ABSTRACT

JESSEE, EMILY GEORGE. Understanding Student Experiences: A Case Study in Scientific Visualization and Civics and Economics. (Under the direction of Dr. V. William DeLuca.)

This research study provides the finding of a qualitative case study in Technology, Engineering, and Design Education as well as Social Studies Education. The purpose of this study was to describe the role of graphics within a social studies lesson by examining a student’s experience when a new lesson is implemented in class. The participants were nine students in a single CTE class at a public high school in North Carolina that was near Research Triangle Park and offered a Scientific Visualization II course. The integration of scientific visualization into a civics and economics lesson provided insights in both curricula and the learning process. The qualitative data showed instances in which the student had a greater understanding of the subject when using scientific visualization to understand a lesson focused on supply and demand. The study’s findings can be used to demonstrate how much visual representation impact a student’s learning as well as the importance of listening to their voices. The themes that emerged were based on four components outlined in the theoretical framework, pointed to learning that was context-based, active involvement in conceptual learning, identification of learning goals, and a compassionate presence. The second research question, paired with the same theoretical components, found relevance in application to the real world, developing data literacy, learning that is understanding, and exploring creativity.
DEDICATION

I dedicate this dissertation to my loved ones. You are all my biggest cheerleaders and I could not have completed this project without your contributions. First and foremost, I am grateful to my husband, Jared Howard Jessee, senior, who gave me more love, support and understanding than I could have ever imagined. I am also thankful to my little ones, Jared (Rede) Howard Jessee, junior, and Sarah Elizabeth Jessee, your laughs, smiles, and endless love inspired me to finish and achieve one of my dreams. To my parents, Mr. and Mrs. James Philip George, I appreciate your dedication and enthusiasm. You came to my help at the drop of hat without even blinking whenever I needed you. To my sister, Ms. Courtney Bowman George, you kept me going when I first began this journey and always make me laugh. To my in-loves, Mr. and Mrs. James Jackson Jessee, III, you are the best family a girl could ever have and I am thankful for your kindness. There were many a long days with Papa and LiLi for my little ones. To my friend, Mrs. Andrea Barrows Armstrong, you have been my editor long before I started this adventure and I am grateful for your advice and encouragement to achieve my goal. And, to all the teachers in my life, especially my grandmother, Mrs. Gertrude Moore George, my aunts, Mrs. Muriel Weather and Ms. Jan Powell, and a favorite teacher, Mrs. Jean Morgensen, you taught me what it truly is to be a teacher long before I knew God’s plan.
BIOGRAPHY

Emily George Jessee was born on December 29, 1977, to Brenda King and James Philip George in Sylva, North Carolina. She completed her Bachelor of Science degree in Engineering Technology with a concentration in Engineering Design and a focus in Animation, Illustration, and Multimedia from East Tennessee State University in 2001. She was a member of Kappa Delta sorority and Epison Pi Tau, an international honor society for professions in technology. While working in advertising, she decided she wanted to be a teacher and began work on her Masters of Education degree in Technology Education at North Carolina State University where she was inducted into Phi Kappa Phi, the oldest and largest collegiate honor society dedicated to the recognition and promotion of academic excellence in all disciplines. She got her first teaching job in Oxford as a Lateral Entry teacher in 2003 and loves being in the classroom. With encouragement from Dr. V. William DeLuca, she continued in the program to pursue a doctorate. She currently is a teacher with Wake County Schools close to her home and family.
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The faculty of North Carolina State University has always been supportive and gracious with their time and knowledge. To my dissertation committee: Dr. V. William DeLuca, my committee chair who provided encouragement when needed and let me sweat a little when I also needed it. Thank you for taking the time to work with me; Dr. Eric Wiebe, I appreciate your expert knowledge in the field of Scientific Visualization and guidance in an independent study that gave me encouragement to get to where I am today; Dr. Joe Busby, I loved my summer class on hydrogen fuel cell cars and am thankful for the energy you ignited when I was there to continue to push forward. Dr. Kevin Oliver, your online classes are the best I have ever taken. You are at the top of your field and I appreciate all the advice you passed along to me in my qualitative research and technological queries. To other professors in the Education department, this has been an incredible experience. I have not only learned and grown a great deal, but have truly enjoyed this experience.

Also, I am grateful to one small conversation after school during my first year in Wake County that sparked the idea for this dissertation.
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CHAPTER 1

INTRODUCTION

Critical thinking, which is crucial in learning, requires reflection and reason from a student. Scientific visualization visually offers a way for students to process information. The scientific visualization curriculum currently consists of lessons in science, technology, engineering, and math. Scientific visualization is a new branch of Technology Education. It allows students to create mental images from the text they gathered through inquiry (Berson & Berson, 2009). Meaning, students can form a picture in their head of a concept covered in class. One of the goals of scientific visualization curriculum is to enhance knowledge through use of computer technology (North Carolina State University College of Education, Graphic Communications Program & North Carolina State Department of Public Instruction, 2002). Little research has been done to evaluate the ability of scientific visualization to transform learning in other academic subjects, like civics and economics. The purpose of this case study is to understand student experiences in a civics and economics class when a new lesson incorporates scientific visualization into learning.

Statement of the Problem

“For at least a century, educational critics and school reformers have pointed to high school history teaching as the model for poor and ineffective pedagogy” (National Research Council, 2005, p. 179). The above quote points out that civics and economics curricula, as a branch of history, need stronger organization. “Sometimes complicated information is difficult to understand and needs an illustration...by organizing content into digestible pieces, main concepts or issues are easily discernible and can foster dynamic exchanges about timely
subjects” (Berson & Berson, 2009). Students have historically had more difficulty with the civics and economics End-of-Course (EOC) exams than with other social studies EOC exams. Seeing the difficulty in this subject matter, scientific visualization could offer students a way to see material in a new light. Yet these two fields are rarely linked in high school classrooms. In 2008–2009, the North Carolina Department of Public Instruction (NCDPI) reported 100,931 students taking the civics and economics EOC test. Of those students, 72% passed, much better than the 66% for 2006–2007 and the 69% for 2007–2008 (NCDPI, 2010). The growth of these scores is due to the NCDPI’s more direct guidance to make certain that teacher instruction is in line with the standard course of study for students, creation of common formative assessments, and more professional development. In North Carolina, civics and economics is one of the five required high-school classes. The scientific and technical visualization curriculum from the NCDPI explores problems only in science, technology, engineering, and math, yet scientific visualization can include areas like social studies and art. I will extend the existing civics and economics curriculum by incorporating scientific visualization.

Students are able to understand difficult material like circular flow of economic activities in civics and economics by creating a mental image visual language. The process of building the image is important to develop critical thinking and enables better retention than having a student just look at a chart from the book. Not all students have the ability to form pictures in their head when reading. Students can learn from inquiring and thinking, also known as inquiry-based learning. Timmerman, Strickland, and Carstensen (2008, p. 227) stated that “inquiry-based pedagogies promote deeper understanding of content and/or
greater skills in scientific reasoning” (Shymansky et al., 1983; Jensen & Finley, 1996; Johnson & Lawson, 1998; Christianson & Fisher, 1999; Musheno & Lawson, 1999; Abd-El-Khalick & Lederman, 2000; Cabrera et al., 2001; Pelaez, 2002; Schneider et al., 2002; Marx et al., 2004).

“Social studies educators need to be aware of this rapidly evolving technology and applications for our teaching and learning” (Berson & Berson, 2009, p. 4). As stated by the National Research Council in 2005, high school history has been pinpointed as a model for poor and ineffective pedagogy for the last century by educational critics and school reformers. Thus, educators need help to strengthen teachings. Scientific visualization can help educators and students. Having students pose questions, inquire about materials, and create visualizations leads to more effective learning. Therefore, this study addresses if scientific visualization improves students understanding of civics and economics.

Background

“Scientific visualization is the representation of data graphically in order to gain understanding and insight into data or a concept” (North Carolina Department of Public Instruction, 2000, p. ii). Many students seem to have difficulty understanding economic, legal, and political systems in civics and economics courses. These concepts are the foundation for United States history and a precursor for many other courses. It is essential that students understand how to become “responsible and effective citizens in an interdependent world” (North Carolina Department of Public Instruction, 2006). It is apparent through statements made in media and social studies professionals that social studies educators need to implement change to promote learning. With this concern, it is
important to note the proven links between visualization and thinking. Scientific visualization has been successful with other areas of academics and can expand to other subject areas.

Scientific visualization was officially first reported and recognized in 1987 in a report by the National Science Foundation (DeFanti, Brown, & McCormick, 1989). It promotes higher-order thinking skills and a deeper understanding of graphics and scientific and/or technical concepts materials. It is also strongly associated with the technology many students use in the 21st century, including iPods, tablets, podcasts, blogs, wikis, and web 2.0 tools. Though it is an extraordinary way of representing material, courses in scientific visualization and gaming are very popular. NCSU, the NCDPI, and Wake Technical Community College developed coursework in scientific and technical visualization for high school students through a Tech-Prep Innovation Grant (Clark & Matthews, 2000, p. 89). After a pilot study, scientific and technical visualization was first offered to students in the fall of 1998. Over 350 students were enrolled throughout the state by 1999 (Clark & Matthews, 2000, p. 90). There are now multiple conferences that highlight scientific visualization every year, like IEEE and ACM SIGGRAPH. These gatherings focus on recent trends, leading researchers, and fresh techniques in this discipline.

Purpose of Study

Scientific visualization has been proven to link higher-order thinking skills with deeper understanding of graphics. Berson and Berson (2009) said,

Visualization is clearly an important benefit of these graphical depictions of language. They can transform text into powerful visuals that promote inquiry skills. Interactive visualizations help people see and exchange information in novel ways. By making
use of these web-based tools within an inquiry-driven approach, students can expand their analytic capabilities and discover meaning by looking and thinking. (p. 125)

When students solve real-world problems, critical thinking and learning can enhance a student’s skills. In this research project, teachers facilitate learning in a scientific visualization classroom while implementing a civics and economics lesson. The purpose of this study is to describe the role of graphics within a social studies lesson by examining a student’s experience when a new lesson is implemented in class. The research will report their experiences and find themes and patterns.

Need for Study

The study will fill a gap in existing literature and contribute valuable information to scientific visualization and social studies curricula. Current written material has volumes of data to demonstrate the link between visualization and science education and between visualization and mathematics educations, but few articles address scientific visualization being used in other academic disciplines. Visual thinking and learning can exist at the same time within the brain. Fifty percent of the brain’s neurons are linked with the ability to perceive with eyes (DeFanti et al., 1989), and 40 to 65% of students are visual learners (Reed, 2007, para. 5). Animations, game development, and computer programming foster visual learning throughout students’ lives.

Scientific visualization can help students understand complicated information like civics and economics. In performing this study, students will be shown how to make sense of one area of social studies. “Visualization enable(s) scientists to inspect, interpret, and analyze large multi-dimensional data sets” (Tateosian, Healey, & Enns, 2007, p. 8). There is evidence
that visualization aids in cultivating understanding and thinking. Edward Tufte believes “graphics reveal data” (Tufte, 1983, p. 13). He wrote about standards of design concepts in his books. He wrote about characteristics of command, market, traditional and mixed economies, and political systems. From his work, the researcher derives all of these concepts could be put into a graphic form that enables students to see data, consequentially, enabling students to have a deeper meaning of civics and economics content.

In 2000, Hyrkäs stated that scientific visualization “can be seen as a method of conceive otherwise troublesome entities, organizing knowledge and achieving new, sometimes surprising, viewpoints” (Hyrkäs, 2000, p. 2). The fundamental need for students to make sense of difficult data can be done in any curriculum, but this study concentrates on one academic area: civics and economics. Using scientific visualization this case study is integrating content from both civics and economics and scientific visualization curricula. Scientific visualization is based on a foundation that is deeply rooted in time that can enrich, identify, strengthen, and synthesize learning. Unwin & Fisher (1998) provided another example of the importance of scientific visualization:

In the last few years Scientific Visualisation (ViSc) (as defined in the landmark report to the US National Science Foundation; McCormick et al., 1987) has become one of the standard investigative tools of all the physical and natural sciences (Hall, 1994). Visualisation in the sense used here is not a set of techniques to communicate the known as is done with traditional graphics and maps, but a means, a mechanism, for exploring data sets and structures, to generate ideas and explore alternatives. (para. 1)
Graphics are simply a tool, but visualization is the process. A student can use the scientific visualization process to understand data. Short-term memory can only hold a short list of items or concepts. Keeping this in mind, expertise has a fixed capacity, recalling four items, so experts introduced and practiced in a course can guide a deeper comprehension of material and that skill can be learned and used again in any subject, time, or place (Alvarez & Cavanagh, 2004). Scientific visualization can give students a new way to view and interpret data that can often overwhelm the short-term memory. Presenting data using colors, lines, charts, and graphs can enable a student to better recall the data.

This study seeks to understand what students experience when using a civics and economics lesson in their scientific visualization classroom. Using scientific visualization as an educational tool can be very powerful, as affirmed by many notable scientists and organizations. Einstein said that imagining himself traveling through space next to a beam of light helped him discover the special theory of relativity (Trafton, Trickett, & Mintz, 2005). Richard Feynman, a Nobel Prize-winning physicist, discussed the use of visualization and how it helped him understand a phenomenon. The Feynman diagram is a tool by used in physics. It is defined by the American Heritage Science Dictionary (n.d.).

A diagram used to help describe and visualize the possible interactions between particles in quantum electrodynamics and quantum chromodynamics. Fermions, such as electrons, are represented with straight lines and bosons, such as photons, with wavy lines. Points of intersection indicate an interaction, such as an electromagnetic interaction, between the particles.
To show how significant visualization is to universities, schools including Georgia Institute of Technology, Virginia Polytechnic Institute and State University, Tufts University, New York Naval Research Laboratory, and University of Minnesota have devoted scientific visualization laboratories for scientific study through creativity (Trafton et al., 2005).

Scientific visualization is an effective didactic method in many classes like science, technology, engineering, and mathematics. One reason it works well for these areas is its roots in the scientific method. “Data collection and pattern recognition are essential components for the predictive power of the scientific method” (Park & Slykhuis, 2006, p. 3). In addition to the procedural steps of the scientific method, science has years of research done by scientists, researchers, teachers, and students. Scientific visualization is based upon the foundation of science and the scientific process to help students make gains in making visualization out of data; data that might not be understood without this development.

Conceptual Framework

Seeing the strength of scientific visualization and the need for a stronger curriculum in high school history classes, Historian Edward L. Ayers (1999) said the “writing of history has remained virtually untouched and unchanged,” despite the changes in technology available to academia (p. 2). On the other hand, it is noted social studies is highly appropriate to work with digital technology, more so than any other disciplines (Hammond & Manfra, 2009). This statement provides one background to enhance the civics and economics curriculum.

Gordin, Edelson, and Pea (1996) examined the capacity in which scientific
visualization can provide learning in the field of science by becoming the foundation for students to understand real-world and hypothetical occurrences. They wrote, “Our decision to use SciV to aid student inquiry is influenced by the crucial role representational media play in achieving successful scientific practice” (Gordin et al., 1996, p. 2). The researcher connects to Gordin et al.’s points by planning to engage students in organized activities like those in a science class that will use scientific visualization to aid in learning. The visualization that will be created is one part of the experience, but explaining how and why a student creates the drawing is a large part of this case study. Making sense was important in the experience and discussion, according to Gordin et al. (1996).

We identify two primary ways that SciV helped with sense-making. First, we discuss students' qualitative reasoning through colors. Second, we categorize students' activity, while drawing and interpreting SciV, as making connections between data and models. Finally, we suggest several revisions to these activities that can be incorporated into the next version of the Global Warming curriculum. (p. 13)

This study will apply the following four points stated by Gordin et al. (1996) listed below to extend scientific visualization as a lens to examine the lesson and detail the experiences of students.

1. the use of activities that provide learners with the opportunity to engage in all four combinations of interpretive/expressive and objective/rhetorical activities
2. the introduction of human geographic data sets to help better connect scientific visualization to students' interests
3. the incorporation of a modeling capability for the examination of hypothetical scenarios as a means to provide greater opportunities for sense-making conversations
4. the establishment of learning cultures in which students can engage in critical dissent without social penalty

These four points will serve as the theoretical framework for presenting the findings of this study, which will implement a class lesson in analyzing gasoline prices in the United States during 1995–2005 using graphical representations of authentic data. The lesson plan is explained in Appendix A. Students will explain why gasoline prices fluctuate according to the supply and demand of petroleum. They will use x- and y-axes to demonstrate the equilibrium price through bar graphs and histograms. Findings are significant in future insight for curriculum development and student growth. These findings will form a new lesson plan for scientific visualization to be incorporated into civics and economic as well as adding to the four points stated earlier.

Research Questions

The questions guiding the research are:

1. How does scientific visualization help students understand complicated data?
2. What is the experience that participants have when using scientific visualization in a civics & economics lesson?

Specific interview questions are designed to garner thorough responses to see if scientific visualization improves students understanding of civics and economics (Appendix C and Appendix D).
Limitations of the Study

When deciding what form of qualitative inquiry and how to set up the study, a case study was chosen out of Creswell’s five approaches as the best fit for the problem. A case study is a form of qualitative inquiry that “understands an issue or problem using the case as a specific illustration” (Creswell, 2007, p. 73). All studies have limitations, and the researcher must responsibly recognize the possible limitations (Glesne, 1999). For this study, the following limitations were taken into consideration: (a) one class with limited number of students’ forms data and therefore may not be typical of the general population, (b) the method of studying and behavior is only described, not explained, (c) people will provide information and may choose not to divulge certain information or truthfully respond, (d) the environment where the study occurs is open, and the study cannot be completely controlled, (e) lack of geographical diversity, and (f) there can be a lot of data for analysis.

This study investigates how a selected group of individuals make meaning of a new lesson implemented in a Career and Technical Education (CTE) class. The results for the one class in this study may not be generalizable to every scientific visualization class. As stated by Hodkinson and Hodkinson (2001), case studies can help understand complex inter-relationships. Since this method of qualitative research was chosen, the behavior will be described as the phenomena telling about the genuine experience. Since people are involved, exploration of the unpredictable and awe-inspiring can emerge in data. Looking at the atypical and typical behavior shows the true nature of the learning process that occurred throughout the lesson in a scientific visualization classroom.
Another thing to consider is the time limitations of the case study. It will be done during a single quarter of a high school student’s life. The sample classroom was chosen for its proximity to the Research Triangle Park area, where the researcher lives and attends school.

Role of the Researcher

A large amount of data can be found in a real-life situation. The researcher is the primary instrument of data collection and analysis according to Creswell (2007), but the researcher also selects how to present the information and in what light to showcase generalizations. That practitioner must use judgment when presenting information relative to the case study. Through the research methodology, assessing information and synthesizing data until meaning emerges from research demonstrates what truthfully occurred in the study. Looking at how a student learns when a civics and economics lesson is implemented in this CTE class allows the researcher to see connections in the study.

Definition of Terms

Critical thinking - using logic to find an end result; observing the world, generating questions, being creative all in support of a conclusion.

Problem solving - a structure for solving real-world issues

Scientific and technical visualization - course offered though many states and universities. Specially, it is offered by the North Carolina to high school students in Career and Technical Education as a branch of Technology Education classes.
Scientific visualization - uses the graphical representation of data as a means of gaining understanding and insight into the data (Scientific Computing and Imaging Institute, n.d., para. 1).

Technology education - “A study of technology, which provides an opportunity for students to learn about the processes and knowledge related to technology that are needed to solve problems and extend human capabilities” (ITEEEA, 1995, para. 3)

Chapter Summary

This chapter introduced the topic of scientific visualization. It presented the problems and questions that are to be addressed in this research that includes qualitative analysis of student’s understanding of a civics and economics lesson. This qualitative study utilizes a purposeful sample of students who are learning about social studies through a second-level CTE course. Research seeks to understand a learner’s experience when a brand new lesson is introduced into the person’s class. Through exploration of the major research questions, this study seeks to understand how students understand complicated data.
CHAPTER 2
LITERATURE REVIEW

“Presenting results in a static spreadsheet or table may do the job. But sometimes it’s like driving with your eyes closed. With visualization, it might be possible to open your eyes and see something that will help you — for instance, patterns, clusters, gaps or outliers in the data.” (Dawson, 2008, para. 1)

The above quote by Ben Shneiderman, a professor at the University of Maryland, describes the impact visualization can make for any learner. Current scientific visualization curriculum is mostly connected with lessons in mathematics, science, technology, and engineering. If it has strong success with those areas, why is it not being used with other areas of academics? In this chapter, I will provide a historical framework for the emergence of scientific visualization. Then, I will cite existing literature concerning the theoretical frameworks to support the importance of my scientific visualization research. Finally, I will summarize how my research aids in filling a gap in existing literature and contributes valuable information to scientific visualization and social studies curricula.

Understanding Scientific Visualization

With roots in science and the scientific method, scientific visualization explores a topic. It enables students to take difficult information presented in class, analyze it, and present it in a new way. For example, a student studying the history of North Carolina might have a hard time linking the five themes of geography to North Carolina and its people. If using scientific visualization to understand the same concept, a student could explore the
major landforms, bodies of water, and natural resources in North Carolina by studying maps, texts, articles, and other data. Then, the student could analyze that data by comparing physical characteristics and evaluating the way the people of North Carolina have used, modified, and adapted to the physical environment, past and present. Last, the student could use a color-enhanced map to assess human movement as it related to the physical environment. Thus, using scientific visualization can aid in understanding the five major themes of geography for North Carolina and its people. Examples of lesson plans are available on NCSU’s scientific visualization website. It has sample lesson plans, design briefs, lesson notes, and project ideas. One similar lesson has students create color-coded maps in earth and environmental science. This specific example meets goals and objectives in both scientific visualization and earth and environmental science. The possibility to increase and expand academic knowledge is present.

