digital microscopes in your classroom?
5. What do you dislike about using the hand-held magnifiers and CD-ROM images/regular microscopes/digital microscopes in your classroom?
6. How does working with the hand-held magnifiers and CD-ROM images/regular microscopes/digital microscopes help you to learn about cells?
7. If you were talking to your teacher about using the hand-held magnifiers and CD-ROM images/regular microscopes/digital microscopes in this class, what would you tell her?
8. If you were talking to your friends about using the hand-held magnifiers and CD-ROM images/regular microscopes/digital microscopes in this class, what would you tell them?
9. Which learning activities did you think were the most helpful to you in learning about cells?
10. What else would you like for me to know about this unit of study?
11. What else would you like for me to know about the hand-held magnifiers and CD-ROM images/regular microscopes/digital microscopes that were used in your classroom?

Additional questions asked of students in the classroom where the digital microscopes are used:

12. If you had the chance to use both brands of digital microscopes, what did you think of each one?
13. If you worked with both brands of microscopes, which one did you think was better? What did you like better about that microscope than the other one?
14. If you could erase this unit and start again, would you want to use the digital microscopes?
15. If you used any of the picture software that comes with the microscopes, what did you do with the software?

16. If you used any of the picture software that comes with the microscopes, what did you think about the use of that software?
17. If you used the software to create a presentation (like a slide show,) what did you think about using your own pictures to create a presentation?
18. If you shared any pictures that you took with the digital microscopes with other students or with your teacher, what did you think of that experience?
19. If other students shared any pictures with you that they took using the digital microscopes, what did you think about looking at the pictures that they took?

APPENDIX J: INFORMED CONSENT - STUDENTS AND PARENTS

North Carolina State University
INFORMED CONSENT FORM for RESEARCH
Students and their parent(s) or legal guardian(s)

Through the microscope lens - looking at digital microscopes in middle school science

Principal Investigator: Jackie S. Ennis Faculty Sponsor: Dr. Ellen S. Vasu

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Students, we are asking you to participate in a research study. The purpose of this study is to learn about the use of microscopes in the study of cells in middle school science. This letter is intended to provide information to students and their parent(s) or legal guardian(s) regarding this study, which will be conducted in the context of the science classroom. If you choose to participate, and if your parent agrees to your participation, then please complete the consent form at the bottom of the second page. You are receiving two copies of this form. One is yours to keep. The other copy should be signed and returned to your science teacher if you and your parent agree to your participation in this study.

INFORMATION
If you agree to participate in this study:

- You will be asked to complete the Scientific Attitude Inventory II before the study begins and after it ends. This survey is used to help determine the attitude that students have toward science. You will answer the survey questions before your teacher presents the unit on cells, and you will answer them again at the end of the unit of study. I will compare the results of the average of the scores of the pre-tests to the average of the scores of the post-test to determine if the students in general have changed their attitudes toward science after completing the unit of study on cells. This instrument is just a survey, and it will have no effect on your grade in any class. This survey will not be used to evaluate individual students in any way. Taking this inventory should require about 20 minutes of class time for each administration. No individual student results will be reported.
- You will be asked to complete a content test before the study begins and after it ends. This test will be in the format of a multiple choice test and will address information that will be taught in the unit on cells. Students will be asked to take this test before the unit on cells and after the study of cells so that I can compare the class average on each test administration. I would like to use that data to see how much better or worse students perform on the test after the unit on cells has been taught. This test will not be used as grade in any class. Taking this test will have no effect on any student's grade. This test will not be used to evaluate individual students in any way. Taking this test should require about 20 minutes of class time for each administration. No individual student results will be reported.
- The researcher will videotape some of the class sessions in one of your teacher's classes. If the student and parent have not signed a consent form for the student to be videotaped at school, then that student will not be taped. The student will be seated in an area where the camera is not able to film. The student will not be restricted in any way from participating in the class activities. He/she will simply be seated in a section of the room where the camera cannot record.
- In addition to these procedures, twelve students from this school will be invited to participate in an interview with the researcher. Those students and their parents will receive an additional

permission form for this purpose. The list of questions that the researcher plans to ask will be attached to that form.

- This study is expected to last for approximately six weeks, during the time that the teachers are presenting the unit on cells.

RISKS

I do not foresee any risks to students who participate in this study. I am a former classroom teacher who taught middle school mathematics, science, and/or technology classes for 15 years. I am interested in learning from the students as they participate in a unit of study on cells. All observations and interviews will occur in the regular classroom with the teacher present. I do not intend to ask the students any questions that they should find embarrassing or that should make them uncomfortable. Students may end their participation in this study at any time with no penalty.