When thinking about scientific visualization, one needs to understand its evolution. When studying scientific visualization, popular words like technology, science, and education are often mentioned when scientific visualization is discussed. Educational technology varies greatly from the field of technology education, where scientific visualization exists. Educational technology typically looks at specific uses of technology in education through hardware, software, and Internet applications. Some of the most common educational applications of scientific visualization are curriculum and software that create graphical depiction for students rather than students creating their own.

Gray and Lewis compiled a report for the National Center for Education Statistics, Institute of Education Sciences and the U.S. Department of Education in 2009 about public
school districts’ use of educational technology. Educational technology is technology and media in education.

This study collected data on number of schools with a local area network; district networks; types of connections; formal computer replacement plans; types of technology resources offered to teachers and students; written acceptable use policies; types of student data kept in an electronic data system; employment of educational technology leadership; and teacher professional development offered or required by districts. Technology education is to develop a familiarity and recognition of tools and history. Technology education looks at the past, present, and future to generate a technologically literate learner. The essential difference in technology education and educational technology is knowledge in technology education and tools of educational technology.

“Scientific visualization techniques offer plenty of opportunities for enhancing learning in the high school and undergraduate classroom” (Emigh & Zaslavsky, 1998, abstract). In general, pictures are a form of visual thinking, and scientific visualization offers students a way to organize those visual images. It allows students to focus on the connections and clarify their thinking rather than just looking at text.

“Scientific visualization as currently understood and practiced is still a relatively new discipline” (Johnson, 2004, p. 13). Since being formally defined and introduced to education in 1987 by the NSF, it has grown and developed to be more than graphical illustrations. “It includes generating abstract computer imagery from data-intensive computer simulations or massive repositories of scientific digital data. These repositories encompass data collected with instruments like satellites and electron microscopes” (Berson & Berson, 2009).
The National Research Council (2005) said that through scientific visualization, “better understanding of key second-order ideas can help students make sense of any new topics they encounter.” Historically, student learning has been guided by Bloom’s taxonomy, a hierarchical structure set in a triangle with six different levels of thinking. In progressing from the lowest level (i.e., define, describe, identify) to the top level (i.e., appraise, compare, conclude), a student’s thinking becomes more complex and abstract.

The National Research Council (2005) stated that teachers and students advance by skillfully constructing ideas through inquiry. This view coincides with some points in the framework; I attempt to provide a thorough description of what students experience. Students lead the way and teachers facilitate the journey, always keeping the end point in mind.

Background of Scientific Visualization

Scientific visualization has evolved into a field of study distinct from visualization (Carlson, 2003). When analyzing scientific visualization, a person benefits by understanding scientific visualization’s background. If looking at visualization, one really needs to start with information design, the graphical organization of informative data. Tufte authored three books, Visual Display of Quantitative Information, Visual Explanations, and Envisioning Information, all focusing on the belief of function before form. According to MacLeod (2003) when studying Tufte and his principles, verified the importance of studying graphics:

Printed and graphical information is now the driving force behind all of our lives. It no longer is confined to specialized workers in selected fields but impacts nearly all people through the widespread use of computing and the Internet. Rapid and accurate transfers of information can be a life and death matter for many people (an example
being the Challenger disaster). The extent to which symbols and graphics affect our lives can be seen by the dramatic increase in IQ scores in all cultures which have acquired information technology: in the United States there has been an average increase of 3 IQ points per decade over the last 60 years, for a total of an 18 IQ point increase. There is no known biological explanation for this increase and the most likely cause is widespread exposure to text, symbols, and graphics that accompany modern life. (para 1)

The above quote is a statement to study when analyzing the history of Tufte’s belief and work done in the field of information design. Tufte also dug deep into history when assessing visual displays of information.

One of the earliest forms of visual data relates to cartography, or map-making, where one graphically translated perceptions. Some of the earliest maps were found on the walls of the Lascaux Caves, showing wars, searches, and possibly even constellations. The Babylonian Map of the World represents the Ancient Near East, and historians have found a symbolic map instead of a literal map like most maps at that time. A clay tablet from 500 BC is a “sketch of the earth accompanying an elementary Babylonian discussion on the nature of the universe” (Danzer, 1988, para. 8). The claim of the earliest map varies, but one more significant contribution to early cartography is the Çatalhöyük in Anatolia, a nine-foot wall painting depicting the town of Çatalhöyük with approximately 80 buildings (Messenger, 2003).

Charles Joseph Minard’s map Carte Figurative des Pertes Successives en Homes de l’Armee Francais dans la Campagne de Russe 1812–1813 (Napoleon’s disastrous March on
Moskow) is claimed by Tufte (1983) to be the “best graphic ever produced.” It shows a huge amount of data like the shrinking size of Napoleon’s Army superimposed on a map of Russia. These data are meticulously analyzed by Minard because there is information from more than one variable; thus, it is hard to explain with the number of variable even in a single table. The visual display of the data works best for this scenario.

L. J. Henderson made a contribution to the world of medical illustration and also to graphics. Henderson was in the laboratory studying only the chemical and physical science of blood of mammals, when “he found that the only way he could describe a chemical system as complicated as blood was by a diagram called a nomogram” (Hankins, 1999, abstract).

Hankins cited others who he believed contributed to our modern understanding of visualizations. A French cotton manufacturer from Rouen, Louis-Ezedchiel Pouchet, created a graphic scale, the first graph to illustrate three variables at the same time, using a curve to depict a third variable. Engineers and students during the eighteenth century focused on moving dirt to hide and create fortresses. Gaspard Monge, a draftsman working in a school, created a three-dimensional concept on a two-dimensional surface, a concept which now serves as the basis for all engineering drawing and is known as descriptive geometry (Hankins, 1999, p. 62). A former student of Monge, Charles Joseph Minard, constructed a thematic map of Europe’s railroad system that showed flow of traffic between population centers, which was the first of its kind and in frequent use today.

Visual language development was prominent in the twentieth century and was the basis for visual devices and modern technology. According to Thomas and Cook (2006), “Visual representations and interaction techniques take advantage of the human eye’s broad
bandwidth pathway into the mind to allow users to see, explore, and understand large amounts of information at once.” Visually understanding data relates into one’s comprehension and can lead to further understanding that one could with only words.

Bertin (1983) wrote that meaningful graphics aid the viewer’s understanding. His book, *Semiologie Graphique*, is a classical manuscript discussing that creating meaningful graphics for the viewer is essential and can be done through organization of the visual and perceptual elements. His theory of cartographic communication established a philosophy on the function of graphics that extends beyond cartography and into diagrams, networks, and mapping. Data found on map relies heavily on the use of graphics where spatial relationships as well as perceptual properties of symbols are meaningful for understanding. His theory discusses eight variables, differentiated into six retinal and two locational. The retinal variables are size, value, texture, hue, orientation, and shape, whereas the locational variables are horizontal and vertical co-ordinate axes of the scatterplot and latitude and longitude. Bertin (1983) said graphic representation constitutes one of the basic sign-systems conceived by the human mind for the purposes of storing, understanding, and communicating essential information. Creating graphics evokes relationships between information, which is significant in the field of scientific visualization as graphics are used in communication.

**Visual Performance in Scientific Visualization**

Visual performance is another area that has heavily influenced scientific visualization. When opening one’s eyes, a person sees colors, objects, shapes, and details that are absorbed and constantly move to absorb information. As stated by Martinez-Conde (2006), the “eyes are never still” (p. 151). Eye movement constitutes visual searching. Eye
movements, also known as eye tracking, are studied in the visual performance field. Eyes are visually searching, which consists of three aspects crucial to seeing. The first is visual searching, which is notation of eye movements. Second is the visual field, which encompasses the scope and perception of vision. Last is the physiology of the eye, where images are formed.

When studying the physical nature of the eye, relationships can be seen through color and coding in visualizations. Color is strong part of one’s world concerning the mind and causes movements of the eyes. In addition, “simple geometric shapes can communicate complex concepts” (Keller & Keller, 1993). Evaluating pictures involves visual cues. Size and shape of three-dimensional objects are more easily understood when projection planes (two-dimensional) are shown. Understanding that the eye has visual cues is important in the field of scientific visualization because the eye send messages to the brain to interpret these colors and shapes.

Eye movement is also fundamental to visualization. The eyes take in information in a specific manner so that the brain can process what it sees. Josephson noted that the image created in one’s brain is known as a mental image, constructed by the consistent sweeping motion of the eyes absorbing the world (Josephson, 2008). Researchers have studied eye movement, and marketing professionals spend vast resources making graphics to attract the viewers’ attention. Josephson (2008) assessed the readability of serif, fonts with heavier and lighter elements throughout the letter, and sans serif fonts, font with uniform strokes throughout the letter. Participants read four stories, during which their eye movement was tracked. Veranda, a sans serif font, was the quickest read for all participants, although this
result was not statistically significant. This illustrates how the mere choice of font affects readability by influencing eye movement.

Lohse (1997) investigated the eye movement patterns of consumers when looking at advertisements in the telephone directory. He found that three main variables influenced attention. The first was size of an advertisement. Like Tufte, he saw the importance of size on a page, as 93% of the larger ads were seen versus 26% of the plain, spreadsheet-like listings (Lohse, 1997). The second was color. A hint of color added to a simple black-and-white photograph can pull the viewer into the image. Last was the amount of information in an area as larger chunks of text are harder to read in quick passes like advertisements.

Visual perception has a close relationship to human memory and establishment of association. In a lesson plan developed and given by Jessee and Wiebe (2009), students learned about color, different color models, and production of color. The three color models discussed were red, green, and blue (RGB); cyan, magenta, yellow, and black (CMYK); and hue, saturation, and value (HSV). “Of these, HSV comes closest to mimicking how humans perceive color” (Jessee & Wiebe, 2009). In their lesson, students were able to use the HSV color model to coordinate colors on the monitor to the colors outputted by a printer. This specific model “allowed students to use graphic technologies guided by their perception of color to effectively communicate the intended message” (Jessee & Wiebe, 2009).

Understanding how one sees is crucial to development of data by individuals. “The approach integrates the human mind’s exploration abilities with the enormous processing power of computers to form a powerful knowledge discovery environment that capitalizes on the best of both worlds” (Wong, 1999).
Strength in the Eyes

With a rich history in science, scientific visualization shares a common strength in visual systems. Kosslyn and Haber and Wilkinson researched the importance of the visual perception aspect of visualization. Effective communication is the main goal of Stephen Kosslyn based on the way of thinking between one’s eyes and mind. His theory is based on three guiding principles of perception and cognition when generating graphs, “the mind is not a camera; the mind judges a book by its cover; and the spirit is willing, but the mind is weak” (Kosslyn, 1994, p. 3). Haber and Wilkinson look at how students are able to process visual elements. Lohse studied eye movement when assessing a page, like an advertisement for example. He noted where eyes moved and how the graphic was processed through the eyes.

Kosslyn (2006) proposed eight principles to construct graphics. He stated that there are many guidelines to forming graphics, but few people take into account that the audience is human and has certain perceptual and cognitive strong points and borders (Kosslyn, 2006). Similar to Tufte, Kosslyn presented scientific evidence that simplicity is essential to effective graphs. He links the art and science of designing a graph, and discussed how that connection applies to scientific visualization and researched the psychological principles behind designing for the human mind.

Haber and Wilkinson (1982) said, “Visual data, in the form of scenes and pictures, are often processed in visual terms alone, without any corresponding translation or recoding into verbal labels or representations” (p. 23). The authors discussed visual perception and how the human visual system is made to generate ordered perception. Items like space, form, and arrangement are formed by the mind to formulate visual representations. Using three-
dimensional forms is useful by students to understand models, and using movement to represent structural progress is also something the mind can process. The eyes will use form a simulation to create multidimensional information. Rather than principles by Tufte and Kosslyn, Haber and Wilkinson looked into cognitive psychology to form organizational principles that structure perception.

Multiple Meanings in Scientific Visualization

The choice of font, placement of text, and spacing is all part of this visual image that is first seen, even when reading a printed page. The works of Tufte, Kosslyn, and Bertin all contributed to the production and in the interpretation of meaning. While the earlier mentioned work fall into Multimedia Semiotics, one new researcher, Lemke, brings a new approach to this topic. He studied visual semiotics, but, put a modern spin on the meaning of signs.

“Multimedia semiotics is based on the principle that all meaning-making, because it is a material process as well as a semiotic practice, necessarily overflows the analytical boundaries between distinct, idealized semiotic resource systems such as language, gesture, depiction, action, etc.” (Lemke, 1998). This means that all signs have multiple layers of meaning, so written text carries linguistic and visual meanings. The earlier-mentioned researchers as well as He assessed their interconnectivity classifications, as they are perceived in copy. Traditionally, an individual giving a presentation does not just speak but uses his or her hands to draw shapes, make gestures, etc. Multiple angles of communication are included in every visual sign.
The multiple meanings within signs are evident from diagrams in scientific texts. "Diagrams...have been a common means of recording scientific information since the fifteenth century" (Hegarty, Carpenter, & Just 1991). Diagrams offer the reader a spatial representation often difficult to derive from text (Hegarty et al., 1991). The process of making meaning from the text and diagram is vital for interpretation. In turn, multiple representations must collide and impart with the reader to understand these scientific texts according to the authors.

Application of Scientific Visualization

When looking to extend visual thinking, scientific visualization is a newer way of thinking in comparison to math, English, and science. Researchers and literature looks at the different approaches to learning. Mathewson (1999) found science teachers often overlook the magnitude of visual imagery in their classrooms. The brain has the capability break down large quantities of information to relay an image. Atlas bends to the practical side of making goals and setting steps for using this technology in the classroom.

Visual spatial thinking and imagery should be a crucial part of any science classroom. Mathewson discusses links in this line of thought just like Kosslyn, Lemke and Hegarty, Carpenter and Just. He says, “Visual-spatial thinking includes vision—using the eyes to identify, locate, and think about objects and ourselves in the world, and imagery—the formation, inspection, transformation, and maintenance of images in the ‘mind’s eye’ in the absence of a visual stimulus,” (1999, p. 33). Mathewson gives a great example in his literature. He discusses how science teachers routinely complain about students not demonstrating the foundational building block needed to understand a more complex
concept. He believes that visual-spatial thinking and learning can be done to have students observe, form and analyze scientific concepts that would build those foundational steps. Change in the curriculum and pedagogy is necessary to change the format of image thinking skills (Mathewson, 1999). Thus, embracing this knowledge can extend students’ visual spatial thinking and imagery skills.

Using the scientific visualization tools of technology are essential to successful visual spatial thinking and imagery. Exposing current students to scientific visualization means they will be using a tool to help them gain understanding of a concept where prior generations have not had access to this tool. Many computer applications, like 3D Studio Max and IRIS Explorer, aim to support post-training performance, meaning that the user should grasp general procedures for tasks. “In order to use this [scientific visualization] software effectively, students need to understand how it works as a representational device” (Friedman & diSessa, 1999). Understanding the software helps students have meaning experiences that they will be able to build upon in future learning. The authors point out the need for technology to be visible. When a student demonstrates evident use and obvious understanding of how the technology works, growth emerges. Friedman and diSessa outlined several principles behind effective software for scientific visualization:

1. Design to support understanding of representational aspects of scientific visualization technology

2. Design to take advantage of students’ resources for creating and interpreting representational display (i.e., the scientific visualizations)

3. Design for personal engagement and success (p. 176–177)
These findings are based on empirical and theoretical studies about symbolic portions of scientific visualization tools that further engagement. Friedman and diSessa found students need to actively understand how technology works to form knowledge. Creating learning experiences for scientific visualization is easily seen throughout these three points to work in an educational setting.

From information design to practical applications, scientific visualization has strong roots in the professional and educational world. Tufte’s belief of function before form was evident in the early cartography of the Babylonians and in Minard’s account of multivariate data. Hankins’ research with nomograms showed how modern information visualization rests upon Minard’s traffic flow maps of the railroad system in Europe and Bertin’s work to design graphics, even before computers, with measurable objectives. Lastly, there are rhetorical and practical aspects to this area of study that emphasize the effectiveness of scientific visualization learning experiences.

**Link between Academic Subjects**

Many studies examined the integration of technology with social studies, but Berson and Berson (2009) studied the use of visualization tools. Students were evaluating recent public speeches and utilized a software, Word Clouds, that evaluates the texts and speeches to create a visual image that highlight words used frequently in large print, thus showing students the common words a speaker might use and consider to be important. Bersen and Berson stated of students in a single U.S. government course, “They (students) can transform text into powerful visuals that promote inquiry skills. Interactive visualization helps people see and exchange information in novel ways” (2009).
Examples of Technology and Visualization in Science Education and Math Education

Many case studies of technology and visualization have been conducted in science and math education, but few in technology education. In science education, Ganguly (1995) and Kozhevnikov, Hegary, and Mayer (2002) conducted qualitative studies with a focus on visualizations. Ganguly examined the importance of integrating science teachings with visual thinking. In a different study, Kozhevnikov, Hegarty, and Mayer (1999) studied students’ use of imagery in solving problems in physics.

In math education, McClintock, Jiang, and July confirmed that a technology-rich environment benefits students and that visualization can help students process information. They used a constructivist approach in assessing a class of 24 students while they used a common tool, GSP. Results of a comparative approach revealed that the tool along with activities using the GSP were successful in helping the students understand three-dimensional images and obtain a fundamental understanding of geometry. It also found that technology can be beneficial in learning. Enthusiasm, feedback, and logical properties of visualization were seen through the researchers’ analysis of transcription during the activities, which told the story of students’ advancement in the course of the teaching sessions.

Oliver and Hannafin (2002) also researched student thinking skills and processes supported by web-based tools, and teacher intentions for using web-based tools. They examined how students used technological tools to solve open-ended problems involving building collapse during earthquakes. Reinforcing the belief of a constructivist epistemology, this case illustrates the benefit of technology with open-ended problems.
Diem (2002) explored the connection of participation to implementation of technology. The author used a mixed-methods approach to collect data about the effectiveness of technological interventions with preservice social studies methods students before graduation. The author wanted to see if the adoption of technology as a student would increase adoption of technology as a teacher or in some other instructional setting. Of the outcomes found, one was significant. Use of Internet, at secondary level was stronger than at university level and that advanced instruction is needed to develop deeper knowledge. This article found the importance of introducing technology to preservice teachers to give them confidence when using technology as well as spurring their expertise for the future.

Ganguly sought after visual thinking in science education. He found science deals with teaching concepts that are abstract, meaning the student may not have a picture of how that function, process or cell looks, similar to the way a scientist forms a picture through measurements, assumptions and conclusions. Ganguly (1995) conducted a qualitative study to show to what degree analogies are used to learn. Six teachers employed 12 analogies in a high school science classroom and met success. Instructional data were even gathered from one chemistry classroom where analogies were used. It also makes a conclusion about critical thinking and problem solving. This study reveals the importance of using visualization in teaching, especially for detailed concepts. It demonstrates the links between teaching complex concepts and the use of visual thinking in education.

Kozhevnikov, Hegarty, and Mayer (1999) explored the connection between mental imagery and problem solving in physics, specifically kinematics. They distinguished between visual and spatial imagery seeing both type of problem solving techniques as different. Both
qualitative and quantitative methods were used. The qualitative research used the interview to look at the relationship between visual imagery and problem solving in physics. It was found that some students were higher-level spatial thinkers who intuitively know schematics, motion, planes, etc. In contrast, the lower-level spatial thinkers often took images literally. They assumed that a particular color always represented a given plane. The researchers pointed out the findings to help teach visual types of learners, which will help students understand physics better. Instructors do not explain in enough detail for these thinkers and leave them confused. These findings show that visual and spatial learners should be taught using images as well as words. The authors said, “Instruction could be aimed explicitly at teaching students to construct and interpret different types of representations and to translate between different representations of the same phenomenon.” Not all students are able to visualize data and pictures are another form of learning that can yield a high comprehension of material. Emphasizing the process is key to teaching all learners.

Field of Technology Education

In 1993, Wicklein carried out a study about the existing and potential problems in the Technology Education profession. He identified 15 future problems in Technology Education. The purpose of the study was to help educators recognize issues and concerns to build a strong future for Technology Education. Building on the work he had done, Lazaros and Rogers (2006) conducted a survey to answer two questions: “What is the current level of severity of the 15 future problems identified by Wicklein (1993) as perceived by Indiana Technology Education teachers?” and “Do Indiana Technology Education teachers’ perceptions of the 15 future problems (Wicklein, 1993) differ based on the Indiana teachers’
demographic characteristics?” Quantitative analysis was done on the data gathered from the descriptive survey. Qualitative data were gathered through the second part of the survey, where participants freely responded to current problems that were not currently listed on survey options. From data analysis, researchers learned of two main concerns: graduation requirements seem to keep students out of Technology Education classes, and people other than educators do not know the true meaning of Technology Education.

Lazaros and Rogers (2006) stated, “Technology education must establish among the general public an understanding of its content and its relevance to society.” As a part of this program, scientific visualization demonstrates how students can be an active part in their learning. The qualitative findings of this study emphasize the expectations for the program of enriching, exploring, and building in technology education.