BENEFITS

1. I think that students will benefit this study because pictures on CD-ROMs are being added to all classes during their study of cells, and the eighth grade classes will have the addition of microscopes. The seventh grade students will have a study on cells again next year, so the students in her classroom will have the opportunity to use traditional and/or digital microscopes with their eighth-grade teachers if the teachers decide that their presence in the classroom is beneficial to their students. Also, the Delta Education kit Diversity of Life has been purchased for use by all three of these classes. I think that students will enjoy using these materials, and I anticipate that they will learn from using these hands-on resources.
2. I plan to share information that I learn from this study with the education community. As noted, no students or teachers will be personally identified. However, generalizations that are gleaned from the attitude inventory, the content test, the observations, and the interviews will likely offer insights to your teachers and to other middle school science teachers as they prepare a unit of study on cells.

CONFIDENTIALITY

The information in the study records will be kept strictly confidential. Data will be stored securely and will be made available to no one outside of the study. No reference will be made in oral or written reports which could link you to the study.

COMPENSATION

No compensation is offered to individual participants. The school will receive three Digital Blue Microscopes as appreciation from the researcher for allowing the study to take place at this location. However, students and teachers will not receive compensation for their participation. Likewise, they will not be penalized for not participating or for deciding to end the participation before the study ends.

CONTACT

If you have questions at any time about the study or the procedures, you may contact the researcher, Jackie Ennis, at 3462 Wollett Mill Road, Battleboro, NC 27809, or 252-399-6434. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Dr. Matthew Zingraff, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Box 7514, NCSU Campus (919/513-1834) or Mr. Matthew Ronning, Assistant Vice Chancellor, Research Administration, Box 7514, NCSU Campus (919/513-2148).

PARTICIPATION

Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed, your data will be returned to you or destroyed at your request.

CONSENT

"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may withdraw at any time."

Subject's signature_____ **Date** _____

Parent's signature _____ **Date** _____
(or legal guardian's)

Investigator's signature_____ **Date** _____

North Carolina State University
INFORMED CONSENT FORM for RESEARCH
Additional form to be provided to students and the parents or legal guardians of the students who are invited to participate in interviews

Through the microscope lens - looking at digital microscopes in middle school science

Principal Investigator: Jackie S. Ennis Faculty Sponsor: Dr. Ellen S. Vasu

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Students and parents(s) or legal guardian(s),

This permission form is being sent home with selected students and parents(s) or legal guardian(s) who have already signed permission slips allowing the student to participate in the research study about the use of microscopes in the study of cells in middle school science. Twelve students are invited to participate in interviews with the researcher regarding the use of microscopes in this unit of study. Below is some information explaining this interview process. If the student chooses to participate, and if the parent(s) or legal guardian(s) agrees to the student's participation, then both the student and the parent or legal guardian should complete the consent form at the bottom of this page and return it to the student's science teacher.

INFORMATION

- I was a public school teacher who taught math, science, and technology classes in the Nash-Rocky Mount School system for 15 years. I am interested in learning what the students can teach me about the use of microscopes in the middle school classroom during the unit on cells.
- I will ask the students the questions which are attached to this form.
- I will write down the answers that the students provide. I will show the students what I am writing so that they can see that I am writing down their responses.
- I will use an audio tape recorder to record the students' answers. No one but me will listen to these tapes. The tapes will be stored securely in my home, and I will destroy them upon the completion of this research study.
- I will ask the questions of the students during regular science class time. The teacher and other students will be present in the room.
- I will probably spend about 10 minutes on two different days to ask the questions of the student.

RISKS

I do not foresee any risks to students who participate in this study. As I stated, I am a former classroom teacher who taught middle school mathematics, science, and/or technology classes for 15 years. I am interested in learning from the students as they participate in a unit of study on cells. All observations and interviews will occur in the regular classroom with the teacher present. I do not intend to ask the students any questions that they should find embarrassing or that should make them uncomfortable. Students may end their participation in this study at any time with no penalty.

BENEFITS

1. I think that students will benefit this study because pictures on CD-ROMs are being added to all classes during their study of cells, and the eighth grade classes will have the addition of microscopes. The seventh grade students will have a study on cells again next year, so the students in her classroom will have the opportunity to use traditional and/or digital microscopes with their eighth-grade teachers if the teachers decide that their presence in the classroom is beneficial to their students. Also, the Delta Education kit Diversity of Life has been purchased for use by all three of these classes. I think that students will enjoy using these materials, and I anticipate that they will learn from using these hands-on resources.