In preparation for twenty-first century learning, many schools and programs are strengthening science, technology, engineering, and mathematics (STEM) education programs. “Graphics communication can be a unifying factor when looking at the intersection of science, technology, and design,” said Wiebe, Clark, Petlick, and Ferzli (2004, p. 3). These programs are designed to provide students with strategies and skills needed to compete in today’s global economy. It is a “multidisciplinary” curriculum according to Wiebe, Clark, and Hasse (2001, p. 41). In North Carolina, the technology education program is meeting the challenges of students at a secondary and higher educational level. In discussing the importance of visualization in engineering classes Wiebe said, “One of the prime motivating factors for integrating graphics into scientific and technical fields is the ever-growing volume and complexity of information needing analysis” (1992, p. 3). This
movement toward STEM demonstrates the need for continuous improvement in the field of education as well as scientific visualization.

**Relationship between Graphics and Learning**

A relationship exists between graphics and learning. Researchers delved into this relationship in the cognitive theory of multimedia learning:

The cognitive theory of multimedia learning is based on three assumptions suggested by cognitive research: (1) dual-channel assumption—the idea that humans have separate channels for processing visual/pictorial representations and auditory/verbal representations (Baddeley, 1998; Paivio, 1986); (2) limited capacity assumption—the idea that only a few pieces of information can be actively processed at any one time in each channel (Baddeley, 1998; Sweller, 1999); and (3) active processing—the idea that meaningful learning occurs when the learner engages in cognitive processes such as selecting relevant material, organizing it into a coherent representation, and integrating it with existing knowledge (Mayer, in press; Wittrock, 1974). (p. 91)

The authors noted that the purpose of multimedia in the classroom is to show the learner information in both text and graphics. They gave seven principles for designing animations for presentations. Understanding how people learn from words and pictures tells one how to use animation effectively (Mayer & Moreno, 2002).

Vekiri (2002) also discussed the value of graphics in learning. He examined current principles of effective design. His discoveries are based on three theoretical viewpoints: dual coding theory, visual argument hypothesis, and conjoint retention hypothesis. Table 1 provides a summary of these three perspectives.
Table 1

A summary of three theoretical frameworks on graphic processing and related research (Vekiri, 2002).

<table>
<thead>
<tr>
<th>Theory</th>
<th>Assumptions</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual coding</td>
<td>1. Two different memory representations for verbal and visual information. Connections between them provide two ways to retrieve information.</td>
<td>Neuroscience research provides evidence for the existence of visual memory representations</td>
</tr>
<tr>
<td></td>
<td>2. Visual representations are organized in a synchronous manner and processed simultaneously, whereas verbal representations are organized hierarchically and processed serially.</td>
<td>Dual-coding studies provide no evidence for the second assumption that visual representations are processed more efficiently than are linguistic representations</td>
</tr>
<tr>
<td>Visual argument</td>
<td>1. Because of their visuospatial properties, graphics are search and computationally efficient</td>
<td>Graphical displays designed using Gestalt principles of perceptual organization are more effective than text in communicating information about data relations, trends, and patterns</td>
</tr>
<tr>
<td>Conjoint retention</td>
<td>1. Two different memory representations for verbal and visual information. Connections between them provide two ways to retrieve information</td>
<td>Maps improve memory of text information but there is no evidence from conjoint retention studies for the existence of two memory representations</td>
</tr>
<tr>
<td></td>
<td>2. Maps are encoded as intact units, and their mental images maintain information on their visuospatial properties</td>
<td>There is evidence for spatial but not intact display encoding</td>
</tr>
</tbody>
</table>

Vekiri stated, “All of them are based on information processing approaches to learning, and the assumptions on which they rest are not necessarily in conflict with one
another. Their differences arise from their focus on different aspects of graphic processing” (Vekiri, 2002, p. 262). When studying these frameworks, pictures and text add value to learning. The mind processes verbal and visual information independently. Research with graphical display is just the beginning.

Synergy

History and scientific visualization are connected. Both subjects engage the learner and also sustain motivation of individual students. With the advent of technology and a child’s exposure to multimedia applications, visualizations, and activities, there is an opportunity to promote scientific visualization in education. Rushmeier, Dykes, Dill, and Yoon (2007) discuss visualization education. They also argued for expansions of visualizations in non-technical areas: history and archaeology, public policy, literature, and security and intelligence (p. 13).

The NSF-funded Visualization in Technology Education (VisTE) project at NCSU promotes technological literacy and developed 12 units for students in eighth through twelfth grade. This project identifies the 20 Standards of Technological Literacy (STL). Each VisTE unit has students critically think about a technical or scientific issue and uses various visualization tools to solve the problem. Units on power and energy, bioengineering, and communication were researched, created, and tested to further the use of graphical visualization using STEM objectives of strengthening educational programs and supporting new initiatives to better content knowledge. The research done for this project has led to the new Game Art and Design course at NCDPI.
Conceptual Framework

Gordin et al. (1996) advocated utilizing scientific visualization in a science classroom to support a student’s natural inquiry. They made four key points, which will be used to examine information gathered throughout this study.

The authors have an extensive background in expanding learning and teaching in the areas of scientific visualization, science, math and technology. Individually and collaboratively, they have multiple research grants and project to further these same ideas. This paper gives credit to Learning through Collaborative Visualization Project (CoVis), which was founded by Pea at Northwestern University. The program was started by the National Science Foundation, but also had several corporate partners like Apple, Sony, and Sun Microsystems. This project sought to give students an authentic scientific experience, to promote successful learning experiences like those of scientific researchers. Pea also has been awarded several million-dollar grants within the past ten years. A few addressed the following topics: online media personalization, learning and informal environments and a development of a high-performance digital video collaborator for learning sciences research. Edelson also has several projects backed by NSF, such as: developing instructional materials for an Environmental science curriculum, engineering scaffolded work environments and learning science through design. Gordin too has several projects backing his work. The authors continue to regard incorporating scientific visualization into the classroom as a valuable tool to keep learners engaged. “Scientific visualization has had a tremendous impact on the practice of science over the last decade by capitalizing on the power of the human
visual perception system to identify patterns in complex data” (Edelson, 1998). Edelson, Gordin, and Pea (1999) conducted the Supportive Scientific Visualization Environments for Education (SSciVEE) project, which cultivated scientific visualization environments for the examination of climate and global climate alterations. To do this, students used WorldWatcher, a visualization setting for two-dimensional, gridded statistics, just like scientific professionals would use. They are able to see the sites, fashion illustrations, and scrutinize climate data of a scientific nature.

This study was also cited another article addressing visualizing for learners a few years later. “The medium of scientific visualization offers learners the ability to interact with data in the form of visual representations rather than numeric or symbolic ones” (Edelson & Gordin, 1998). It is seen that using relative data is important to stimulate students’ interest, as took place in the SSciVEE project.

Rogers, Connelly, Hazlewood, & Ledesco (2010) noted that using modern technology, to explore learning provides the ability to make easy, sensemaking tasks make connections between the unknown and known. Gordin et al. (1996), they stated, “It can be facilitated through making connections between digital representations (e.g., a graph, a numerical dataset) on a PC and the scientific phenomena they are intended to represent” (p. 112). Rogers et al. focused on a mobile learning application, LillyPad used by teams to “make sense” of their observations during scientific activities. Teams used the LillyPad in their study to quantify, give details, and forecast tree development for dissimilar planting techniques used in an environmental restoration location. In two studies using different versions of the software, groups of students scrutinized the outcome of various planting
approaches for an environmental restoration spot. Rogers, Hazelwood, and Tedesco (2009) suggested that the studies offer students a chance to grow and develop (p. 112).

A potential benefit of being able to switch intermittently between activities and foci of interest over time and space in this manner is to provide multiple opportunities for students to step in and out and reflect upon these transitions. In so doing, it could deepen their understanding and help integrate their ideas, data, and observations.

LillyPad revealed differences of experiences of the physical environment and high level ideas and concepts to the researchers in amount of sensemaking that occurred. They concluded that mobile devices can be used to enhance sensemaking during scientific activities.

Land (2000) cited Gordin et al. (1996) as support for her reasoning that learners need support to interpret the meaning of visual representations. Gordin et al. demonstrated for students the relationship between color and values in data by making maps, first by hand and then with the visualization tool. Table 2 provides a summary of open-ended learning environment (OELE) capabilities, cognitive requirements, problems and issues and implications from Land (2000, p. 64).
Table 2.

A summary of open-ended learning environment (OELE) capabilities, cognitive requirements, problems and issues and implications. (From Land, 2000.)

<table>
<thead>
<tr>
<th>OELE Capabilities</th>
<th>Cognitive Requirements</th>
<th>Problems and Issues</th>
<th>Implications for Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of visualization or manipulation tools to facilitate experimentation of complex phenomena.</td>
<td>Generate, test, and refine theories, based on supporting evidence perceived from visual displays.</td>
<td>Limitations of novices to accurately perceive and interpret visual cues.</td>
<td>Direct learner attention to key variables and visual cues.</td>
</tr>
<tr>
<td></td>
<td>- Recognize whether changes in a visual display have occurred as a result of manipulating a variable (while holding others constant) (selective perception);</td>
<td>- Attending to, and attaching meaning to, irrelevant visual cues (Brungardt &amp; Zollman, 1995; Gyllenhaal &amp; Perry, 1998);</td>
<td>- Emphasize critical variables visually (Hannafin &amp; Peck, 1988; Prete, 1995);</td>
</tr>
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<td></td>
<td>- Discriminate which visual cues are relevant to attend to in a visual display;</td>
<td>- Drawing inaccurate conclusions from visual cues (Land &amp; Hannafin, 1997);</td>
<td>- Enhance more objective comparison of different visual displays; (Roth, 1995; Tufte, 1983);</td>
</tr>
<tr>
<td></td>
<td>- Draw accurate conclusions from observations of visual cues (causal reasoning);</td>
<td>- Making biased observations of visual cues based on preconceptions (Chinn &amp; Brewer, 1993; Gyllenhaal &amp; Perry, Land &amp; Hannafin, 1997).</td>
<td>- Provide explicit support for learners to interpret the meaning of visual representations (Foley, 1998; Gordin, Edelson, &amp; Pea, 1996);</td>
</tr>
<tr>
<td></td>
<td>- Relate conclusions to plausible explanations (inferenceing; theory building).</td>
<td></td>
<td>- Use modeling, dialogue, or both to help learners attend to and interpret complex visual representations (Gordin et al., 1996).</td>
</tr>
<tr>
<td>Use of authentic contexts to foster connections between formal knowledge and everyday experience</td>
<td>Integrate new and prior knowledge.</td>
<td>The situated knowledge paradox.</td>
<td>Prompt and guide connections to prior knowledge.</td>
</tr>
<tr>
<td></td>
<td>- Make voluntary references to examples, analogies, metaphors, prior knowledge, or personal experience to map new, classroom knowledge on to natural, everyday events (transfer; analogical reasoning);</td>
<td>- Referencing incomplete or inaccurate prior knowledge that interferes with new learning (Brickhouse, 1994; Land &amp; Hannafin, 1997);</td>
<td>- Use familiar experiences and orienting strategies to prepare learners conceptually (Ausubel, 1963; Cognition and Technology Group at Vanderbilt, 1992; Hannafin &amp; Rieber, 1989, Schwartz, Brophy, Lin, &amp; Bransford, 1999);</td>
</tr>
<tr>
<td></td>
<td>- Evolve initial, naive conceptions and explanations (conceptual change).</td>
<td>- Making imprecise and unreliable observations of everyday experiences and using them to justify naive theories (Brickhouse, 1994).</td>
<td>- Use external models such as diagrams, analogies, metaphors, or adjunct questions to stimulate transfer and conceptual change (Mayer, 1999);</td>
</tr>
<tr>
<td>Use of resource-rich environments to support learner-centered inquiry</td>
<td>Generate and refine questions, topics, or information needs (metacognition);</td>
<td>The metacognitive knowledge dilemma: Monitoring learning in the absence of domain knowledge.</td>
<td>Provide explicit scaffolding of metacognition and teaching-learning strategies.</td>
</tr>
<tr>
<td></td>
<td>- Monitor the effectiveness of search results and strategies and refine them when unproductive (metacognition: procedural knowledge);</td>
<td>- Failure to refine known strategies when ineffective (Hill &amp; Hannafin, 1997);</td>
<td>- Embed scaffolds directly into technology interface to prompt and model the reflective process (Bell, 1998; Hmelo &amp; Day, 1999; Lewis; Stern, &amp; Linn, 1993; Lin, Hmelo, Kimmer, &amp; Secules, 1999; Salomon, Gleberson, and Gueterman, 1989; Scardamalia, Bereiter, McLean, Swallow, &amp; Woodruff, 1989);</td>
</tr>
<tr>
<td></td>
<td>- Monitor the fine details of a project or investigation, remaining focused on the “forest” or broader purposes without getting lost in the “trees” (comprehensive monitoring);</td>
<td>- Topic knowledge is often incomplete, which hinders deep evaluation and strategic use of information resources (Lylons, Hoffman, Krajaic, &amp; Soloway, 1997);</td>
<td>- Use organizing frameworks to help teachers and learners making strategies and progress explicit (Schwartz et al., 1999).</td>
</tr>
<tr>
<td></td>
<td>- Integrate information coherently from a variety of sources (reasoning);</td>
<td>- Epistemological orientations that are counter to those required for effective learning with OELs (Wallace, Krajaic, &amp; Soloway, 1997; Oliver, 1999).</td>
<td></td>
</tr>
</tbody>
</table>
Gordin et al. (1996) wrote the following, “... a design can engage students in inquiry activities through which they achieve mastery of specific inquiry skills and can develop new content understanding through discovery and refinement” (p. 55). This study will use four points stated by Gordin et al. that can extend scientific visualization as a lens to examine the lesson and detail the experiences of students (16). They are listed below:

1. the use of activities that provide learners with the opportunity to engage in all four combinations of interpretive/expressive and objective/rhetorical activities

2. the introduction of human geographic data sets to help better connect SciV to students' interests

3. the incorporation of a modeling capability for the examination of hypothetical scenarios as a means to provide greater opportunities for sense-making conversations

4. the establishment of learning cultures in which students can engage in critical dissent without social penalty

The four points will serve as the theoretical framework for presenting the findings of this study. The lesson in this study that students will use is a practical application of analyzing gasoline prices in the United States during 1995–2005 through graphical representation of authentic data. Students will explain why gasoline prices fluctuate according to the supply and demand of petroleum. They will create an x- and y-axis to demonstrate the equilibrium price through bar graphs and histograms. Findings are significant in forming a new lesson plan for scientific visualization and civics and economic teachers to use as well as supporting four points stated earlier.
Conclusion

The four points of Gordin et al. (1996) demonstrated that the learner is actively participating in their learning. First, using activities draws a learner into their experience through interpretive, expressive, objective, and rhetorical activities. Table 3 provides a summary of interpretive and expressive activities that students need to understand when making scientific visualizations from Gordin et al. (1996, p. 3).

Table 3.

A summary of interpretive and expressive activities that students need to understand when making scientific visualizations. (From Gordin et al., 1996.)

<table>
<thead>
<tr>
<th>Activity \ Intention</th>
<th>Objective</th>
<th>Rhetorical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interpretation</td>
<td>What does this tell me about the world?</td>
<td>What did the author intend to communicate?</td>
</tr>
<tr>
<td>Expression</td>
<td>How should I describe the world?</td>
<td>What point of view do I want to communicate?</td>
</tr>
</tbody>
</table>

Second, real data allow students to be interested in the data used. Third, modeling provides a student with the ability to comprehend the data. Fourth, classrooms that establishes a culture where students feel safe to talk about learning without being penalized is important. Thus, this framework will guide this case study.

Chapter Summary

This literature review covered the history of scientific visualization as well as its importance in the classroom. Scientific visualization’s background was explored from
technology education to Tufte’s mapmaking beliefs to the meaningfulness of graphics by Bertin. Visual performance studied eye movement, eye patterns, and visual perception. The significance of graphics imploring multiple meanings was described in Lemke. Berson and Berson demonstrated the link between social studies and scientific visualization as other cases in science and math. As described in depth previously, this study will focus on the four points in the Gordin et al. (1996) Integrated Inquiry Planning Model. The following chapter will describe the case study approach taken in this study to explore student learning in a new light.
CHAPTER 3

METHODOLOGY

This case study sought to discover how students understand complicated data, ultimately revealing how they learn. Using the research questions outlined in Chapter One and the conceptual framework described in Chapter Two, this study explored the underexplored relationship between history and technology education. Scientific visualization is a branch of technology education. Because this topic has been seldom explored, the investigation was approached as a single case study. It was anticipated that the results would be the basis for new lesson plans and curricula that bridged civics and economics with scientific visualization.

Research Design

Qualitative methods are remarkably well-adapted at investigating issues dealing with multiple realities and experiences, providing a rich, thick description of the “how?” “why?” and “in what ways?” types of questions that quantitative studies simply cannot address (Lincoln & Guba, 1985). Qualitative data reveal the observed effect, whereas the qualitative methods assess human behavior and provide a detailed description of participants and their settings. This method of research provided a more “complex, detailed understanding of the issue that can only be established by talking directly with people, allowing them to tell the stories unencumbered by what we expect to find or what we have read in the literature” (Creswell, 2007, p. 40).
Case Study

Using a single case to describe a student’s experience with visualization in civics and economics was the focal point of this case study. The teacher for this study implemented an experimental lesson plan. The researcher was aware that implementing a new lesson could negatively impact the study as no formal testing had occurred, but wanted the discourse expressed by students to be the focal point, as reiterated in the second research question. Also, the lesson idea was from the NCDPI curriculum support document for civics and economics, which suggested strategies and learning experiences to maximize consistency among classrooms across the state.

Although a single case with multiple individuals could provide many insights, these might not apply to the entire population. Everyone was unique, and repeating the research with another group of students could well produce different results. Also, in order to keep the study manageable, a single classroom was studied. The researcher examined the student’s experience in a CTE class to gain insight into a new curriculum’s implementation. With the intention to give rich description of the phenomenon of student understanding, the researcher wanted to give readers the essence of the experience and visually construct the entire situation. This method of study was appropriate to examine the four points of Gordin et al. (1996) to promote scientific visualization and its approach to learning by using it in a real-world setting with a single classroom of students. The study was conducted with no preconceived notions about data that emerged in addressing the research questions. What will be unearthed was what the participants of the study allowed the researcher to uncover.
Researcher’s Role

A qualitative researcher seeks to understand the contexts or setting of a complex issue (Creswell, 2007, p. 40). Often this type of research is done to study a specific population or group of unheard of voices; thus, revealing individual or collective matters of concern.

Wanting to explore human nature, my role as a qualitative researcher as to tell my participants’ story in a holistic, naturalistic setting. The epistemological objective was to identify with the human event and convey what happened. The understanding was crafted to be empathetic and guide the reader through an in-depth story. Using trustworthiness and strong ethical morals discussed later in this paper, the researcher aimed to bring to light to new understanding through interpretations.

More specifically for this study, “the case researcher plays different roles...that may include teacher, participant observer, interviewer, reader, storyteller advocate, artist, counselor, evaluator, consultant, and others” (Stake, 1995, p. 91). Being aware of these roles, a researcher also needed to hone in on her attributes that strengthen and make his or her case more credible. Yin (2009) defined five skills to being a good case study investigator.

1. Be able to ask good questions-and interpret the answers.
2. Be a good “listener” and not be trapped by her or his own ideologies or preconceptions.
3. Be adaptive and flexible, so that newly encountered situations can be seen as opportunities, not threats.
4. Have a firm grasp of the issues being studied, even if in an exploratory mode. Such a grasp reduces the relevant events and information to be sought to manageable proportions.

5. Be unbiased by preconceived notions, including those derived from theory. Thus, a person should be sensitive and responsive to contradictory evidence. (p. 69)

By asking good questions, a researcher was able to produce an intense discussion reflecting specific instances or events. In the same light, being a good listener involves hearing what the subject was saying. Learning to be quiet yet active rather than passive, all while capturing the words, mood of the subject, and context, was difficult. Yin reiterated one of the major complaints of case study research—that the researcher makes changes without even realizing it and reveals gaps and biases (Yin, 2009, p. 71). Thus, the researcher was aware that perfect execution of planned research was not attainable and that one must keep the purpose of the original case in mind. Having a firm grasp on the issues being studied meant not only being aware of theories and lenses for the case, but looking for the information present between the lines of the participants. Last, avoiding biases was elemental to a case study research project. “All of the preceding conditions will be negated if an investigator seeks only to use a case study to substantiate a preconceived position” (Yin, 2009, p. 72).

Research Participants and Sampling Procedure

For this study, sampling procedures were meaningful to provide a thorough description of a participant’s whole experience. Creswell (2007) suggested purposeful sampling, which means, “the inquirer selects individuals and sites for study because they can purposefully inform an understanding of the research problem and central phenomenon in the
This qualitative study utilized a sample of students who are learning about social studies through a second-level CTE course. Research determined the value of extending visualization into other academic classes, specifically civics and economics. The study was conducted at a single CTE class at a public high school in North Carolina that was near Research Triangle Park and offers a Scientific Visualization II course. As stated by Creswell (2007), a maximum-variation sampling strategy is best for a case study to “document diverse variations and identifies important common patterns” (p. 127).

Purposeful sampling involved recruiting participants who are easily accessible to the researcher (Auerbach & Silverstein, 2003). The population selected for this study was a single classroom made up of nine students enrolled in CTE’s Scientific Visualization II class. The one-class model was used to remove any variability that could have risen in a two-class comparative model. The Institutional Review Board (IRB) of the university where the researcher was studying gave approval before the study began.