2. I plan to share information that I learn from this study with the education community. As noted, no students or teachers will be personally identified. However, generalizations that are gleaned from the attitude inventory, the content test, the observations, and the interviews will likely offer insights to your teachers and to other middle school science teachers as they prepare a unit of study on cells.

CONFIDENTIALITY

The information in the study records will be kept strictly confidential. Data will be stored securely and will be made available to no one outside of the study. No reference will be made in oral or written reports which could link you to the study. Only pseudonyms will be used when writing the research report.

COMPENSATION

No compensation is offered to individual participants. The school will receive three Digital Blue Microscopes as appreciation from the researcher for allowing the study to take place at this location. However, students and teachers will not receive compensation for their participation. Likewise, they will not be penalized for not participating or for deciding to end the participation before the study ends.

CONTACT

If you have questions at any time about the study or the procedures, you may contact the researcher, Jackie Ennis, at 3462 Wollett Mill Road, Battleboro, NC 27809, or 252-399-6434. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Dr. Matthew Zingraff, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Box 7514, NCSU Campus (919/513-1834) or Mr. Matthew Ronning, Assistant Vice Chancellor, Research Administration, Box 7514, NCSU Campus (919/513-2148).

PARTICIPATION

Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed, your data will be returned to you or destroyed at your request.

CONSENT

"I have read and understand the above information. I have received a copy of this form. I agree to participate in the student interview process of this study with the understanding that I may withdraw at any time."

Subject's signature_____ **Date** _____

Parent's signature _____ **Date** _____
(or legal guardian's)

Investigator's signature_____ **Date** _____

APPENDIX K: TEACHER INTERVIEW QUESTIONS

Teacher Interview Questions – to be asked of each of the three teachers participating in this study. The questions below refer generically to the use of CD-ROM images, analog (regular) microscopes, and digital microscopes. However, I will ask each teacher specifically about the item that is being used in his/her classroom. (One teacher will use the CD-ROM images, another will use analog microscopes, and the third teacher will use digital microscopes.) I will emphasize to the teachers that I am not there to judge their classes or their teaching. My goal is to learn from them about using the CD-ROM images, analog microscopes, and digital microscopes in the teaching of cell theory to middle school students.

1. Before this study began, how readily available were technology resources for you to use in your teaching?
2. Before this study began, what digital technologies (such as computers and CD-ROMS with pictures, digital microscopes) were available in this middle school for you to use when teaching the unit on cells?
3. Before this study began, how accessible were digital technologies (such as computers and CD-ROMS with pictures, digital microscopes) for you to use when teaching the unit on cells?
4. In what ways that have you used magnification devices, including hand-held magnifiers, regular microscopes, and digital microscopes, when teaching the unit on cells in past years?
5. What was your perception of the use of magnification devices in past years?
6. How easy/difficult did you find it to use the hand-held magnifiers and CD-ROM images/regular microscopes/digital microscopes that were provided for your classroom use this year?
    a. What factors contributed to the ease of use?
    b. What factors contributed to any difficulties that you encountered?
    c. What suggestions might you offer for making it easier for other teachers to use them in the future?
7. How would you describe any learning experiences that you, as a teacher, might have had as the result of preparing to use the hand-held magnifiers and CD-ROM images/regular microscopes/digital microscopes in your classroom and in actually using these items with your students?
8. What is your perception of the students' views about the inclusion of the hand-held magnifiers and CD-ROM images/regular microscopes/digital microscopes in your classroom?
9. How would you rate the students' engagement in their learning when the hand-held magnifiers and CD-ROM images/regular microscopes/digital microscopes were used in your classroom in the unit on cells?
10. How would you rate the students' engagement in the unit on cell theory this year as compared to past years that you have taught this unit? What prompted you to reach this conclusion?
11. What types of student engagement activities have you observed while teaching the unit on cell theory this year?