Through recommendations of professors at NCSU, a CTE Scientific Visualization II public school teacher was identified. Once the teacher was contacted and his or her principal approved the study, the same teacher was asked to recommend student participants from within the class according to the following criteria: student as passing class (reduces absentee students and students actively participated daily in class), and time spent participating did not detract from classroom success as it was part of the existing Scientific Visualization curriculum. Each student was given an IRB Informed Consent form to complete before participating in the study. Each of the steps listed below in the checklist was required for a participant to take part in the study. Students were informed that they were enrolled in a class
that was part of a research study on the case study method of research. The instructor described the research study. All participants were asked to sign a consent form before being allowed to participate in the study. The consent form had to be signed by both student participant and his or her parent or guardian. The participants ranged from 13 to 18 years of age since CTE classes were open to all high school students, typical for high school students. And, the participants reflected diversity with respect to race, gender, and academic performance within the class.

All participants were given my key contact information as well as my intent to request copies of organizational documents, plan for storage, classify, and retrieval of these items with the interview data. The researcher assumed the role of neutral observer while working with the participants. This number of participants allowed a useful amount of data to be collected despite student absences, which are difficult to control. As Creswell (2007) stated, intentionally sample a group of people that can best inform the research about the research problem under examination (p. 118).

In this case study, a new lesson plan was implemented in a second level scientific visualization class. The goal of this lesson was to analyze gasoline prices in the United States between 1995-2005 through graphical representation of authentic data. Students explained why gasoline prices fluctuate according to the supply and demand of petroleum. The lesson plan began by establishing a foundation. Students looked at bar graphs and histograms using Microsoft Excel. In guided practice, participants talked extensively about graphing as well as data visualization examples. On their own, each participant created a visualization depicting
their understanding of the economic nature of gas prices over time in 3D Studio Max. Using static and animations, the participants illustrated their understanding of civics and economics.

Data Collection Methods

“Qualitative study capitalizes on ordinary ways of getting acquainted with things” (Stake, 1995, p. 49). Utilizing the four points of Gordin et al. (1996) facilitated my data collection effort. Once the data was collected, it was categorized into four areas as discussed by Gordin et al. (1996). They believe that “scientific visualization enables questions to be clearly communicated through drawing qualitative relations and enables students to compare their hypotheses with data” (Gordin et al., 1996). The researcher expanded their conversations and observations. The data gathered fitted into one of the four areas summarized by Gordin et al. as listed below:

1. use of activities that provide learners with the opportunity to engage in all four combinations of interpretive/expressive and objective/rhetorical activities
2. introduction of human geographic data sets to help better connect scientific visualization to students' interests
3. incorporation of a modeling capability for the examination of hypothetical scenarios as a means to provide greater opportunities for sense-making conversations
4. establishment of learning cultures in which students can engage in critical dissent without social penalty

The first point engaged learners finding meaning in scientific visualization and uses scientific visualization to design a solution. The writers stated “these activities are counterparts to one
another, like reading and writing,” (Gordin et al., 1996, p. 2). Human geographic data set was understandable data for students expressed in the second point. Point three expressed clear communication of data. The last point allowed creative safety in the class. Cultivating a climate in the classroom began with support from teachers and students from supportive teachers and teachers were where a student was challenged and not penalized for learning and communicating was essential in this point.

The researcher used three complementary methods for data collection: observations (direct observation field notes), interviews, and documents (physical artifacts and rubric). Creating a balance of resources of the case, multiple sources revealed evidence to fit the framework of student learning for this study. Figure 1 offers a compilation of different ways to collect data for a qualitative study. Descriptions of the three data sources follow.
### Observations
- Gather fieldnotes by conducting an observation as a participant.
- Gather fieldnotes by conducting an observation as an observer.
- Gather fieldnotes by spending more time as a participant than as an observer.
- Gather fieldnotes by spending more time as an observer than as a participant.
- Gather fieldnotes first by observing as an “outsider” and then by moving into the setting and observing as an “insider”.

### Interviews
- Conduct an unstructured, open-ended interview and take interview notes.
- Conduct an unstructured, open-ended interview, audiotape the interview, and transcribe the interview.
- Conduct a semi-structured interview, audiotape the interview, and transcribe the interview.
- Conduct a focus group interview, audiotape the interview, and transcribe the interview.
- Conduct different types of interviews: e-mail, face-to-face, focus group, online focus group, telephone interviews.

### Documents
- Keep a journal during the research study.
- Have a participant keep a journal or diary during the research study.
- Collect personal letters from participants.
- Analyze public documents (e.g., official memos, minutes, records, archival material).
- Examine autobiographies and biographies.
- Have informants take photographs or videotapes (i.e., photo elicitation).
- Conduct chart audits.
- Review medical records.

### Audiovisual materials
- Examine physical trace evidence (e.g., footprints in the snow).
- Videotape or film a social situation or an individual or group.
- Examine photographs or videotapes.
- Collect sounds (e.g., musical sounds, a child’s laughter, car horns honking).
- Collect e-mail or electronic messages.
- Gather phone text messages.
- Examine possessions or ritual objects.

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Figure 1. Data collection methods. From —Qualitative Inquiry & Research Design: Choosing among Five Approaches Creswell, J.W. (2007)
Observations

Observations were meant to be unobtrusive and were recorded in the form of field notes, which allowed for open-ended narrative data to be collected while observing the lesson being taught and the experience of the students. The researcher performed continuous monitoring during the lesson implementation, so as to record as much of students’ behavior as possible. In the field notes, any dialogue in the classroom was noted that involved teacher, researcher, or students. A diagram was also included to illustrate the classroom layout.

Descriptive, inferential, and evaluative data meant that data was correctly communicated from the researcher to the audience (Brown, n.d.). Descriptive and inferential data appeared in the field notes, while evaluative data appeared in analysis. Observations did not depend on another individual to fill out a survey or converse on the topic at hand. The field notes gathered from observations were be used to solidify the researcher’s thoughts during observations and notate any other pertinent information that contributed to additional analysis (Stake, 1995; Yin, 2009). Field notes were coded and integrated in the breakdown of this case study. Appendix B detailed the plan the researcher took as suggested by Stake (1995).

Interviews

According to Kvale (1996), the researcher who uses qualitative research interviewing intends to interpret meaning from the participants’ experience. Questions to guide the conversation were established beforehand and were given much thought. They were more detailed than research questions.

The research questions sought answers regarding how students understand complex
data. Therefore, those students directly involved in a scientific visualization class where a civics and economics lesson was utilized were best able to provide data about their processes of understanding material covered in class. While studying one classroom has its limitations, “the real business of case study is particularization, not generalization” (Stake, 1995, p. 8). The researcher’s role was to clearly explain what occurred during the study rather than making comparisons as to how it was different. Cousin (2005) stated, “Although a form of generalization might come from a focus on the singularity of a case (these are some of the issues that may attend disability and fieldwork or geography departments), the research aims to generalize within rather than from the case” (p. 2).

Through personal interviews, the researcher set out to further describe the experience of the lesson as it related to each participant. Semi-structured, one-on-one interviews were conducted and recorded to allow the researcher to accurately capture data and give attention to interview (Hoepfl, 1997). There were two sets of interviews with each study participant. One interview took place before the study began, and the second took place at the end of the lesson in a separate classroom or private section of the classroom. Engaging in an interview prior to the lesson’s being taught allowed the researcher to understand participants’ expectations of the experience as well as help establish trust between the researcher and participant. Before any initial interview with a given participant, the researcher explained the time it would take, the researcher’s plans for using the results, and the need to the participant to verify data collected. The interviewer asked the guiding questions created in advance (see list of interview questions in Appendix C and Appendix D) and allowed the subject to do most of the talking. The interview was recorded to allow accurate transcription of the
conversations. The researcher memorized the questions to keep conversation flowing and will thank each interviewee at the end of the session. After completion of the interviews, they were transcribed verbatim. When transcriptions were complete, interviewees were given a hard copy of the transcriptions and were given the opportunity to review his or her transcript. Thus, this method of data collection was the principal way of gaining a deeper understanding of this case study.

**Documents**

Documents came in the form of data collected from participants. It provided the researcher a chance to make inferences about student learning through the unit of instruction. At the conclusion of this civics and economics gas-price activity, each student produced a two-dimensional or three-dimensional visualization explaining the circular flow of economic activities. The illustrations showed the prices of goods and services, specifically petroleum prices, during 1995–2005. Having each student create his or her own visual representation of the data revealed the depth a participant understands. The rubric presented to students at the beginning of the lesson was used to score student visualizations. The instructor and the researcher scored the visualizations and results were used. Anonymity was key in this section of data collection. Visualizations did not have student names and rubric scored by the instructor and researcher did not have student names on the scoring sheet. The removal of major identifying details, like a name, maintained the limits around personal information while permitting the rest of the data to be employed in additional contexts. Information from students about the lesson relative to the integration of academic and CTE course content were revealed as well as showing how participants interpreted complicated information.
Data Analysis

Analyzing the findings of this case study illustrated the integration of scientific visualization with social studies. Through the theoretical lens of the four points of Gordin et al., the researcher attempted to provide a thorough description of what students experience. To effectively analyze data, the researcher had a process to accurately represent one’s findings, in which Creswell (2007) noted was important. First, the researcher created and organized files for one’s findings. Next, the researcher read through all texts and made margin notes, which were a systematic way of identifying words, actions, and other noteworthy observations. After this step, the researcher described the case, framework, and matter. Then data was classified to see emergent themes and patterns from the case. Once that was been done, the researcher materialized naturalistic generalization, a process that is in part innate through similarities and differences in text, through direct interpretation. Through relating categories to analytic framework in literature and displaying the data, the researcher showed the findings in tables and figures to give the reader an understanding of the event at hand.

Analysis of Research Findings

For a case study, thick descriptions and rich details were made though analyzing the case and its setting (Creswell, 2007). A computer program provided organization of information for analysis. It allowed the researcher to locate material, such as trends in participant interviews and field notes from the observer. Also, it easily, facilitated a researcher’s close examination of meanings, and visually displayed relationships and themes (Creswell, 2007). This program allowed importation of audio files (with or without
transcriptions) as well as word processing files. It was secure and had features that allow one to make sense of information found in models and charts, revealed themes and patterns. Interview transcriptions, field observation notes, and descriptions of physical artifacts that emerged from data were used to recognize themes that become apparent during the research experiment.

Once the data was collected and analyzed, the four items listed by Gordin et al. (1996) in my previous writing were used to compare findings and make them clear and explicable. “People learn by receiving generalization, explicated generalization, from others, regularly from authors, teachers, and authorities. People also form generalizations from their experience” (Stake, 1995). Reporting the researcher’s findings in a naturalistic manner means giving the reader the experience of what occurred while participants were learning. Relevance of the findings and even discrepancies were reported to appraise a framework for research. Stake (1995) emphasized that a case study had practical points to assist in the validation of naturalistic generalization.

1. Included accounts of matters the readers are already familiar with so they can gauge the accuracy, completeness, and bias of reports of other matters.
2. Provided adequate raw data prior to interpretation so that the readers can consider their own alternative interpretations.
3. Described the methods of case research used in ordinary language, including how the triangulation was carried out, especially the confirmation and efforts to disconfirm major assertions.
4. Made available, both directly and indirectly, information about the researcher and other sources of input.

5. Provided the reader with reactions to the accounts from data sources of input.

6. Provided the reader with reactions to the accounts from data sources and other prospective readers, especially those expected to make use of the study.

7. De-emphasized the idea that validity is based on what every observer sees, on simple replication; emphasize whether or not the reported happenings could have or could not have been seen

The data analysis reported made contributions to the literature and expanded scientific visualization as well as civics and economics curriculum.

Coding

No matter what software was used, the researcher completed data analysis.

“Qualitative coding is the process by which segments of data are identified as relating to, or being an example of, a more general idea, instance, theme, or category” (Lewins & Silver, 2007, p. 81). The initial step in data analysis was to simply read the interview transcripts several times. As themes emerge, I began open coding, which allows for similar words, descriptions, and interactions to be grouped into categories and subcategories. "The first major analytic phase of the research consists of coding the data. In short, coding is the process of defining what the data are all about while bringing order to a researchers study. Unlike quantitative coding, which means applying preconceived codes (all planned before the researcher even collects data) to the data, qualitative coding means creating the codes as you study your data” (Charmaz, 1994, p. 37).
The software was the tool to searching, marking up, linking, and reorganizing the data. It also was representing and storing reflections, ideas and theorizing so the researcher will always analyze qualitative data (Denzin & Lincoln, 2003). A holistic approach was implemented to systematize data in this study. The emergent data was arranged according to their relevance with the research goals. The coding process for this project was both inductive and deductive. Inductive coding consists of open coding (code labels termed *in vivo* coding), axial coding (second look at data and links and identifying fragmented data), and selective coding (revisiting data for the third time to assess codes and relationships, themes, etc.) (Lewins & Silver, 2007, p. 84). A deductive approach to coding predefined areas of interest. As noted by Miles and Huberman (2007), there are three levels of consideration for interpretation of data (cited in Lewins & Silver, 2007, p. 86). They are as follows:

1. Descriptive codes are fairly objective and self-explanatory in nature; they are the first pass in the coding process when looking at text for a first time and developing organization of data according to its description.

2. Interpretive codes are used to add another layer of detail to the meaning of descriptively coded data. Coded data is revisited with close examination to similar links. Existing concepts may be deconstructed into detail, and elements of a particular theme could show lineage to other areas of similar interest.

3. Pattern codes are used in the third stage, which is much more explanatory in nature. Comparing and contrasting relationships reveal meaningful and illustrative patterns in data.
Using these means of looking, relooking, and continued thinking analytically provided the researcher to understand how students comprehend complicated information.

**Reporting Study Results**

Through the theoretical framework used, the researcher attempted to provide a thorough description of what students’ experience. To effectively analyze data, the researcher had a process to accurately represent my findings as noted by Creswell (2007). First of all, files were created and organized for the study’s findings. It was important that the researcher have a pre-determined, methodical way to manage data. Next, the researcher read through all texts, made margin notes which was a systematic way of identifying words, actions, etc with icons to start notating things that are seen. After this step, the case, framework, and matter was described. Then the researcher classified data by using a collection of instances to see emergent themes and patterns from the case. Once that has been done, the researcher materialized naturalistic generalization through direct interpretation. Through relating categories to analytic framework in literature where the researcher contextualized in framework from literature and displaying the data where finding were displayed in tables and figures to give the reader an understanding of the event at hand. The data was entered into one of the four following areas listed by Gordin et al. (1996). Researchers utilized activities that asked students to interpret and express their understanding though a scientific visualization just as students will do for this lesson. Relevance of the findings and even discrepancies were reported to appraise a framework for research. Data may add to existing literature and expand scientific visualization as well as civics and economics curriculum.
Trustworthiness

Glaser and Strauss (1967) defined trustworthiness as the magnitude to which one can be certain of a research finding. The researcher implemented validity, reliability, and objectivity where qualitative studies exist. The literature contained multiple studies and perspectives on validation. The perspectives vary based on the researchers’ epistemological approach. Lincoln & Guba’s (1985) criteria for trustworthiness include credibility, transferability, dependability, and confirmability. Credibility assessed what was done during the data collection phase of the study. Assessing sampling techniques and the care to participants was studied in this area. Transferability lended to replication of the study, meaning, it had an extensive description of every step of the case study to allow another reader to transfer findings and be consistent. Dependability was seen in documentation of a researcher’s decision in a study that showed good inquiry methods. Confirmability demonstrated that findings were truly from the voice of the participant and data, not from the researcher’s bias.

The researcher implemented several strategies to satisfy trustworthiness as defined by Lincoln and Guba (1985). These included member checks, triangulation, and rich descriptions and thick details. The researcher also incorporated Creswell’s (2007) recommendation for mitigating researcher bias. Member checks allowed participants to see transcriptions of interviews and see if interpretation makes sense to them and depicts their experience. The collection of data from multiple methods was triangulation. Interviews, observation, and physical artifacts all reinforced themes and patterns that emerge from study. Rich and thick description permitted the readers to see if the study was conducted in a
transferable manner. As the writer, the researcher gave much detail about the setting, lesson, students, teacher, interaction, framework, process, and outcome. Last, in clarifying my bias, the researcher let the reader know her position and experiences that could have shaped the interpretation and overall approach to the study.

Research Limitations

When deciding the form of qualitative inquiry and how to set up the study, a case study was chosen out of Creswell’s five approaches as the best fit for the problem. A case study is a form of qualitative inquiry that “understands an issue or problem using the case as a specific illustration” (Creswell, 2007, p. 73). All studies have limitations, and the researcher must responsibly recognize possible limitations (Glesne, 1999). For this study, the following limitations were taken into consideration: (a) one class with a limited number of students’ may not be typical of the general population, (b) the method of studying and behavior is only described, not explained, (c) people provided information and may choose not to make certain statements in an interview or truthfully respond, (d) the environment where study occurs is open and anything can happen (not controlled), and (e) there can be masses of data for analysis.

This study investigated how a selected group of individuals make meaning of a new lesson implemented in a CTE class. The results for the one class in this study were not generalizable to every student in every scientific visualization class. As stated by Hodkinson and Hodkinson (2001), case studies can help understand complex inter-relationships. Because this method of qualitative research was chosen, the behavior was described as a vivid experience. Since one was studying people, the unpredictable and awe-inspiring can emerge
in data. Examining the atypical and typical behavior shows the true nature of the learning process that occurred throughout the lesson.

Not only is the researcher the primary instrument of data collection and analysis (Creswell, 2007), but that person selects how to present the information and in what light to showcase generalizations. That practitioner went by gut instinct and inherent abilities when presenting information relative to the case study. Through the research methodology, pulling apart information and re-examining data time after time using synthesis until meaning emerges from research exemplifies what truthfully occurred in the study. Looking at how a student learns when a civics and economics lesson was implemented in this CTE class allowed the researcher to grasp the actuality through variegated connections.

Time was limited in the study to a single quarter of a high school student’s life. The sample classroom was chosen due to ease of location. The researcher lived in the Research Triangle Park area and attends school close by, so she chose to study a class that was nearby her home versus sampling classes across the state.

Ethical Conduct of Research

The protection of students in the study was important, as participants were asked questions regarding their experience within a class. Their best interest was always paramount. According to Ulin, Robinson, and Tulley (2002), The Belmont Report solidified three core principles for research ethics: respect for person, beneficence, and justice (p. 9). Each person remained autonomous, and his or her confidentiality was respected. The researcher listened to the participant and saw him or her in the person’s usual classroom surrounding. The second ethical principle was to strive to do no harm and keep participants’
well being in mind. The researcher conducted herself with the highest professional integrity. She pursued objectivity by not causing harm to any participant, keeping all research participants fully informed throughout study, and ensuring that no group was put at a disadvantage by being excluded from consideration during the study.

Summary

This chapter provided the rationale for choosing a qualitative case study. The researcher described the setting and participants, including the process of selection. Data collection and analysis methods were presented, as were the data analysis, limitations, trustworthiness, ethics, and verification. In Chapter 4, using data gathered from interviews and physical artifacts, finding and interpretations of the data by themes were presented in an attempt to gain a better understanding of how students understand complicated data.
CHAPTER 4
DATA ANALYSIS AND RESULTS

This chapter addresses the data analysis and results of the case study. To understand what students experience when using a civics and economics lesson in their scientific visualization classroom, a qualitative case study was guided by two research questions:

1. How does scientific visualization help students understand complicated data?
2. What is the experience that participants have when using scientific visualization in a civics and economics lesson?

This study examined the lesson and identified how the student-participants’ experiences were influenced by the following components of the theoretical lens of Gordin et al. (1996):

1. use of activities that provide learners with the opportunity to engage in all four combinations of interpretive/expressive and objective/rhetorical activities
2. introduction of human geographic data sets to better connect scientific visualization to students' interests
3. incorporation of a modeling capability for the examination of hypothetical scenarios as a means to provide greater opportunities for sense-making conversations
4. establishment of learning cultures in which students can engage in critical dissent without social penalty
Overview of Research Participants

The data supporting these findings were collected from nine students who were enrolled in a second-level scientific visualization class in a local North Carolina high school close to Research Triangle Park. There were eight boys and one girl. Of those students, five were juniors and three were seniors in high school. IRB approval was gained from North Carolina State University (see Appendix E). Research Review Committee of the school also concluded that the proposal met the requirement of state legislation and current research policy to conduct the study (see Appendix F). The teacher selected for this study had over twenty years of experience and wanted each student to be offered a chance to participate. The teacher felt that if six students were selected, the other three might feel left out and it would be detrimental to the study. Thus, each student was given the chance to participate in the study, and all nine students were given introductory letters and submitted signed Informed Consent Forms (see Appendix G) and chose to participate.

Overview of Data Collection Methods

Data took the form of three complementary methods: observations, interviews, and documents. Observations were documented as field notes in my journal. Interviews of the student-participants were semi-structured and were audiotaped and transcribed. Also, the physical artifacts produced by participants served as documents. The first student interviews were done before the scientific visualization curriculum was used. The researcher spoke with each student in succession in a quiet area that was unobtrusive to the other students and the learning environment. Next, the teacher taught the new civics and economics gas-price lesson. The researcher took field notes while the teacher was facilitating the lesson. Each
student produced a two-dimensional or three-dimensional visualization explaining the
circular flow of economic activities. The researcher then conducted the post-lesson
interviews after visualizations were complete. Participant 2 was absent the fourth day.
Participant 3 was only present for the pre-lesson interview and absent the following three
days when the lesson and post-lesson interview was conducted. Data from these students was
included at interviews in which the participant was present. At the conclusion of the lesson,
students saved their projects.

As with any pre-made lesson, the teacher customized the plan outlined by the
researcher. She explained and reviewed the types of graphs used in the lesson. While
discussing the features of the economic system of the United States, they discussed the
purpose of displaying information on a graph. The entire class did the guided practice
together. She pulled up sample data about revenues of every store in a local mall in
December given in the lesson and created a simple bar graph using Microsoft Excel. The
teacher guided the discussion about the purpose of the graphs and the information they
provided; yet, she did not pull up any data visualization examples given in the sample lesson
plan. She also requested that the project in the lesson be altered to individual work instead of
group work. Students in a second-level course were able to do this project individually and
this change made their learning experiences more meaningful.

During the study, the researcher took notes. A diagram of the classroom appears in
Appendix H and notes the desks, students, teacher, Liquid Crystal Display (LCD) projector,
and screen. In addition to interviewing each participant, the researcher observed the class
during the study to gain an understanding through narratives and actions. This data collection method was discussed in Chapter Three as part of the triangulation process.

Overview of Data Analysis

All interviews, field notes and documents were coded and analyzed to find emergent themes and patterns from the case. The process used was to create and organize files, read through all the texts and make margin notes, describe the case, framework, and matter. The researcher used NVivo, software that supports qualitative research by gathering, organizing, and analyzing data from interviews and field notes. As the researcher worked through information, main ideas were highlighted and nodes, virtual file cabinets containing all data on a theme there were summarized together, were used for recall and analysis. Through NVivo’s query and visualization tools, connections were uncovered and trends were revealed. The findings of the study, which used the research questions and theoretical framework, are presented and analyzed in tables. Information (see Tables 4 and 5) is presented to show the finding of this study with emergent themes. Each theme (see Tables 6 through 14) is followed by a descriptive summary.
Table 4

Alignment of Themes and First Research Question

1. How does scientific visualization help students understand complicated data?

<table>
<thead>
<tr>
<th>Components of the Theoretical Framework</th>
<th>Emerging Themes</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Use of activities</td>
<td>(1) Learning is context-based</td>
</tr>
<tr>
<td>(2) Use of human geographic data</td>
<td>(2) Active involvement in conceptual learning</td>
</tr>
<tr>
<td>(3) Incorporation of modeling capability</td>
<td>(3) Identify learning goals and objectives</td>
</tr>
<tr>
<td>(4) Establishment of learning cultures</td>
<td>(4) Compassionate presence</td>
</tr>
</tbody>
</table>

Note: The themes that emerged out of the content coding were aligned to the research questions and connected to the theoretical framework.

Table 5

Alignment of Themes and Second Research Question

2. What is the experience that participants have when using scientific visualization in a civics and economics lesson?

<table>
<thead>
<tr>
<th>Components of the Theoretical Framework</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Use of activities</td>
</tr>
<tr>
<td>(2) Use of human geographic data</td>
</tr>
<tr>
<td>(3) Incorporation of modeling capability</td>
</tr>
<tr>
<td>(4) Establishment of learning cultures</td>
</tr>
</tbody>
</table>

Note: The themes that emerged out of the content coding were aligned to the research questions and connected to the theoretical framework.

Emergent Themes

The research questions were each assessed according to the theoretical framework.

The framework facilitated analysis of the data collected. The data were collected and categorized into four components of the framework, which allowed themes to emerge.

Similarities and differences in the data revealed patterns that lead to a theme. Each theme
was notated in detail to understand how students comprehend complicated information. Any statistical data, such as from the documents, were woven into the data as a means of supplementing the narrative (Bloomberg and Volpe, 2008).

Introduction to Research Question #1

The first research question, How does scientific visualization help students understand complicated data, focuses the research. The four components of the framework used for this study, led to four main themes. First that learning is a context-based, meaning, “learning in context is paying attention to the interaction and intersection among people, tools, and context within a learning situation,” (Hansman, 2001, p. 44). Second, active involvement in conceptual learning. Using human geographic data, students were active in their research and created unique projects based on their conceptual learning. Third, identifying the learning goal. When a student and teacher understand their learning objectives, it makes the learning process was found to be understandable. Fourth, exploring creativity. The learning culture of the classroom allows students to explore their creativity and extends their learning to understand complicated data through the use of scientific visualization.

Theme 1: Learning is context-based

Applying the component “use of activities that provide learners with the opportunity to engage in all four combinations of interpretive/expressive and objective/rhetorical activities” to the findings revealed that learning is context-based. For example, using gasoline prices from recent years helped the student-participants to develop an understanding about gas prices. When students made their visualizations they were putting their knowledge
into practice. Thus, learning is context-based. Two categories point to this theme as noted in Table 6.

Table 6

**Theme 1: Learning is context-based**

<table>
<thead>
<tr>
<th>Categories</th>
<th>Sample Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contextualized in authentic activities</td>
<td>Capitalized on student understanding</td>
</tr>
<tr>
<td>Linked to prior knowledge and experiences</td>
<td>Instruction started with fundamental knowledge</td>
</tr>
</tbody>
</table>

*Note: The categories that emerged out of the content coding were aligned to the research questions and connected to the sample evidence.*

The information collected showed that the civic and economic activities were important to student understanding when making scientific visualizations. In a class discussion before beginning work on the second day, two participants stated, “What does my rendering tell me about global gas prices” and “How should I create my piece to describe what is going on in the world like everyone’s gas prices.”

The category, “linked prior knowledge and experiences” also helped students when engaging scientific visualization. Questions appeared in class discussions much more than during interviews as students were more comfortable with their teacher than the researcher. The students were very comfortable with the researcher by the post-lesson interview, but it took several days of being together to gain trust and confidence. On the first day, the teacher spent 45 minutes preparing students for their lesson by linking prior knowledge from previous activities. During this time, the instructor was talking about two projects each
student had completed. One in particular, the kitchen project, sparked a conversation. When discussing it, the teacher asked what students remembered about the projects. One participant said, “I wanted to show my parents what I wish our kitchen looked like.” His statement points to the rhetorical intent of interpretation. He wanted a specific person(s) to identify an upscale model of a specific room. He went on to discuss specific brands of appliances, colors of walls, and dimensions of a counter. This learner is actively participating in his learning and demonstrating his prior knowledge of a project. Without the teacher’s activation of fundamental knowledge, this student-participant might not have recognized the relevance of his or her memories.

Using activities to activate prior knowledge and building on an existing foundation was important as this category emerged from sample evidence to help students understand complicated data. Learning as creating occurred when the prior student created a model of the family’s kitchen. This student described in detail the project, allowing expression of different learning combinations of interpretive/expressive and object/rhetorical activities. Class discussions and questions from participants demonstrated this point in the first research question.

Theme 2: Active involvement in conceptual learning

Applying the component “the introduction of human geographic data sets to help better connect scientific visualization to students’ interests” to the findings revealed students’ active involvement in conceptual learning. Real data tended to stimulate students’ interest. Table 7 illustrates three categories with sample evidence to support this idea.
Table 7

**Theme 2: Active involvement in conceptual learning**

<table>
<thead>
<tr>
<th>Categories</th>
<th>Sample Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding through participation</td>
<td>High interaction with students, use example students can relate to</td>
</tr>
<tr>
<td>Knowledge grows from personal reconstruction</td>
<td>Prior work, related work</td>
</tr>
<tr>
<td>Learning involves personal meaning</td>
<td>Practical engagement, learners actively engaged</td>
</tr>
</tbody>
</table>

*Note: The categories that emerged out of the content coding were aligned to the research questions and connected to the sample evidence.*

Being an active participant in one’s learning is well noted by Sirinterlikci, Zane, and Sirinterlikci (2009):

Active learning is one way to capture the students’ attention because it involves hands-on and collaborative methodology ... Active learning’s critical components include using multiple senses and doing; problem defining, generating, and solving; interacting within and outside teams; high-level thinking; and relieving stress. (p. 14)

The second point of the framework pointed to the importance of using human geographic data sets to better connect Scientific Visualization to students’ interests. Understanding through participation, knowledge reconstruction, and development of personal meaning were found. Participant 8 said, “We had to do a project with cameras where we videoed a car crash, and we had to use different angles with the camera to get a better look at the car crash.” Students created a model for a road, a car, etc. The student said, “just a lot of knowledge about computer graphics and design and lighting and cameras ...” Knowledge
was gained from personal reconstruction. The teacher consistently circulated throughout the room. She spoke with each student at least four times throughout the class period.

The meaning a person develops through learning was important. Using real world data was evident in students’ modeling kitchens and making cars. A student said, “Is gas (a) transparent, amber color or brown? All I can say is it smells funny.” Finding the exact saturation and value is key was to learning and engagement. Participant 7 said during an interview, “I think that it does put in perspective how much gas prices do go up through the years, and it kind of just helps me understand where I’m at now, as opposed to where I was when I was born, in 1995.” The student was showing perspective and the meaning it has on life.

Using this gas-price activity shows how a learner was actively involved in the conceptual learning of scientific visualization while using civics and economics. Using the knowledge of basic concepts in scientific visualization, participants created an illustration through understanding, knowledge, and personal meaning. Students were able to explain the objectives of the lesson. Therefore, it was important for students to know the learning objective before starting a lesson or project. Participant 7 also said, “. . . what I have is the bars of gasoline, there—those cylinders of gasoline—and they’ll rise up as the animation goes through, and it’ll show that it is growing over the period of time from 1995 to 2005.” Students used the human geographic data of gasoline prices from 1995 to 2005 to make projects about the world.
Theme 3: Identify learning goals and objectives

Applying the component “the incorporation of a modeling capability for the examination of hypothetical scenarios as a means to provide greater opportunities for sense-making conversations” revealed that participants identified learning goals and objectives. Table 8 provides specific categories and sample evidence.

Table 8

<table>
<thead>
<tr>
<th>Categories</th>
<th>Sample Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Know expectations</td>
<td>Use language and examples students can relate to while introducing a new lesson</td>
</tr>
<tr>
<td>Audience</td>
<td>Repeat expectations of lesson</td>
</tr>
</tbody>
</table>

Note: The categories that emerged out of the content coding were aligned to the research questions and connected to the sample evidence.

Specific interview questions were designed to determine whether scientific visualization improved students’ understanding of civics and economics. Some students were able to explain how they used scientific visualization as a vehicle to convey their thoughts. Participant 8 said, “I had to take data, explaining gas and prices over the years, and I had to represent what happens, with using 3DS Max, whatever we wanted.” Learners who reflect are aware of and control their learning by actively accessing what they know and how they bridge that gap (Sezer, 2008). Participant 9 said, “I made a diagram showing—like, I averaged all the years, the months, and made the average, and then I did like a bar graph, put it in Max . . . as the years progress, some years the gas price is higher than the years before,
or it can be less.” This student used two programs, Microsoft Excel and 3D Studio Max, to create his final illustration and was able to explain his thought process when reflecting in his post-lesson interview. When students were starting this lesson, the teacher asked students to brainstorm how to show gas prices and she then let them sit silently to think. Seven of eight students were actively brainstorming about the project or how they were going to accomplish it. The teacher discussed with students her expectations of their work on this project. She also had students retell the learning objectives in their own words. When two students retold their expectations to the class, their discussion prompted three other students to voice questions.

The rubric used for scoring projects at the end of the lesson revealed a student’s ability to identify and work toward specific learning goals and outcomes. Students were evaluated on the following areas:

1. description of traditional graphs
2. presentation uses color, safe and ideal design
3. image of gasoline prices from 1995-2005 present
4. explanation of data visualization is included
5. presentation works and is correctly assembled
6. image is accurate, is scaled correctly and explains the data

In looking at the total scores given by the teacher and researcher, averages of each student’s work are fairly close in comparison to one another. Table 9 shows the scores determined by each evaluator:
Table 9

Student Scores

<table>
<thead>
<tr>
<th></th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
<th>P7</th>
<th>P8</th>
<th>P9</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher</td>
<td>72</td>
<td>77</td>
<td>93</td>
<td>64</td>
<td>83</td>
<td>83</td>
<td>83</td>
<td>84</td>
<td>79.875</td>
<td></td>
</tr>
<tr>
<td>Researcher</td>
<td>67</td>
<td>72</td>
<td>93</td>
<td>89</td>
<td>83</td>
<td>90</td>
<td>87</td>
<td>88</td>
<td>83.625</td>
<td></td>
</tr>
</tbody>
</table>

Participant 3 was present only the first day, during pre-lesson interviews, and did not submit a project. The scores functioned as grades on the project and indicated the extent to which students followed the teacher’s directions. In these examples, modeling provided a student with the ability to comprehend the data, which was important in the third component of the framework.

Theme 4: Compassionate Presence

Applying the component “the establishment of learning cultures in which students can engage in critical dissent without social penalty” reveals a “compassionate presence.”

The researcher found four categories related to a compassionate presence in analyzing data that emphasized the importance of a teacher who not only cares, but values being with students. McClain, Ylimaki, and Ford (2010) defined compassionate presence as follows:

As we grow in wisdom and mindfulness, our actions become more fully beneficial expressions of generosity, carefulness, patience and diligence. Compassion is not contrived; compassion is produced by nature. It is in the dynamic interaction of
relationship, in that praxis, that we find the natural expressions of wisdom and mindful awareness springing forth as compassionate action in our midst. (p. 312)

Presence was essential in unlocking a learning culture where students can freely express themselves while learning. Table 10 has details relevant to this theme.

Table 10

*Theme 4: Compassionate presence*

<table>
<thead>
<tr>
<th>Categories</th>
<th>Sample Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informal discussions</td>
<td>Facilitate classroom conversations</td>
</tr>
<tr>
<td>Experiences after school</td>
<td>Increase immersion, enhance engagement</td>
</tr>
<tr>
<td>Attitude</td>
<td>Supportive, well-organized, positive disposition</td>
</tr>
<tr>
<td>Expectations</td>
<td>Clear goals</td>
</tr>
</tbody>
</table>

*Note: The categories that emerged out of the content coding were aligned to the research questions and connected to the sample evidence.*

This theme outlined the importance of a classroom culture where students can engage in critical discussions without punishment. The teacher began class each day with informal dialogue to set the tone, define expectations, and have students’ recall knowledge about previous work. For example, “What happens to the sale of roses during the spring?” Students spoke about months when the price of gasoline rose, like during holidays. The teacher facilitated a discussion that included student discussion of supply and demand. Participants discussed how other events were also similar to supply and demand. For example, a student enthusiastically related the sale of a basketball tickets for the game between University of
North Carolina (UNC) versus Duke University. Seat prices would be more costly at this one game than at a less popular game, like UNC versus Wake Forest.

Later in the lesson, a sidebar conversation concerned which program a student might use for the project. Participant 4 spoke with Participant 5 about 3D Studio Max versus Photoshop. Participant 4 was more comfortable with “Max,” and Participant 5 agreed. They spoke in a murmur for two minutes about the details of the program and conversations included the phrases, “building,” “modeling,” “easier to use,” and “I am stronger in Max.”

The students were consistently at ease when the teacher would come to his or her seat. Participants liked knowing that the teacher could answer their questions. Participant 2 said, “Thank you, teacher, for helping me.” Those simple words illustrated the theme of compassion. The teacher visited each student at least four times each class period. This cycle was natural. She would visit each student at the beginning of class and toward the end, moving in an efficient path among students. The other two visits, in a less formal pattern. The teacher moved her chair as help was desired. She would visit a student if help was not requested. Those visits were met with ease. Students did not appear upset. This dialogue may have been something as simple as “This is what I’m doin” or “I have no clue what [this area] needs.” These observations supported idea of expert guidance in a comfortable, flexible, informal manner. Conversations allowed students to engage in critical exchange, which led to scientific visualization helping students understand complicated data.

Another category that emerged was the experiences a student has after school. Participant 2 was participating in the Technology Student Association (TSA), which was dedicated to teaching technology education and promotes Science, Technology, Engineering,
and Math leadership opportunities. The teacher expressed that this participant had taken an active role in the TSA and how the meaningful leadership opportunities had made a positive impact on the student’s learning inside the classroom. This one organization had provided challenging activities where the student was able to excel in competition, which provided an incentive to do better in class. The teacher noted that the student had been able to take skills gained inside the classroom and put them to work outside the classroom. In being a leader in this organization, the student was selected to go during the last day of the study to a leadership event for the school. The student was bused to another facility for a county workshop and engaged in conversations related to leadership with other students. This example shows value in student participation outside of class, as it increases immersion and engagement.

Attitudes contain elements of emotion and potential behavior, as stated by Caduto (1985). The attitude in the classroom played a vital role in the culture of the classroom. At the beginning of the second day, the teacher said, “Most of you have ideas now. Who needs help?” This statement showed the teacher’s ability to facilitate guidance. Participant 1 said, in contrasting the present project to a past project for this class, “It’s different, very different. We usually get to come up with what we—there’s not really a topic that we have to work on. It’s more of, once you’ve done a tutorial, just go and redo that tutorial but make it better, I should say.” The student’s attitude was reflective in the student’s willingness to participate and finish this project. Participants 8 and 9 stayed after class one day to talk to the teacher about their projects. The teacher answered each question with ease, detail, and enthusiasm.
Her willingness to stay after class, as well as the two students’, alludes to the culture where students can speak without worry while learning.

Expectations were a crucial part of the compassionate presence that emerged during the study. Clear expectations were provided from the first day. The teacher said in her opening statement, “Today, we are going to look at a lesson plan in Scientific Visualization related to graphing.” This general statement told students what they were going to be working on for the duration of the project. In showing students how graphs are used, the teacher followed the lesson plan set by the researcher and demonstrated graphing with the class. She displayed a bar graph and engaged with students in conversation about x-axes and y-axes. These conversations were used as part of the foundation for the lesson that enabled students to create a visualization based on gasoline prices for a certain time period.

Simple statements by the teacher as she moved around the room defined her expectations for her students and the project. “All right . . . go,” as she sent students to the computers to begin working on the assignment. In releasing them on the third day, she said, “I am going to come around in a minute.” In working with students individually, with Participant 9, “How can you creatively display data?” In further discussion with the same participant, she said, “Go ahead and graph liked planned.” This particular student appeared to struggle with the creative aspect of the project. The student spoke with her about several ideas, but the student needed help. In working with Participant 8, the teacher said, “Think of some other way to display prices . . . it’s boring but better than nothing.” Her acceptance was something the student seemed to need, to continue with the project. The student worked with
the animation and added more detail, like color, to make his or her project better. These sidebar conversations demonstrate a culture where expectations are clearly outlined.

During the post-lesson interviews, students were able to repeat the expectations of the lesson. For example, Participant 2 said, “Well, she gave us a list of different gas prices and we just had to kind of make—create our own scene showing different gas prices in different years . . . I took all the months of each year and I averaged them and put them all in one can and made different cans from 1995 to 2005, showing each average.” This participant made a model of one gasoline can and replicated it for each year. This indicates that the student understood the expectation of the project. Participant 5 said, “Well, it was like you take gas prices from several different years and you compare them to see like when gas got higher and when it got lower, . . . I, like, made gas signs, and I had, like, the year on it, and just I put June for everyone. And I put like the gas price that month and year on every single one. And they were all different.” The student also clearly defined the expectations of the project.

Compassionate presence was seen in this case study through informal discussions, experiences after school, attitude, and expectations. The teacher clearly set up the classroom for informal discussions. Students also conversed with one another about how to work on a project. The students and teacher interacted when guidance and support was needed and when feedback was needed to keep a student moving toward completion. Experiences outside the class also contributed to a compassionate presence in the class. A student was engaged in meaningful learning outside the classroom that positively affected her learning inside the classroom. In informal discussion, the teacher noted she believes it was helping this student graduate. This demonstrates the teacher’s compassion for students and subject
area. The teacher’s expert guidance, supportive nature, well-organized lesson, and project plan contribute to positive culture for students. Last, expectations within the classroom led to a strong teacher presence. Knowing one’s boundaries, within the classroom and within the project, foster students’ ability to work. In this case study, students’ goals are clearly defined. Thus, scientific visualization gives students a way to process information, and the theme of compassionate presence is seen in the comfort of a classroom culture. This specific culture is one in which students can freely learn.

Summary of Themes

The first theme highlighted capitalizing on student motivation for meaningful activities and linking prior knowledge and experiences in instruction. Establishing and building on background knowledge is key for context-based learning which stimulates student understanding of complicated data using scientific visualization. Student motivation was a vehicle to understand complicated information, like scrutinizing gas prices. Linking previous knowledge is fundamental to comprehending this data so a student can analyze gas prices and produce an illustration deepening their understanding of the material.

The second theme showed that active involvement in conceptual learning contributes to a student’s understanding complicated data. Through frequent interaction, participants were learning through participation. Knowledge was also further developed through personal reconstruction of prior related scientific visualization and civics and economics work. Learning involves personal meaning. Students were able to create an illustration based on their choice whether using 3DS Max or Microsoft Excel to make a project, illustration, or animation. Each student was also able to create the details of the project. For example,
students made animated bar graphs, oilcans, moving cars, and gasoline stations to show their personal understanding. Through practical engagement and active engagement, learners built concepts necessary for understanding and growth.

The third theme showed that when students were able to identify learning goals and objectives, it contributed to their understanding of complicated material. When introducing a lesson, the teacher used language and examples that students could understand. Students were able to recognize the directions and expectations of the teacher. Using the oral instructions given by the teacher, the Excel file stored on a mapped drive for all students, and a rubric given at the start of the lesson, students were able to unpack the complicated data in a civics and economics lesson and using scientific visualization.