12. How easy or difficult did you find it to learn about how to use hand-held magnifiers and CD-ROM images/regular microscopes/digital microscopes in your classroom?
13. How easy or difficult was it for you to use the hand-held magnifiers and CD-ROM images/regular microscopes/ digital microscopes in your classroom?
14. What recommendations do you have to make it easy for another teacher to learn to use the hand-held magnifiers and CD-ROM images/regular microscopes/digital microscopes and to implement the use of magnification tools in their classrooms?
15. In your opinion, was it worth the trouble that it took to learn to use the hand-held magnifiers and CD-ROM images/regular microscopes/digital microscopes and to implement the use of these items in your classroom?
16. If you were to teach the unit on cell theory again next year, would you prefer to use the hand-held magnifiers and CD-ROM images/regular microscopes/digital microscopes in your classroom or to teach this unit on cell theory using the same tool(s) that you used last year? What factors contributed to this decision?
17. What hints would you give other teachers to make the use of hand-held magnifiers and CD-ROM images, regular microscopes, or digital microscopes more successful in their classrooms?
18. What other suggestions do you have to enhance the study of cells in a middle school science classroom?
19. If your students create multimedia projects using pictures of cells, please describe what you noticed about student engagement as the students worked on these projects.
20. If your students created multimedia projects, what did you think of the value of the learning experience associated with the creation of the multimedia projects?
21. If your students created multimedia projects, how did you evaluate those projects?
22. What suggestions regarding safety issues associated with teaching this unit on cells, espcially when using hand-held magnifiers and CD-ROM images/regular microscopes/digital microscopes, can you offer to other middle school science teachers?
23. What else would you like for me to know about the use of hand-held magnifiers and CD-ROM images/regular microscopes/digital microscopes in your classroom?

APPENDIX L: TEACHER CONSENT FORM

North Carolina State University
INFORMED CONSENT FORM for RESEARCH - Teachers

Through the microscope lens - looking at digital microscopes in middle school science

Principal Investigator: Jackie S. Ennis Faculty Sponsor: Dr. Ellen S. Vasu

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We are asking you to participate in a research study. The purpose of this study is to learn about the use of microscopes in the study of cells in middle school science.

INFORMATION
If you agree to participate in this study:

- You will be asked to administer the Scientific Attitude Inventory II to each class you teach. You will ask the participating students to complete this inventory before the study begins and after it ends. This survey is used to help determine the attitude that students have toward science. I will compare the results of the average of the scores of the pre-tests of each teacher's students to the average of the scores of the post-test to determine if the students in general have changed their attitudes toward science after completing the unit of study on cells. This instrument is just an attitude survey, and it will have no effect on your students' grade in any class. This survey will not be used to evaluate individual students in any way. Taking this inventory should require about 20 minutes of class time for each administration.
- You will be asked to administer a content test before the study begins and after it ends. This test will be in the format of a multiple choice test and will address information that will be taught in the unit on cells. Students will be asked to take this test before the unit of cells and after the study of cells so that I can compare the average of each teacher's classes on each test administration. I would like to use that data to see how much better or worse students perform on the test after the unit on cells has been taught. Taking this test will have no effect on any student grade. This test will not be used to evaluate individual students or teachers in any way. Giving this test should require about 30 minutes of class time for each administration. The purpose of this testing is to compare the methods being introduced by each teacher, and not to compare any teachers themselves.
- You will be asked to allow the researcher to observe one of your classrooms two or three times a week during the 6-weeks period that the unit on cells is being taught. The researcher will simply observe and make notes regarding students' participation in the class as the unit on cells is taught. No students or teachers will be identified by name. Instead, pseudonyms will be used for the school, the school system, the teachers, and all students referenced in this study. The purpose of the observations is to study the methods being introduced by each teacher, and not to evaluate the teachers in any way.
- If some of your students do not wish to participate in this study, the researcher will make no notes regarding their class participation. If a student is assigned to a class where the observations are occurring, and he/she does not wish to be a part of this classroom, the student and his/her parents can request that the principal move student to another classroom taught by this teacher where the observations are not occurring. No student evaluations will be made as the result of the observations.
- You will be asked to allow the researcher to videotape some of the class sessions in the classroom where the observations occur. If a student and his/her parent(s) have not signed a consent form for the student to be videotaped at school, then that student will not be taped. (The student will be seated in an area where the camera is not able to film. The student will

not be restricted in any way from participating in the class activities. He/she will simply be seated in a section of the room where the camera cannot record.)

- You will be asked to participate in interview sessions with the researcher. A list of questions that will be asked by the researcher is attached. Interviews will be conducted during the teacher's planning time. It is estimated that it will take about 30 minutes of your planning time on 3 different days.
- You will be asked to allow the researcher to interview four students from the class in which she is observing. Students and their parent(s) will sign permission forms before the interviews take place.
- This study is expected to last for approximately six weeks, during the time that you will be presenting the unit on cells.