The fourth theme was having a compassionate presence. Through informal discussions in the classroom, students were able to further their learning. The teacher facilitated classroom conversations to aid in their understanding of the material. Also, experiences after school enhanced a single participant’s understanding. Being a member of a club, specifically the TSA, led to a greater experience within the school. Having a positive and supportive attitude along with clear goals is key for a classroom. The conversations, experiences, attitudes, and expectations contribute to a safe classroom where students feel free to be themselves while learning.

Introduction to Research Question #2

Probing the second research question, What is the experience that participants have when using scientific visualization in a civics and economics lesson, and using the theoretical framework revealed four key areas related to presence in analyzing data. The fifth emergent
theme was found in the framework’s first component. Through classroom activities, real-world application contributed to a participant’s experience. Through the second component of the framework, developing one’s data literacy reveals the sixth theme. The seventh theme that emerged was based on the previous component, learning is understanding. Using representations to model and interpret phenomena were crucial. The eighth theme emerged from examining the establishment of learning cultures. Exploring creativity revealed information about a student’s experience in the lesson. Table 4 depicted the findings of this study with emergent themes. Tables 10 through 13 are followed by a descriptive summary.

**Theme 5: Apply to Real World**

Applying the component “the use of activities that provide learners with the opportunity to engage in all four combinations of interpretive/expressive and objective/rhetorical activities” to the findings revealed a theme of application to the real world. During the first interview, one question elicited a strong response from participants. The interview question varied from student to student, but mainly asked, “Tell me why you chose to take SciVis or take this specific class.” Some responses prompted the researcher to probe deeper during analysis. Participant 6 said, “Because, like, a lot of other electives that you are like boring, for lack of a better term, and it’s like one of those classes you can look forward to going to.” During the same interview a minute later, discussion concerned one project the participant had worked on throughout the semester. The student said, “We worked with how to use cameras—move them around, to make things look more realistic and not like just one angle of something. I can see it, like its potential [ph]-that it’s actually a 3D program.” Table 11 provides of this theme.
In the first interview, Participant 7 said, “I think that we take cartoons and animations for granted, and once you get into this class you do realize how much it takes to make those two-hour videos, and it’s more than just the two hours of work that go into it.” This participant elaborated on a further question by saying, “I think that SciVis would help me if I do come up with a medicine that helps people. It would help me create a diagram to help people understand to sell my product that I would make if I did make it someday.” In response to a question about insights from being a part of the SciVis class, Participant 9 said, “Well, they use it in the real world, and I think that’s pretty cool—how they interpret stuff from the outside and use it in, like, models.” Students are required to use their brain when processing information, become creative, thus, making content authentic and meaningful.

All of these conversations led to the theme of real-world application. Participants were able to take their experience as members of society when using scientific visualization and adept it to their civics and economics project. At the end of the second interview, Participant 4 said about this subject matter, “I mean, it’s really different, like usually we just
like learn about different things you can do in Max, but this is kind of—applies to the real
world.” In the first round of interviews, students revealed alterations in how they could use
scientific visualization in general after completing this Scientific Visualization II course.
Whether in a future career, a different class, or the medical world, the participant is able to
adapt their experience from the classroom.

The second category within this theme is the future. In the first interview, Participant
5 said, “I learned a lot about, like, 3D Studio Max. Like last year, I—it was everything that
seemed so hard last year is so much easier now because you learned so much.” The student
went on to say, “I think—I was thinking about it, and I’ve been thinking about it for a while.
Maybe one day I might do something like this, or anything . . .” This case study highlights
that students’ interest in the subject matter furthered their academic motivation. Students
were motivated to learn academic matter when they have a reason to learn them.

In discussing taking this class, Participant 3 said, “. . . It’s—you learn at the same
time, but you’re doing fun things while you’re learning.” The researcher concluded that when
students are motivated to learn, they achieve higher goals, retain more information, and
transfer information better between contexts. The first round of interviews allowed students
to share their feelings about the course, which varied. One student was stuck, or placed, in
the course. The participant had taken the first-level class and was not especially interested in
taking the second level. Participant 8 said, “Actually, to be truthful, I was put in this SciVis
class by just chance, but it worked out fine, and I like the class.” The researcher took this
dialogue to mean the student’s feelings changed over time.
Participant 8 also said in response to a question about being a part of the SciVis class, “You get to learn about a lot more things than you would think you would learn. You get to learn about lighting, cameras, different terms for making objects, and how to use computers better. Stuff like that.” In the second interview, Participant 4 said, “. . . this is kind of—applies to the real world.” These comments seemed to indicate that real-world applications provide students with some understanding events they would encounter in the world outside school.

From real-world application, the researcher also saw links between interest in the subject matter and internal motivation. Motivation was a critical aspect to sustain a student’s satisfaction. Pintrich and Schunk (2002) discussed student motivation as a massive precursor to learning. These scholars believed motivation carries a great weight in a successful classroom. In discussing Participant 5’s project, he or she said, “I like it. I think it was a pretty good idea. I don’t think I’ve ever done anything really like it before that.”

The second activity discusses what the student intended to communicate. This could be seen in discussions of the project and during the interview. In the first interview, Participant 6 said, “Oh, like, how to lighten things, and how things like work together and make stuff look real and it's not like—I don’t know how you—what word am I looking for. But like, you know how like if you just look at an object, like you don’t really know what it’s about; you just see something. In this class you kind of learn stuff about like what it’s made of.” Later in the interview, the participant said, “It kind of like broadens your, like—like, yeah, your opportunities. Like, you can go into a whole set of careers that don’t just focus on one thing.”
The expression activity emphasized in the first component of the theoretical framework is seen in each student’s work. Participant 5 was describing an animation from previous experience and said, “We did, last year—or, well, I guess, this year—but we did this little kitchen project. Or this house—yeah, kitchen. And it’s like you had to put materials, and you had to, like it was complex materialing [ph], basically. And you had to basically make a kitchen from scratch. You had to make a ceiling fan, a stove, a fridge to open—a stove had to open too, and all that.” Students decided to describe a part of a project without prompting. This participant told the researcher about the parts of the kitchen that had to be included as well as parts that had to open and move.

Last, the student must think about whom the project’s target audience is and what point they were communicating. When asked for whom the project was intended. Participant 2 said, “My audience was mainly just anybody who has any interest in what they were using on their cars . . .” Participant 4 said, “My audience is anybody who is interested in these types of things—gas prices. And I was just trying to commute [ph] or show how—how much it can change and like how drastic it can be in the changes.”

Active participation and high internal motivation revealed an understanding for activities and intentions. Learning played a large role in the experience a student has. Students were motivated about their current studies, future projects, and possible job opportunities. These samples emphasize the theme of application to the real-world.

Theme 6: Develop Data Literacy

Applying the component “introduction of human geographic data sets to help better connect scientific visualization to students’ interests” to the findings highlighted developing
data literacy. Through the lesson and engagement, students discussed connectivity between interests’ and technology (software) used in classroom. This theme is emphasized through the NSF Cyberinfrastructure report (NSF, 2007) as follows:

The dynamic integration of data generated through observation and simulation is enabling the development of new scientific methods that adapt intelligently to evolving conditions to reveal new understanding. The enormous growth in the availability and utility of scientific data is increasing scholarly research productivity, accelerating the transformation of research outcomes into products and services, and enhancing the effectiveness of learning across the spectrum of human endeavor.

(Discussion section, para. 2)

The above-mentioned changes can be applied toward enhancing education. This class is a CTE class that provides skills for lifelong learning and maturation. Table 12 gives the categories and sample evidence for developing data literacy.

Table 12

<table>
<thead>
<tr>
<th>Theme 6: Develop data literacy</th>
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</thead>
<tbody>
<tr>
<td>Categories</td>
</tr>
<tr>
<td>Robust design</td>
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<tr>
<td>Simulation</td>
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Note: The categories that emerged out of the content coding were aligned to the research questions and connected to the sample evidence.
This framework assessed how scientific visualization can provide learning by becoming the foundation for students to understand real-world and hypothetical situations. Real data facilitated students’ interest. In this study, students were creating a visualization based on real-world gas prices from 1995 to 2005. They were able to grasp the range of prices through simple Excel graphs and to create a visual aid based on personal understanding. The experience was key in this second research question, and from their experience in using real data; students were able to develop data literacy through robust design and simulation.

Using a robust design, a lesson planned with problem solving and critical thinking, to define a theme of data literacy includes lessons, learning, and teaching that all occur in a variety of settings. The teacher in the study was a vessel to carry her students forward in this setting. Students’ eagerness on the first day of the study was evident. Students did not enter rolling their eyes, talking loud, or being disruptive or slouching in their seats, which would show displeasure in this lesson and class. The researcher could see their eyes light up as the teacher talked about their new project. It was a nice day outside, and the warmer air seemed to filter into the room and complemented the students’ pleasurable disposition.

During second day, the mood of the classroom changed. It was rainy and dark outside, which seemed to permeate and reflect the atmosphere of the classroom. Students were serious and focused. There was 6 to 7 minutes of instruction and students were starting to work. Most of the conversations occurred at the commencement of class and between the teacher and students. Students tended to work alone. There were two or three conversations between students regarding the project. Again, students were attentive and constructing their
visualization. The mood at the end of the second day was lighter than when students began. A few students were close to finishing their project and seemed more relaxed as a result. The researcher heard murmurs of “done, sweet” and “I didn’t know if I would ever get going but something finally popped in my head.”

The third day was the final day available for students to finish their projects. Only one student was done at the end of the second day. The calm aura had returned, similar to the first day, and students came in ready to work. The sun had returned this third day, and the warmer air and light might have contributed toward the ambiance. The robust design of the setting contributed to the students’ experience.

The lessons students’ learn and the places where they learn were extended to the beyond the classroom in this study. Since this lesson combined a civics and economics concept and a real world example of how that concept is used, it asked students to become actively involved in the learning process. They were able to do research as a class as well as individually. They were able to use computer-based technology, such as the three-dimensional software in this lesson, to interact with human geographic data. In the second interview with Participant 4, the student said, “Well, it shows, like—I put them from year to year, and it shows like how they increase and then how some decrease, and the amount that they increase and decrease, and from year to year.” The participant continued by saying, “. . . and I was just trying to communicate [ph] or show how—how much it [gas] can change and like how drastic it can be in the changes.” As the discussion continued, the participant also said, “Well, it’s just kind of brought me into the process and, like, learning about them, and how it can raise and fall and—yeah.”
Participant 1 said regarding his visualization, “When holidays or something bad comes, gas prices rise, and gas companies make more money when people go out of town . . .” Similarly, Participant 5 said about the flow of economic activities and how those interactions determine the prices of goods and services, like gas prices, “Well, like, when people don’t go out and buy enough, because they don’t have enough money, the economy gets really bad and all the prices on everything increases because the companies need more money. But when the economy is good and everyone has the money to go out and buy stuff, the prices get a lot lower.” Asked to elaborate on the lesson, the participant said, “I thought it was pretty fun. I got to—this is one of the first things I’ve actually done, like, without tutorial. I mean, I’ve done quite a few things, but I thought this was pretty cool.” All of these quotations show the students’ ability to interpret human geographic data. They are becoming literate using digital data by creating their own visualizations from graphs. The experience fosters creative thinking, problem solving and high-order thinking skills, which allowed students to make connections between disciplines.

In this study, there are integrated subject matters, like civics and economics and scientific visualization, inside and outside the classroom walls to expand learning. One question in the first interview asked what a student might have learned and possible outcomes that could transpire from the class and experience of being a part of this CTE class. Participant 6 said, “It kind of like broadens your, like—like, yeah, your opportunities. Like, you can go into a whole set of careers . . .”

Participant 7 said, in talking about his project process, “I think that the creative process with this is a lot more harder to kind of make a concept for, because you are still
representing data, in the end, and you have to show that data somehow. And when we usually have a project we have a scientific process we have to visualize. So it’s more of a data representation than it would be for a process.” The participant’s statement made two points. First, the realm of the project was different from what the participant typically did in class. Second, the participant had a different experience with this new lesson. The robust design of the lesson contributed to his development. The student had to alter their creative process to accomplish this project. This particular student is also interested in medicine and spoke earlier about potentially using this method of showing data to illustrate his or her medical solutions. The student is crossing scientific visualization with the civics and economics concepts used in this lesson for the future.

Also in this theme is the importance of simulation through engagement. Throughout various interviews, students retold the story of circular flow of economic activities. Student stories provided a deeper meaning, like a participant’s future career, in illustrations and animations. Creating a project based on real data seemed to emphasize this civics and economics lesson.

In explaining the participant’s animation, Participant 7 said, “. . . Well, for the background, I have it in a box so you can visualize it in a room, so you can get the 3D effect of the program. And the background or the wallpaper of the room is money, to represent the price of gasoline. And also the representing the actual values during the period of time is cylinders of gas, and it has a clear yellow effect, like gasoline should be in real life.” The participant later said, “I think this graph shows that over time inflation takes place, and that as time goes by things rise in price. And it also reflects on the supply and demand aspect of
the market because, as the holidays do come up, the price of gases go up because there is such a demand for the product.” Participant 6, in discussing the techniques used by that student, said, “. . . instead of making it like a normal graph. It’s kind of boring to look at. So, when you put it in 3D like that, it kind of looks cooler.” The participant later said, “Actually, I used something from, like, Game Design, which is a different class, on how to like model things and make a reflection on the car window.”

Both of these conversations seem to allude to the value of a simulated project. Each student was aware of using concepts from various CTE courses to prepare this project. Students’ liked working with real-world data. The students also examined different years and created visualizations based on realistic data; thereby demonstrating the ability to see situations from multiple perspectives as consumers and students to gain a better understanding of supply and demand. Learners were to be empowered to create individual projects in this safe classroom, while developing data literacy.

This theme seems important in the life a 21st century learner. Students need to be prepared for success in the global market. Using robust design and simulation fostered students’ enthusiasm and mastery of this lesson. They were able to take their experiences outside class and made enthusiastic learners. The data depicts a unique experience from this lesson.

Theme 7: Learning is Understanding

Applying the component “the incorporation of a modeling capability for the examination of hypothetical scenarios as a means to provide greater opportunities for sense-making conversations” to the findings led to the theme “learning is understanding.” The
findings indicated the use of scaffolding instruction, which means that a foundation was laid and built upon for further learning. Kong (2002) explained the importance of scaffolding for both teachers and students:

Teachers share their end vision of the practice and assist the students to develop the knowledge and skills needed for participating in the practice through multiple instructional strategies, including explicit instruction, modeling and scaffolding. At the same time, students construct their own understanding of what the practice should be and appropriate and internalize the knowledge and skills while being assisted in their participation in the practice.

Scaffolding instruction was evident in the study when the teacher discussed graphing. The basic components were discussed and then students created a project based on this simple idea. A few other examples were facilitating student engagement and participation and asking students to contribute their own experiences that relate to the subject at hand.

Table 13 presents the categories and sample evidence of this theme.

Table 13

<table>
<thead>
<tr>
<th>Theme 7: Learning is understanding</th>
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<tbody>
<tr>
<td>Category</td>
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<tr>
<td>Scaffolding instruction</td>
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Note: The categories that emerged out of the content coding were aligned to the research questions and connected to the sample evidence.
This theme means that a student’s experience was enhanced by the participant’s learning and understanding as preparation for the lesson. Through sequencing of examples, a lively pace, and a systems approach, students were instructed in a scaffolding manner. In the second interview, Participant 9 said regarding the techniques implemented, “. . . And then I did use, like, what I’ve done in the previous lesson and stuff like that, and like, the gasoline, pulling [ph] out of that. We’ve used that to simulate like a fire hydrant.” The student alluded to a previous lesson from which the student applied techniques to this project. Also, Participant 6 said in response to the same question, “Actually, I used something from, like, Game Design, which is a different class, on how to like model things and make a reflection on the car window.” This student was using understanding from a different class to create this project and help analyze gas prices. The student later said, “I’m going to start saving more money whenever I get a car.” This proved the student’s awareness of the volatility of supply and demand. In support of scaffolding instruction, Participant 1 said in response to the same interview question, “. . . and I used a technique that we recently learned which was lights and cameras.” Again, these statements supported the importance of helping students to build a foundation of skill and knowledge. Participants used prior knowledge to support their visualizations as seen in their interviews and discussions.

The teacher was given a lesson that provided scaffolding and she accurately followed its instructions. She laid out a sequence of examples through which her students could understand the material necessary to get started. She explained the concept of supply and demand using high school jargon and discussed graphs with the class. The whole class talked about the purpose of presenting data in a graph as well as the features of the economic
system of the United States. The class did the guided practice together, and the teacher pulled up sample data and created a simple bar graph using Microsoft Excel. After this overview, students had a foundation on which to build their civics and economics activity for this project. The teacher also gave students a scaffolding-type instruction at the start and end of each class. She opened the day with general information and reminders and concluded the day with closing remarks and project expectations.

The lively pace and use of a systems approach were apparent from observation as well as student interviews. The lesson was intended for students to work quickly. The teacher continued this expectation each day in her conversations at the beginning of each class. On the first day, in reference to a concept from Scientific Visualization I, Participant 1 said, “I don’t remember how to do this.” Sitting by the student’s side, at eye level, the teacher patiently showed the student the steps in a software program the student did not recall. With Participant 2, the teacher advised this student to break down data to visualize small sections. In response, this student liked the idea of small chunks of information. The participant started working in Microsoft Excel as the teacher moved on to other students and was able to create different graphs using the data points in the general file given to all students. On the third day, the teacher and Participant 8 discussed rendering. They continued discussing the importance of data as the teacher walked around the room during the final 20 minutes of class. The student wanted to show the transparency of gas in his animation with an image of money as wallpaper in his background. The teacher talked with the student about how to get that look, but she also expressed the importance of finishing the work by end of class that day.
One question in the second interview led students to discuss the circular flow of economic goods, which brings to light the systems approach. Students’ moving from an individual view to a global view translates to the top of Bloom’s Taxonomy. In explaining of their visualization, Participant 2 said, “I just put it in a perspective of a town [ph]. And I had like this person looking at a gas price on a certain year, and looking at it . . . It was like it was an annual year [ph]. Just they—somebody put up posters and it said the gas prices change in 1 or 10 years, and it said who—the people would walk by and see how much the gas prices changed.” The student later said, “. . . there was supplies and demand and that’s what everything runs on.”

Also in the second interview, Participant 4 said in regards to the project, “Well, I’ve learned like how it can affect the economy and how people are affected also by the gas prices because of, like, how much gas they have to pay for.” The student continued, “Well, it’s just kind of brought me into the process and, like, learning about them, and how it can raise and fall and—yeah.” Similarly, Participant 5 said, “I think it showed that—it kind of showed me how much gas has gone up from the old—like from the 90s to now.”

All of these sentiments express how these students were able to grasp data points using scientific visualization and explain a complex civics and economics concept. Thus, scaffolding-type instruction enforces the theme when studying complex concepts. And, it brings out the theme of understanding; as students examined hypothetical scenarios provide greater opportunities for sense-making conversations.
Theme 8: Exploring Creativity

Applying the component “the establishment of learning cultures in which students can engage in critical dissent without social penalty” to the findings revealed a theme of exploring one’s creativity. A study by IBM (2010) of approximately 1,500 Chief Executive Officers from 60 counties and 33 industries said “more than rigor, management discipline, integrity or even vision—successfully navigating an increasing complex world will require creativity.” Categories provided in data revealed importance in action, like selection of a project, mastery of a concept, and help throughout a lesson related to presence in analyzing data. Sample evidence was found in capitalizing on student interest and continual evaluation of product by teacher and student supported these ideas. Table 14 shows the categories and sample evidence supporting this theme.

Table 14

<table>
<thead>
<tr>
<th>Theme 8: Explore Creativity</th>
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<tbody>
<tr>
<td>Categories</td>
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<td>------------</td>
</tr>
<tr>
<td>Choice</td>
</tr>
<tr>
<td>Mastery</td>
</tr>
<tr>
<td>Help</td>
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Note: The categories that emerged out of the content coding were aligned to the research questions and connected to the sample evidence.
The establishment of a learning culture emphasized student choices and concept mastery. Students were given the choice as to how to create the project illustrations. In the first round of interviews, students were asked to talk about a lesson or a project that they had done in class. Participant 1 said, “The kitchen was a fun tutorial here. We made our own kitchen how we wanted it to be, and we got to model it and everything.” In past learning experiences in this classroom, the student had experienced the freedom to be creative and explore his or her own avenues of interest. In a similar response, Participant 2 said, “. . . like most people, it was the kitchen because that was like the biggest thing that we’ve done.” The student later said, “it has a lot of stuff in it, like, put in there, and I enjoyed putting in extra stuff like food and a little teapot. It was the funnest thing to far.” These two statements illustrate the theme as students were thinking on a higher level.

In the second round of interviews, students’ were asked about their projects and creative choices of colors. Participant 2 said, “The materials, I picked the fence for—because it just looked interesting, a fence that you’d find in the neighborhood. And the materials for the posters, I just got it off the grids [ph] and did it [ph].” The student later said, “I enjoyed it. It was different. It was a very enjoyable experience . . . It’s helped me figure out what I want to do in life and . . . it’s creativity . . .” Also in the second interview, Participant 5 said about this project, “I thought it was pretty fun. I got to—this is one of the first things I’ve actually done like without tutorial. I mean, I’ve done quite a few things, but I thought this was pretty cool . . . I like it. I think it was a pretty good idea. I don’t think I’ve ever done anything really like it before that.” Using student interest was significant in data analysis for understanding experiences.
Concept mastery was also achieved by continual evaluation of a project by the teacher and student. To help them master a concept, students were given examples that demonstrated the concept, like circular flow of economic goods, remembered old ways to think about information, and demonstrated new concepts through their project. On the second day, the teacher was speaking to a few participants and said, “You guys are much more creative than I gave you credit for.” This lesson involved fewer directions and boundaries than a typical project in class. Students seldom had to devise a whole model or construct an entire building. They were given a model and directions to complete parts. The teacher was impressed by her students’ creativity and their creative capabilities.