RISKS

I do not foresee any risks to teachers or students who participate in this study. I am a former classroom teacher who taught middle school mathematics, science, and/or technology classes for 15 years. I am interested in learning from the teachers and their students as the teachers present a unit of study on cells. All observations will occur in the regular classroom with the teacher present. Teachers and students may end their participation in this study at any time with no penalty.

BENEFITS

1. I think that students will benefit this study because pictures on CD-ROMs are being added to all classes during their study of cells, and the eighth grade classes will have the addition of microscopes. The seventh grade students will have a study on cells again next year, so the students in her classroom will have the opportunity to use traditional and/or digital microscopes with their eighth-grade teachers if the teachers decide that their presence in the classroom is beneficial to their students. Also, the Delta Education kit Diversity of Life has been purchased for use by all three of these classes. I think that students will enjoy using these materials, and I anticipate that they will learn from using these hands-on resources.
2. I plan to share information that I learn from this study with the education community. As noted, no students or teachers will be personally identified. However, generalizations that are gleaned from the attitude inventory, the content test, the observations, and the interviews will likely offer insights to your teachers and to other middle school science teachers as they prepare a unit of study on cells.

CONFIDENTIALITY

The information in the study records will be kept strictly confidential. Data will be stored securely and will be made available to no one outside of the study. No reference will be made in oral or written reports which could link you to the study.

COMPENSATION

No compensation is offered to individual participants. The school will receive three Digital Blue Microscopes as appreciation from the researcher for allowing the study to take place at this location. However, students and teachers will not receive compensation for their participation. Likewise, they will not be penalized for not participating or for deciding to end the participation before the study ends.

CONTACT

If you have questions at any time about the study or the procedures, you may contact the researcher, Jackie Ennis, at 3462 Wollett Mill Road, Battleboro, NC 27809, or 252-399-6434. If you feel you

have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Dr. Matthew Zingraff, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Box 7514, NCSU Campus (919/513-1834) or Mr. Matthew Ronning, Assistant Vice Chancellor, Research Administration, Box 7514, NCSU Campus (919/513-2148).

PARTICIPATION

Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed, your data will be returned to you or destroyed at your request.

CONSENT

"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may withdraw at any time."

Subject's signature_____ **Date** _____

Investigator's signature_____ **Date** _____

APPENDIX M: SAI II POSITION STATEMENTS AND ATTITUDE STATEMENTS

POSITION STATEMENTS AND ATTITUDE STATEMENTS OF THE SCIENTIFIC ATTITUDE INVENTORY II

These are the position statements and corresponding attitude statements of the *Scientific Attitude Inventory II*.

The position statements are labeled with a number and a letter, for example, 1-A. The letter designates whether the position statement is positive (A) or negative (B). The position statements are in pairs where the pair 1-A and 1-B are intended to be opposite positions regarding the same point of view.

The numbers in front of each attitude statement indicates its number in the SAI II.

1-A The laws and/or theories of science are approximations of truth and are subject to change.
4. Scientists are always interested in better explanations of things.
16. Scientific ideas can be changed.
34. Scientists believe that nothing is known to be true for sure.

1-B The laws and/or theories of science represent unchangeable truths discovered through science.

11. When scientists have a good explanation, they do not try to make it better.
15. Scientists discover laws which tell us exactly what is going on in nature.
35. Scientific laws have been proven beyond all possible doubt.

2-A Observation of natural phenomena and experimentation is the basis of scientific explanation. Science is limited in that it can only answer questions about natural phenomena and sometimes it is not able to do that.
10. Scientists cannot always find the answers to their questions.
19. Some questions cannot be answered by science.
33. The senses are one of the most important tools a scientist has.

2-B The basis of scientific explanation is in authority. Science deals with all problems and it can provide correct answers to all questions.
2. Anything we need to know can be found out through science.
7. We can always get answers to our questions by asking a scientist.
26. If a scientist cannot answer a question, another scientist can.

3-A To operate in a scientific manner, one must display such traits as intellectual honesty, dependence upon objective observation of natural events, and willingness to alter one's position on the basis of sufficient evidence.
17. Scientific questions are answered by observing things.
18. Good scientists are willing to change their ideas.
25. Scientists must report exactly what they observe.

3-B To operate in a scientific manner one needs to know what other scientists think; one needs to know all the scientific truths and to be able to take the side of other scientists.
3. It is useless to listen to a new idea unless everybody agrees with it.
5. If one scientist says an idea is true, all other scientists will believe it.
32. Scientists should not criticize each other's work.