The field notes and interview responses revealed patterns. The continual evaluation of the project through discussions and teacher observations contributed to students’ experiences and creativity. The field notes revealed trends. First, the teacher continually visits students. In her visits, she was observing and discussing student work. Through continual evaluation, the teacher was aware of students’ progress on the project. In talking with Participant 8, the teacher suggested to brainstorm other ways to display prices. She wanted the student to think of something more innovative. In a previous conversation with Participant 9, the teacher said to think outside the box, as he or she was being literal. She told him his visualization did not have to be a graph. The teacher helped each student as needed. On the first day, the teacher asked Participant 3 to go back to the data set and create a graph. The teacher’s informal assessment guided the student to a greater understanding. At the end of this lesson, the teacher was impressed with student projects as expressed in conversation with the students.
She noted that this type of project was different from anything she had given and was eager to celebrate their successes.

The integrity of the content was maintained. Critical features of the content were selected and transformed in a manner that enhanced student learning. On the second day, the teacher and Participant 6 discussed the shape of the oil drum and its view, as they rotated the view to see the whole object. Later that same day, the teacher said to another student, “Do you need help?” The student did not reply vocally but shook his head side-to-side, as the student was very focused on his work. The teacher also knew when to motivate students to keep them engaged in their work. Using phrases like “that’s awesome,” “good,” and “okay” were heard during the second day.

Another aspect of creativity is teamwork as teams can spur creativity. The teacher decided that each student needed to work on the project individually. She felt that as second-level students each person was capable of coming up with his or her own visualization. Yet the students in the room acted as a team, helping each other by offering advice on technique or software to each other. The researcher observed students questioning and persuading one another. After receiving the assignment on the first day, Participant 1 and Participant 2 brainstormed together. Towards the end of class that day, Participants 8 and Participant 9 interacted, discussed, and posed questions to each other about their ideas and plans.

Participants 1, 2, and 3 worked together on the first day. Despite Participant 3’s subsequent absences, Participants 1 and 2 continued to interact. Participants 1 and 2 also engaged with the teacher much more than did other students. Another example of teamwork was seen involving Participants 7, 8, and 9. Each of these students tended to work
individually yet they sought feedback from one another. They also encouraged ideas and
efforts of their teammates. Rendering was also an area that encouraged teamwork. Participant
projects took 2 to 30 minutes to generate the animation. During their down time, students
spoke with one another and discussed the project. These students created a culture where
each member has a unique skill or set of skills to contribute to the whole group. Therefore,
the class had a large pool of expertise.

Creativity was an important part of a learning culture and contributed to the
experience that participants had. Granting students a choice helped motivate them by giving
them ownership in whether the project succeeded. Continual evaluation of a product by the
teacher and by the students created mastery of concepts. Thus, this sample evidence and
these categories exhibit the important focus on creativity.

Chapter Summary

The themes that emerged from this case study have been presented. Data from two
sets of interviews as well as field notes were discussed under the eight themes along with
their associated categories and sample evidence found during analysis. The first research
question, and the four components outlined in the theoretical framework, pointed to learning
that was context-based, active involvement in conceptual learning, identification of learning
goals, and a compassionate presence. The second research question, paired with the same
theoretical components, found relevance in application to the real world, developing data
literacy, learning that is understanding, and exploring creativity.
CHAPTER 5
INTRODUCTION

This study aims to contribute valuable research to both scientific visualization and social studies curricula. The power of scientific visualization as an educational tool has been studied previously by researchers in mathematics, science, technology, and engineering fields. Given the need for a strong curriculum in high school history classes, this researcher sought to investigate the value of scientific visualization in such classes. Beginning with the knowledge that visual thinking and learning can exist at the same time within the brain, the researcher set out to answer two research questions:

1. How does scientific visualization help students understand complicated data?
2. What is the experience that participants have when using scientific visualization in a civics & economics lesson?

Specifically, the researcher sought to understand what students experience when a civics and economics lesson is introduced within their scientific visualization class. The investigation was done by engaging students in structured activities similar to those in science classes.

This case study focused on how students understand complicated data and their experience while learning. Chapter One presented the rationale for problems and questions that were addressed in the research that included a qualitative analysis of a student’s understanding of a civics and economics lesson. Chapter Two presented a review of the literature relating to the history of scientific visualization and its significance as well as the conceptual framework guiding the research. In Chapter Three, the research design, data collection methods, data analysis, and reporting were reported. The fourth chapter presented
a description of the case study as well as the emergent themes found during data analysis.

The present chapter contains a summary, the problems encountered, the primary results of the research, as well as conclusions, interpretations, limitations, possible consequences, recommendations, and suggestions for action.

Summary

The impetus for this research came during a conversation a social studies teacher who was expressing frustration over how to communicate a civics and economics lesson to her students. The researcher shared some of the techniques she used in her own classes. Curious about the potential for scientific visualization in other settings, the researcher developed a qualitative case study that would elucidate the students’ learning experiences.

This study used a single case to describe students’ experiences with visualization in civics and economics. The following are the two research questions that structured this study:

1. How does scientific visualization help students understand complicated data?
2. What is the experience that participants have when using scientific visualization in a civics and economics lesson?

The lesson used for this study presented gasoline prices in the United States from 1995—2005 using a graphical representation of authentic data. Students created a visualization, 2D or 3D, to explain why gasoline prices fluctuated according to the economic flow of supply and demand. They used information from a Microsoft Excel spreadsheet that contained specific months and prices for petroleum. The findings of this study supported the four theoretical components that the study proposed, as well as provided insights that helped to form a new lesson plan for scientific visualization and civics and economic teachers to use in
the future. The findings of this study also showed relevance that scientific visualization has in the classroom currently and could have in the future. The study also revealed implications for possible future work.

The integration of scientific visualization into a civics and economics lesson provided insights in both curricula and the learning process. The qualitative data showed instances in which the student had a greater understanding of the subject when using scientific visualization to understand a lesson focused on supply and demand. From this study, the researcher learned how much visual representation impact a student’s learning as well as the importance of listening to their voices.

Understanding Complicated Data

The first research question asked whether scientific visualization could help students understand complicated data. Many students struggle with the foundational concepts covered in civics and economics courses, concepts they needed to build upon for future studies. As stated by Berson and Berson,

Sometimes complicated information is difficult to understand and needs an illustration. In this Information Age, we are seeing the emergence of alternative means to visually communicate vast stores of information in newspapers, magazines, and reports. By organizing content into digestible pieces, main concepts or issues are easily discernible and can foster dynamic exchanges about timely subjects. (p. 124)

In this study, scientific visualization was used as a vehicle to transport a student toward understanding a complex concept. Jessee and Weibe (2009) developed a lesson plan about visual perception and its close relationship to human memory and establishment of
association. The authors discussed a lesson in which students focused on color. Their lesson showed how students were able to use communication technologies to tell a story. Students used a visualization technique to understand complicated data in this case study.

From this first research question and given the theoretical framework, four themes emerged. First, learning was context-based. Second, being actively involved in conceptual learning was essential for the students. Identifying the outcomes and objectives of learning for students was the third theme. Lastly, having a compassionate presence in the classroom was found to be important. Each of these was important and relevant to this study.

Context-based Learning

By using authentic activities related to the context of the lesson and linking prior knowledge and experience, the study supported the theory that learning is context-based. Participants indicated that their understanding grew when the lesson related to their perceptions of the real world. As noted in the literature review, Emigh and Zaslavsky noted, “Scientific visualization techniques offer plenty of opportunities for enhancing learning in the high school and undergraduate classroom (1998, abstract). Along those same lines, the National Research Council (2005) said that through scientific visualization, students were able to have a better understanding of essential ideas as well as new topics they encountered. When answering questions meant to stimulate prior knowledge, participants re-called experiences from previous lessons that contributed to their understandings of the current lesson. This concept also builds upon Bloom’s taxonomy, a hierarchical structure of learning objectives, and Bloom’s Revised taxonomy, which reflects the current educational and training practices that included the integration of technology.
As a teacher, the researcher learned the value of connecting prior lessons to current subjects to increase students’ learning. Many participants in this study were able to recount past projects in which they used scientific visualization. Students told stories of modeling kitchens, creating textures, and animating a car crash with correct camera angles. Scientific visualization contributed to their ability to organize and process information. This strategy also helped students solve larger, more complex problems. For example, students had to create a visualization based on their past scientific visualization experiences to create a new project using data about the supply and demand of petroleum. The literature on scientific visualization includes early works on information design and Tuft (1983) who discussed early forms of visual data and translated perceptions. In this study, students were able to translate the data easily because the visual display of data conveys information so clearly as shown by L. J. Henderson’s medical illustrations and other graphics.

Reviewing and practicing new concepts in the classroom also showed how learning in-context is effective. At the start of this lesson, the teacher gathered students to discuss the new material. She talked about both new material and old concepts throughout the class discussion. After the first day, she started each following class with a small discussion to engage and enhance the students’ foundation for the activity. Once the main idea was covered, the teacher discussed the circular flow of economic goods in a real situation. She was not quick to provide answers or repeat questions. She probed students until they uncovered the specific concepts. Following Bloom’s taxonomy, the teacher also engaged in interactive dialogue with higher-order-thinking questions to create a unique learning experience. Students evaluated the supply and demand data and broke it parts. Like in
Pouchet, students illustrated multiple variables at the same time using a graphic scale. And, like in Lohse (1997) discussed eye movement patterns of viewers. He attributed eye movement pattern to three variables: size, color, and the amount of information on a page. These variables were apparent in the study as they used similar strategies in color selection and choices of visual information in a page. Linking prior knowledge and experiences supported the value of context-based learning in this case study.

Active Involvement in Conceptual Learning

Active involvement in conceptual learning is facilitated by three factors: understanding through participation, knowledge growth from personal reconstruction, and learning with personal meaning. It can be implied from the data collected in this study that being an active participant in one’s learning is essential. In the literature, Gangley looked at visual thinking in science classrooms (1995). He conducted a qualitative study to measure the degree to which analogies were used to learn. His study demonstrated the links between teacher complex concepts and visual thinking. In cases where concepts were abstract, students benefited from a picture of how a specific function, process, or cell looked.

The current study also indicated that human geographic data sets could be used to better connect scientific visualization to students’ interests. Using the gas activity, the study demonstrated how a learner could be actively involved in conceptual learning using scientific visualization in civics and economics classes. Students could relate to a model of gas prices because many had experience driving or fueling vehicles. Through realization and participation, students were able to understand this civic and economics lesson.
Findings of this study also pointed to knowledge growth from personal reconstruction. Prior work and related work help, students understand complicated data. In the post interviews, the each participant repeated the goal of the lesson. Students shared what the visualizations expressed target audience, and what message the visualizations sent, as well as their effectiveness. The goal of the post interviews was two-fold; students pulled from their past to reflect on previous work that had enhanced their learning experience, and they described a new visualization and how it was made. Land (2000) discussed the need for open-ended learning environments (OELE), their cognitive requirements, and the problems with and implications of such environments (p. 64). The table cited in the literature points to prompting and guiding connections to prior knowledge during instructor-student conversations. Thus, being an active participant in one’s own learning through the use of human geographic data aided the student’s understanding of complicated data.

Identifying Learning Goals

The study was done to see if students could understand the material presented when using scientific visualization. In the case study, the results suggested that participants identified learning goals through language in field notes and interviews. Modeling allowed students to comprehend data in this lesson. Kozhevnikov, Hegarty, and Mayer (1999) discussed the connection between mental imagery and problem solving in physics, specifically in kinematics. Not all students were capable of forming visualizations on their own. Pictures were another form of learning that added to higher comprehension of the material. Also, students were able to engage in conversations relating to the project. They conveyed their thoughts. One’s ability to talk about the lesson, including topics discussed and
implications is essential to learning. It can be implied from the data collected in this study that articulating topics and objectives contributes to one’s understanding of complicated material.

Formulating learning goals was one theme that emerged from the data. One might say that the interview questions, guided this finding, but the researcher believes she was using the lens of participation to explore how students actively relate to learning. This action was one piece of the puzzle as learners use scientific visualization concepts to formulate, analyze, and solve real-world problems. Oliver and Hannafin (2002) researched student thinking skills and processes, supported by web-based tools, and teacher intentions for using web-based tools. The researcher studied how students used technological tools to solve open-ended problems involving the collapse of buildings during earthquakes. This case illustrated the benefit of technology with open-ended problems where students figured out how to solve a problem, like gas prices, without step-by-step instructions to identify a learning goal. Their experience in this rigorous thought and creative problem solving activity was valuable for growth.

Through the use of familiar language-finding reports, students were able to understand complicated data. They formulated an idea, presented a verbal argument to explain why they chose their visualization, and expressed a problem solving strategy. Students focused on their project and demonstrated their own understanding of gas prices. Students verbally expressed their understanding to the teacher, the researcher, and other students. Rogers, Connelly, Hazlewood, Ledesco (2010) noted that using modern technology facilitates learning by performing easy, sensemaking tasks that make connections between the unknown and known. The researchers found that mobile devices could be used to
facilitate sensemaking tasks during scientific activities, giving students the opportunity to make deeper connections (Rogers, Hazelwood, and Tedesco, 2009, p. 112). Using direct and indirect methods, the researcher assessed students to see how well they were meeting the lesson’s goals. A rubric was used to grade each student. The teacher and researcher evaluated these participants’ works and report students’ strengths and weaknesses for review and analysis. Similar scores with expected variances in each area of evaluation were seen. It was also observed that a student was able to learn by applying scientific visualization to civics and economics. Students’ understandings of civics and economics, specifically the circular flow of economic goods like petroleum, were strengthened through scientific visualization.

Establishing a Compassionate Presence

The value of establishing a compassionate presence is evident in the findings relating to informal discussions, experiences outside of class, teacher attitudes, and expectations. The participants of this study revealed that classroom conversation, other engagement opportunities, supportive attitudes, and clear goals greatly contributed to their learning experience. It was implied from the data collected that a clear establishment of learning cultures greatly contributes to one’s learning experience. In this case, the culture encouraged scientific visualization to help students understand complicated data.

This case study revealed that classroom conversations contribute to the formation of the collective knowledge those students’ need to learn. Land (2000) and Gordin et al. (1996) hypothesized that learners need support to interpret the meaning of visual representations. The table in the second chapter of Land (2000) shows how open-ended learning environments (OELE) use visualization or manipulation tools to facilitate experimentation of
complex phenomena, use authentic contexts to foster connections between formal knowledge and everyday experience, and use resource-rich environments to support learner-centered inquiry. “With frequent opportunities to cooperate and to be of service, students can learn the skills involved in relating to others and can develop wider networks of positive relationships,” states Schaps (2009). Likewise, through TSA, one student was successful outside the classroom. It also opened the door for other leadership experiences within the school. As Land stated in his table, “integrat[ing] information coherently from a variety or sources (reasoning)” demonstrated that students were able to generate and refine questions, interpretations, and understandings based on new information (2000). TSA was only one example found in this study, through other opportunities may have been available as well.

Supportive, well-organized, and positive teaching was found to be beneficial to student learning. Data showed that the teacher knew the subject knowledge, conveyed that knowledge to students, and frequently drew connections between her subject knowledge, other disciplines, and real world applications. The relationship of the teacher to student seemed to emulate a professional attitude and create a compassionate classroom. This teacher’s attitude showed a high level of commitment to her students. Her welcoming smile, positive attitude, and general care for each student all contributed to the students’ understanding of new material. The teacher maintained professional boundaries while maintaining approachability. Lemke’s (1998) contribution to the literature showed that all signs have multiple layers of meaning, for example, an individual giving a presentation uses his or her hands to emphasize certain points. The literature has also looked at how diagrams offer the reader a spatial representation that is often difficult to get from text (Hegarty et al.,
1991). The process of making meaning from text and illustrations was important for gaining understanding. Multiple representations helped students to understand text according to Hegarty et al. (1991). This finding was reinforced in informal discussions between the researcher and the teacher. This finding may indicate that the teacher holds a set of beliefs that causes her to behave in a caring manner; this data may also reveal the important role that relationships play in the learning culture of this case study. Thus, this theme emerged with categories and supporting evidence that contributed to the study.

PARTICIPANTS’ EXPERIENCES USING SCIENTIFIC VISUALIZATION:

CONCLUSIONS

Many students struggle with fundamental concepts encompassed in civics and economics courses, and this case study sought to understand the experience of learning and how it changes when scientific visualization is used. Rogers et al. focused on a mobile learning application, LillyPad, used by teams to “make sense” of their observations during scientific activities. Teams used this application to quantify, explain, and predict tree development for dissimilar planting techniques used in an environmental restoration location. Using different versions of the software, participants assessed the outcome of various planting methods for an environmental restoration location. This study suggested that technology offers students the chance to enhance sensemaking during activities in a similar way. The researcher used field notes and interviews to determine what learners experienced during this study.
Applying Lessons to the Real World

The benefits of teaching using real world applications were made evident in this study. Students were aware of the expectations of the lesson including the skills the teacher was targeting in each lesson. The objective of each lesson was to engage students in meaningful learning and purposeful creation. It could be implied from the data that was a key to learning as well as being involved in complex problem solving and application to real world issues. Friedman and diSessa outlined several principles behind effective software for scientific visualization:

1. Design to support understanding of representational aspects of scientific visualization technology
2. Design to take advantage of students’ resources for creating and interpreting representational display (i.e., the scientific visualizations)
3. Design for personal engagement and success (p. 176-177)

Their third principle was key for explain the importance of real world application. In the current study, participants spoke to the fact that learning as purposeful, interactive, and engaging. Their interviews and projects demonstrated this belief. In this case, students analyzed a situation—gas prices from 1995-2005—and solved the problem, creating a visualization based on one’s understanding of this phenomenon. Conversations with students revealed that participants were able to take the experience of using scientific visualization and adapt it to their civics and economics projects. Students said that this project was different than what they usually did. One way to explain the difference is that students were able to move beyond knowledge and comprehension to application and analysis of
information using data instead of a model or scene that was given to them. As members of society, students related the expense of gasoline beyond the classroom.

The second category in this theme revealed the importance of authentic tasks. It propelled students to discuss further academic motivators and furthered their general interest in subject matter. The data implied that this experience might encourage students to think about their future. Berson and Berson (2009) linked the integration of technology, specifically visualization tools, with social studies. In their study, students were using Word Clouds, software, to analyze public speeches. They created a visual image based on frequently used words and their importance. This example showed the importance of interaction based on students’ interest. Students seemed to know whether a subject was an area of interest they would pursue or whether it would be beneficial in their future careers. Some students had no further interests. But, others knew it could enhance their careers. During the interviews, some students who had ended up in the class by chance later took a math class so they could do more scientific visualization. Varying factors all contributed to sample evidence for this finding, yet, all the students echoed the theme of real world application.

Development of Data Literacy

Research participants indicated that they felt the design of the project was important for the development of data literacy. Students also showed a high level of engagement. These factors were important because students in this case study were asked to visualize data, investigate the problem, and understand data independently. This experience was key to the second research question of this study. It was important for students to be forward thinking.
and engaged in their illustrations and animations. These visualizations helped them process large amounts of information because concepts were broken down into smaller bits of information. Mathewson (1999) found that science teachers often overlook the importance of visual imagery plans in their classrooms. The brain has the ability to break down large amounts of information when it relays an image. Visual spatial thinking and use of imagery were important factors for learning. Students benefited from using simulations of various concepts to build projects and uncover knowledge from data in the surrounding world. The researcher found that evidence shed light on the students’ experiences when participating in a civics and economics lesson in a scientific visualization class.

**Learning as a Tool for Gaining Perspective and Understanding**

Regarding the second research question and third point of the theoretical framework, analysis indicated that for students, learning is understanding. This pattern is built upon scaffolding-type instruction. The teacher applied supports for students to learn. She consistently directed learning with queries that confirmed understanding and then brought in students when misunderstandings arose. As noted in the literature, Edelson’s work addressed scaffolding-type work environments and how to teach science through design. In Mayer and Moreno’s work (2002), they offered seven principles for designing animations for presentations. Understanding how people learn from words and pictures involves engaging in cognitive processes, like selecting appropriate material, organizing it in to an appropriate model, and integrating it with the knowledge that is already present (Mayer, in press; Wittrock, 1974, p. 91). Many schools have focused on STEM educations programs. Integrated programs have given students the skills necessary to be successful in a global
economy. All these examples supported existing networks of knowledge, and students saw the bigger picture: how their learning related to newer situations.

Notes taken regarding the lively pace of class and the use of a systems approach also implied the use of scaffold instruction when modeling was incorporated during this civics and economics lesson. Maintaining student interest and keeping that interest was essential to do when the lesson was developed. In mathematics education, McClintock, Jiang, and July confirmed enthusiasm, feedback, and logical properties of visualization were seen through the researchers’ analysis of transcription during activities (2002). They found that a technology-rich setting could help students’ ability to understand information. This review is extremely relevant because students in this case study were given scientific visualization to help them understand civics and economics.