4-A Science is an idea-generating activity. It is devoted to providing explanations of natural phenomena. Its value lies in its theoretical aspects.
20. A scientist must have a good imagination to create new ideas.
21. Ideas are the most important result of science.
28. Science tries to explain how things happen.

4-B Science is a technology-developing activity. It is devoted to serving mankind. Its value lies in its practical uses.
9. Electronics are examples of the really valuable products of science.
24. A major purpose of science is to produce new drugs and save lives.
31. A major purpose of science is to help people live better.

5-A Progress in science requires public support in this age of science, therefore, the public should be made aware of the nature of science and what it attempts to do. The public can understand science and it ultimately benefits from scientific work.
12. Most people can understand science.
23. People must understand science because it affects their lives.
29. Every citizen should understand science.

5-B Public understanding of science would contribute nothing to the advancement of science or to human welfare, therefore, the public has no need to understand the nature of science. They cannot understand it and it does not affect them.
6. Only highly trained scientists can understand science.
8. Most people are not able to understand science.
38. Scientific work is useful only to scientists.

6-A Being a scientist or working in a job requiring scientific knowledge and thinking would be a very interesting and rewarding life's work. I would like to do scientific work.
1. I would enjoy studying science.
27. I would like to work with other scientists to solve scientific problems.
30. I may not make great discoveries, but working in science would be fun.
36. I would like to be a scientist.
40. Working in a science laboratory would be fun.

6-B Being a scientist or working in a job requiring scientific knowledge and thinking would be dull and uninteresting; it is only for highly intelligent people who are willing to spend most of their time at work. I would not like to do scientific work.

13. The search for scientific knowledge would be boring.
14. Scientific work would be too hard for me.
22. I do not want to be a scientist.
37. Scientists do not have enough time for their families or for fun.
39. Scientists have to study too much.

APPENDIX N: SAI II SCORING TEMPLATE

	A	B	C	D	E	A	B	C	D	E
1						0	0	0	0	0
2						0	0	0	0	0
3						0	0	0	0	0
4						0	0	0	0	0
5						0	0	0	0	0
6						0	0	0	0	0
7						0	0	0	0	0
8						0	0	0	0	0
9						0	0	0	0	0
10						0	0	0	0	0
11						0	0	0	0	0
12						0	0	0	0	0
13						0	0	0	0	0
14						0	0	0	0	0
15						0	0	0	0	0
16						0	0	0	0	0
17						0	0	0	0	0
18						0	0	0	0	0
19						0	0	0	0	0
20						0	0	0	0	0
21						0	0	0	0	0
22						0	0	0	0	0
23						0	0	0	0	0
24						0	0	0	0	0
25						0	0	0	0	0
26						0	0	0	0	0
27						0	0	0	0	0
28						0	0	0	0	0
29						0	0	0	0	0
30						0	0	0	0	0
31						0	0	0	0	0
32						0	0	0	0	0
33						0	0	0	0	0
34						0	0	0	0	0
35						0	0	0	0	0
36						0	0	0	0	0
37						0	0	0	0	0
38						0	0	0	0	0
39						0	0	0	0	0
40						0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0

APPENDIX O: NOTEBOOK CHECKSHEET

Student _____

Diversity of Life Notebook March 14 --- until present

The following information should be completed in your child's notebook. Completed assignments **will be scored as 100**. Incomplete assignments will be scored as 70 or less (depending on the amount of work completed.) Your child should be able to flip through his/her not4ebook and show you everything that we have done except for 2 papers that I have taken up to be graded differently.

Look for each of the following:

_____Schedule—contains list of work assignments for each day

_____Activity: Living or Nonliving—should be on notebook paper

_____Lab Safety Checklist and Contract

_____Activity: Five Materials Observation

_____Characteristics of Living Things---on notebook paper

_____Activity: Life in Different Environments

_____Worksheet: Living or Nonliving

_____Worksheet: Microscope Care and Use

_____Activity Sheet: Brine Shrimp Alive!

_____Drawings and Observations of Potato _____

_____Drawings and Observation of Celery _____

_____Activity Sheet: Cheek Investigation _____

_____Activity Sheet: Paramecia _____

_____Drawings and Observations: Paramecium _____

_____Activity Sheet: Elodea _____

_____Drawings and Observations: Elodea _____

_____Activity Sheet: Euglena _____

_____Drawings and Observations: Euglena _____

Parent Signature _____