Interviews, field notes, and discussions showed how students were able to take data points using scientific visualization and explain a complex civics and economics concept. Tufte, Minard, Hankins, and Bertin all emphasized the roots of scientific visualization in the professional and educational world. Informational design of modern information visualization and design graphics was designed with a purpose. The data implied the importance of small talk, high expectations, and fast movement. Students thought about a modeling capability for the examination of hypothetical scenarios as a way to provide greater opportunities for sense-making conversations based on concepts covered during this activity.
Exploration of Creativity

The experience that participants have when using scientific visualization in a civics and economics lesson can also be understood within the framework point of establishing of a learning culture. Through this lens, the exploration of creativity was part of students’ experience in this case study. Patterns in the data suggest that choice, mastery, and aid were essential. Capitalizing on student motivation, continual evaluation of work, and facilitating learning among students fell into this realm.

The data implied that student motivation stems from freedom. Freedom in this case came in the form of being able to create one’s own visualizations. There was a relationship between graphics and learning as pointed out in the literature by Mayer and Moreno as well as Vekiri. Vekiri specifically discussed three theoretical frameworks as they related to graphic processing and related research. “When students learn from preconstructed displays, they develop their own understanding by internalizing information. On the other hand, when students construct their own representations, they need to develop an understanding of the concepts they study before they can represent their thinking,” (Vekiri, 2002, p. 266). By creating visualizations, students created their own interpretations of the data.

Continual evaluation of the product by the teacher and student led to exploring one’s creativity. Rogers, Hazelwood, and Tedesco (2009) discussed the importance of providing many chances for students to reflect upon the transition of activity and study. This reflection deepened understanding in this case study as well as in the literature. In Land’s open-ended learning environment (OELE) table, the ability to use authentic contexts to foster connections between formal knowledge and everyday experience was significant to this study as well.
Modeling, instructor-students conversation, experiences, and external models all contributed to growth, development, reflection, and creativity. Trafton et al., (2005), noted the importance of studying visualization: several leading universities had dedicated visualization laboratories for scientific study through creativity.

VALIDITY OF RESULTS

The researcher used three complementary methods for data collection. Each method created a balance of resources and, through triangulation, demonstrated the credibility of data presented in the study. Observations, interviews, and documents were used to collect data for this study and were analyzed to strengthen interpretations. The synthesis of multiple data sources ensures the validity of results in this study. Lincoln and Guba’s (1985) criteria for trustworthiness include credibility, transferability, dependability, and confirmability.

Trustworthiness

Sampling techniques like using all members of the class in this study and artifacts gathering during the data collection phase was key to ensuring credibility. Regarding the replication of the study, an extensive description of the each step was made to allow readers to transfer finding and be consistent. Dependability was seen in the documentation of interviews and field notes and detailed throughout the study. Confirmation was demonstrated by findings that were directly from the voices of the participants and the data.

To further ensure trustworthiness, the researcher included member checks, triangulation, and rich and thick descriptions in the study. At the end of the interviews, the conversations were transcribed and sent to each participant for review. The participants saw the transcription of both interviews and indicated whether the transcriptions made sense and
depicted their experience. No one reported any misrepresentations or changes needed. Interviews, observations, and physical artifacts reinforced the themes and patterns that emerged from the study. The researcher provided detailed notes about the setting, lesson, students, teacher, interaction, framework, process, and outcome. Details allowed readers to understand what took place during the study. Data was classified using a collection of instances to observe emergent themes and patterns from the case. The researcher related categories to the analytic framework found in the literature and showed findings in tables to give readers an understanding.

Consistency in responses and triangulation of field notes, interviews, and teacher-grading contributed to the validity of the findings. First and foremost, the researcher used a computer program to analyze findings. Then, she entered all conversations exchanged between the participants as well as the researcher’s field notes in the program. From this data, observations were made based on trends found in data. The data showed how people felt about situations, during the study. Using the computer program allowed the researcher to organize and analyze information into patterns and compare data. Teacher grading further guaranteed consistency. Both the teacher and researcher graded assignments independently using the rubric.

Researcher Bias

The researcher is a CTE educator and has worked with both middle and high school students, teachers, and administrators. She has taught technology, printing graphics, computers, and keyboarding during her career. Being a teacher, she has an interest in classroom learning and experiences.
Also, no matter what she has taught, she has always expected her students to be creative. She loves seeing what students can do when allowed the freedom and safety to move beyond the cookie-cutter expectations of life. Her engineering background has led to an interest in scientific visualization, and she hopes that she can contribute to its expansion in all ways possible. Thus, she may bring some bias to the research.

RECOMMENDATIONS FOR PRACTICE

How does one help students understand complicated information? This case study revealed the perceptions of a single CTE class and one teacher. These interviews, along with written observations taken during the study, formed patterns and emergent themes that provided a visual display of the information answering each research question in relationship to a the theoretical framework. Future research could continue to study scientific visualization in the context of civics and economics classes.

The results of this study support and add to the literature discussed in Chapter Two. By examining how scientific visualization helps students understand complicated data and the experience that participants have when using scientific visualization in civics and economics lessons, this study provided insight into the rationale expansion of both civics and economics and scientific visualization curricula. Taking a complex concept like the circular flow of economic goods and using scientific visualization to develop a deeper understanding of the material. To that end, the researcher could see the possibilities for expansion in both areas and the benefits it could add to student understanding. The findings prompt further investigation and several recommendations:
1. The Department of Instruction should expand current scientific visualization curricula to include social studies material, updating the curriculum to stay current.

2. Educators need to use current real-world data to solve real-world problems.

3. Teachers must allow and expect students to think critically and be creative.

4. Teachers need to create, model, and utilize classrooms that foster a climate where students are comfortable.

5. Students should be producing, synthesizing, and evaluating information from a wide-variety of sources.

6. Students and teachers need to continue to be vigilant about understanding data in different forms.

Implications for Further Research

This study was an attempt to study the experiences and understanding of scientific visualization in the context of civics and economics. One might expect different outcomes if different classes were used or even a different school. While the findings of this study show positive and promising trends for civics and economics coursework in the scientific visualization field, future research could address several of the limitations of the study by doing the following:

1. Conduct a similar research study with more than one class, one location, and one teacher;

2. Enhance the present scientific visualization curriculum as well as the civics and economics curriculum sponsored by the North Carolina Department of Public Instruction, emphasizing the inclusion of each area respectively;
3. Perform more studies, both qualitative and quantitative, that could reveal solutions for expanding scientific visualization as well as civics and economics;

4. Replicate the study at other high schools so that solutions found in the data collection could be implemented throughout the state;

5. Replicate the study with a change in the lesson plan to include a more formal presentation for student reflection and insight.

Further study holds high promise in this area. Civics and economics is an important course for all high school students and scientific visualization is a new field with a lot of room for growth and development. Results of this study suggest that future research will only expand the literature. Thus, knowledge about each area and the connection between the two areas will only grow. Quantitative studies could collect data from multiple participants using surveys and questionnaires to provide additional insights. Further qualitative studies involving how scientific visualization helps students understand complicated data could focus on different lessons and different civics and economics materials as well as human geographic data to further illustrate the connectedness between the two subject areas.

Writing, establishing and implementing new lesson plans across the state would be difficult, and the researcher is aware that these are suggestions for action based on the results and the literature, both of which have their limitations. Most implications should lead to future research and can hold promise for the expansion of literature, curricula and development in each field.
Conclusion

One of the limitations of this case study was the small number of participants. The researcher believes this limitation did not reduce the value of the results, but she highlights the need to examine the value of scientific visualization in learning. The results of this study, as reflected by the perceptions of this study’s participants, suggest that there is a link between scientific visualization and how it aids students understanding of complex material and the experience students have. In this study, the use of activities found that learning is context-based. In using human geographic data, participants found that active involvement in important for conceptual learning and incorporating a modeling capability. Establishing a learning culture garnered meaningful relationships that created a classroom for purposeful learning. As far as the experience of participants, the use of activities valued real-world applications. Using human geographic data was essential to a student’s experience. Incorporating a modeling capability helped students represent and interpret the world. Lastly, establishment of a certain learning culture led to creativity in this case study. Scholars and practitioners, as noted in the literature review, have indicated the importance of scientific visualization amid the struggles that the history curriculum is experiencing at this time. These results point to a correlation between these two subject areas. While further examining the two areas of “how” and “what,” future research should include different lessons and different groups of study. Understanding what students perceive may also be use for educators as they develop their curricula and further expand upon the literature.

This study provided a starting point for understanding in the relationship between civics and economics and scientific visualization. When students solve real world problems,
critical thinking and learning enhance their skills. Berson and Berson documented the importance between the two subject areas; this research shows that students are able to understand difficult material, like the circular flow of economic activities in civics and economics by creating visualization. This study focused on the four points of the theoretical framework to explore student learning in a new light.

The results of this study provided insight into the expansion of scientific visualization. It also showed the relevance scientific visualization plays in aiding students’ understanding of complicated material. Also, it revealed some ideas about the experiences that students have in the classroom. Since finishing the research and analyzing the data, it has occurred to the researcher that there is need for future research and development of future lesson plans. One other area that needs improvement is the structure of the lesson plan. Students were rushed to get parts of this project done. PowerPoint presentations suffered the most because most students barely had enough time to get the visualization done.

This study may have been improved if participants were asked to define scientific visualization or supply and demand. Additional questions regarding viewpoints on the lesson may have allowed students to give more detailed responses. Students were asked them to define their project, but they could also be asked to talk about supply and demand. Further questions could also discuss global learning, for example: What story does this activity tell about supply and demand throughout the world? What story might other nations be telling?
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Appendix A: Lesson Plan

Lesson Plan

Objectives and Standards Addressed
Civics & Economics
Competency 8 Goal 8.03 The learner will analyze features of the economic system of the United States
Explain the circular flow of economic activities and how interactions determine the prices of goods and services

Scientific Visualization Objective
Competency 205 Goal 205.09 Demonstrate advanced scientific visualization.
Create an advanced visualization

Description
The goal of this lesson is to analyze gasoline prices in the United States between 1995-2005 through graphical representation of authentic data. Students will explain why gasoline prices fluctuate according to the supply and demand of petroleum. They will create an x and y-axis to demonstrate the equilibrium price through bar graphs and histograms.

Materials
Presentation software such as Power Point
Research medium such as the Internet
Drawing software such as Adobe Illustrator, CorelDraw, etc
3D animation software such as 3D StudioMax or trueSpace

Lesson Outline
Focus and Review
• Attention-getting story/action to focus students’ attention: Have you ever been curious to know how one event affects another event?
• Review what has already been learned to demonstrate scope and structure of this lesson while connecting prior lessons together (go over previous objectives of competency goal). Compare characteristics of command, market, traditional, and mixed economies, describe how the free enterprise encourages private ownership of property and promotes individual initiative, explain the circular flow of economic activities and how interactions determine the prices of goods and services.
• Inform students of objective of the lesson and explain what is expected of the students. Lesson is important to show circular flow of economic activities and how interactions determine the prices of goods and services.

Objectives
• Today we are going to use bar graphs and histograms to analyze features of the economic system of the United States. Bar graphs show trends in data and how one variable is affected as the other rises or falls, how to propose and justify predictions based on bar graph analysis.
• We are going to use your scientific visualizations to depict and produce computer based data visualization projects.

Teacher Input
• Teacher should explain/review the concept of graphs with the class. Discuss the purpose of displaying information or data on a graph or chart while also discussing the features of the economic system of the United States.
  • Bar graphs
    • Bar graph is used to display and compare information often used to compare groups of data and make generalizations.
    • Example: Total sales for 5 department stores in the month of December, comparing heights of students in a class, preference for ice cream flavors, etc.
    • Height of each bar is proportional to the amount of data the bar represents. The higher the bar the larger the number or amount of data.
    • Draw an X-axis (horizontal) and a Y-axis (vertical) on the board. Label each axis. On the X-axis write the different ice cream flavors and on the Y-axis a sequence of numbers from 0 to 25 at intervals of 5. Use a show of hands to record the number of students favoring each flavor, chocolate, vanilla, strawberry, born in each month of the year. Use this data to create an example of a bar graph. For example, 20 students like vanilla and 8 students like strawberry, and so on.
    • Also talk to students about the importance of appropriate interval scaling. Show what happens to the scale when intervals change (ex. small intervals show small differences in bar height).
      • Good example of conversation:
        http://www.shodor.org/interactivate/discussions/VerticalScaleDiscuss/
• When making a bar graph the data to be presented is used to create an appropriate interval scale. This scale helps people visualize and understand the data. (Point out the interval scale of the bar graph that you created.) Ask students how the graph would change in appearance if the
  o Histograms
    • Histograms and bar graphs are similar, but summarize information depicting a count of the data points falling in various ranges.
    • Examples: We have measured revenues of every store in a local mall in December and want to compare numbers of companies that sales total from 0 to 5,000; from 5,000 to 10,000; from 10,000 to 15,000; and 15,000 to 20,000 and so on.
• Ask students to think of graphs that they have seen in the real world. For what purposes were they used? Have students hunt for current examples (look on the Internet, newspapers, etc).
• Review with students the graphing just covered
  o How can statistics help someone plan for the future?
  o How could they use graphs in the following real-world situations?
  o How could it relate to interdependence of consumers and producers?
  o How can salary vs. wages and goods vs. services been seen in bar graphs and histograms?

Guided Practice
• Pull up sample data and create two simple bar graphs and histograms using Microsoft Excel. Guide discussion about why you chose these graphs to represent data and how the graphs of different data sets compare.
  o NCSU Labwrite has a detailed explanation of creating bar graphs & histograms in Microsoft Excel
    http://www.ncsu.edu/labwrite/res/gf/st-bar-home.html
• Today, effectively communicating with one’s audience involves more than the conventional excel charts and graphs. Scientific visualization encapsulates an area known as data visualization which is a modern approach seeing a problem from a new perspective. In data visualization your visual thinking is evident through creative illustrations. Your brain processes images quicker than numbers in rows and columns. You can show patterns and identify outliers.
• Let’s look at some Data Visualization: Modern Approaches as shown by Smash Magazine in 2007,

L image: Time Magazine
R image: Lee Byron describes his approach of creating a histogram about his music listening history.

o Tripwire magazine: http://images.businessweek.com/mzz/07/24/0724_6insid_a.pcf

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• What are some creative ways you could recreate a common bar graph or histogram? What did you see as modern and what was more experimental?

**Independent Practice**

**Requirements**

1. Students may work in groups of two.
2. Students will need to research the topic and develop a storyboard for their presentation.
3. Each group should analyze features of the economic system of the United States with a presentation package such as Power Point.
4. Students need to show a visualization of gasoline prices. Using the data set, each group will make traditional bar charts and histograms using Microsoft Excel. The same data set, groups will create a data visualization of this same data.
   - Step 1: Traditional Graphing
     - Explain what data is present in file and hypothesize about different ways to organize this data.
     - Create graphs with appropriate scales and correct labels for each data.
     - Include a 100-word explanation of how these two different graphs compare.
   - Step 2: Data visualization
     - Now, you are going to take the same information you used to create an ordinary graph in the previous step and re-create a brand new visualization to improve our understanding of a complex concept.
     - Explain what data is present in file and create an illustration about a creative, imaginative method to visualize this data.
     - Create visualization with appropriate scales and correct labels for each data.
     - Include a 100-word explanation of your data visualization image.
5. The presentation should have 2D or 3D visualization explaining the circular flow of economic activities and how interactions determine the prices of goods and services using petroleum prices from 1995-2005.
6. Data and images may NOT be copied off the Internet.
7. All graphics need to be original.

**Assessment**

| Description of traditional graphs with appropriate scales and labels for data | 10 points |
| Presentation uses color, safe and ideal design | 10 points |
| Image of gasoline prices from 1995-2005 present | 40 points |
| Explanation of data visualization is included | 10 points |
| Power Point works and is correctly assembled | 10 points |
| Image is accurate, scaled correctly and explains the data | 20 points |
| **Total** | 100 points |

**Rubric**

**Description of traditional graphs**

<table>
<thead>
<tr>
<th>The graphs were not created or explained correctly. Drawing and labeling of graphs have 3 or more errors.</th>
<th>The graphs were created and explained. Graphs are mostly correct and labeled.</th>
<th>The graphs are accurately created and explained. Graphs are correct and labeled correctly.</th>
<th>Total points</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5 points</td>
<td>6-9 points</td>
<td>10 points</td>
<td></td>
</tr>
</tbody>
</table>

**Presentation uses color, safe and ideal design**

<table>
<thead>
<tr>
<th>Background color does not contrast with the graphics. More than 10 colors are used. The presentation does not follow two or more of the safe design elements.</th>
<th>Background color does not contrast with the graphics. More than 10 colors. The presentation is simple, appropriate, functional and economical.</th>
<th>Background color contrasts with the graphics. 10 or less colors are used. The presentation is simple, appropriate, functional and economical.</th>
<th>Total points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-5 points</td>
<td>6-9 points</td>
<td>10 points</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>-----------</td>
<td>---------</td>
<td></td>
</tr>
</tbody>
</table>

**Image of gasoline prices from 1985-2005 present**

<table>
<thead>
<tr>
<th>Data visualization is partially completed. Some information of gasoline prices may be omitted or not accurate. More than 5 errors.</th>
<th>Data visualization is partially completed. Some information on gasoline prices may be omitted or not accurate. No more than 5 errors.</th>
<th>Data visualization is partially completed. Some information on gasoline prices may be omitted or not accurate. No more than 3 errors.</th>
<th>Data visualization is completely. All of the information on gasoline prices is correct. Information is accurate.</th>
<th>Total points</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-30 points</td>
<td>30-43 points</td>
<td>44-49 points</td>
<td>40 points</td>
<td></td>
</tr>
</tbody>
</table>

**Explanation of data visualization is included**

<table>
<thead>
<tr>
<th>Explanation of image is partially completed or not included.</th>
<th>Explanation of image is partially completed.</th>
<th>Explanation of image is complete.</th>
<th>Total points</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5 points</td>
<td>6-9 points</td>
<td>10 points</td>
<td></td>
</tr>
</tbody>
</table>

**Power Point works and is correctly assembled**

<table>
<thead>
<tr>
<th>Three or more of the following does not work. The program plays correctly, videos play, graphics show up, and proper spacing and font size is evident.</th>
<th>One or two of the following does not work. The program plays correctly, videos play, graphics show up, and proper spacing and font size is evident.</th>
<th>The program plays correctly, videos play, graphics show up, and proper spacing and font size is evident.</th>
<th>Total points</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5 points</td>
<td>6-9 points</td>
<td>10 points</td>
<td></td>
</tr>
</tbody>
</table>

**Image is accurate, scaled correctly and explains the data**

<table>
<thead>
<tr>
<th>The image created does not work or explain why gasoline prices fluctuate according to the supply and demand of petroleum. Data visualization is not accurate.</th>
<th>The imaged created works and explains why gasoline prices fluctuate according to the supply and demand of petroleum. Data visualization is missing some information or not accurate.</th>
<th>The imaged created works and completely explains why gasoline prices fluctuate according to the supply and demand of petroleum. Data visualization is accurate.</th>
<th>Total points</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-13 points</td>
<td>13-19 points</td>
<td>20 points</td>
<td></td>
</tr>
</tbody>
</table>

**Closure**

- Bring the class back together for a discussion of the findings and presentation of project.
- Once the students have been allowed to share what they found, summarize the results of the lesson.

**Extended learning**

Also see histograms in images, like in Photoshop, to analyze images. Underexposed images will show a curve shifted to the left, which means overall there are more dark areas than the bright ones. Overexposed images will show a curve in the histogram is shifted to the right and cut off at the right end. You can also see balance and contrast in an image by looking at the histogram. Often digital photographers, check out a pictures histogram when done to see the distribution of tones.
I. First Visit

   A. Review plan of action and set dates for:
      1. Observation of implementation of lesson plan
      2. Interviews of six participants after lesson conducted
   B. Discuss IRB guidelines and rules set by university
   C. Hand out Informed Consent form to each participant
   D. Discuss arrangements for maintaining confidentiality of data, sources, and reports
   E. Discuss need for participants to review drafts to validate observations and descriptions

II. Gather and Validate Data

   A. Make observations, interview participants prior to the lesson, debrief participants, gather any paperwork
      1. At site, observe teacher and class during implementation of lesson plan
      2. Each interview with a participant will last 8 to 10 minutes
      3. Role of observer is that of an outsider
      4. Methodically record notes in field
      5. Record aspects like physical setting, particular events and activities, and own reactions
6. During observation, have someone introduce research since researcher is an outsider. Researcher will be passive and friendly.

7. After observing, graciously withdraw from site, thanking participants and informing them of the use of data and their accessibility to the study

B. Keep records of inquiry arrangements and activities

C. Select vignettes and illustrations

D. Classify raw data and begin interpretations

E. Redefine issues and case boundaries

F. Gather additional data, replicating or triangulating, to validate key observations

II. Provide Audience Opportunity for Understanding

A. Describe extensively the setting within which the activity occurred

B. Consider the report as a story; look for ways in which the story is incomplete

C. Draft reports and reproduce materials for reader use

D. Help reader discern typicality and relevance of situation as base for generalization

E. Revise and disseminate reports and materials. Talk to people in the field.
Appendix C: Interview #1 Guide

Directions

The interviewer will ask the interviewee the five questions given below. The interviewer may ask follow-up questions based on remarks provided by the interviewee (for clarification, trigger of thought, etc.). The interview will take approximately 5 to 10 minutes to complete.

Introduction

Thank you very much for agreeing to participate in the study. This is our first interview of two interviews. Your time is very valuable, and we are going to keep this to 5 to 10 minutes. Again, I appreciate your time and willingness to participate in the study.

Before we go any further, I would like to gain your permission to tape-record this interview. I will use the recording only to create an accurate account of what we have conversed about here. Once all interviews are finalized, I will type up the dialogue. I will hand the typed text to you and have you assess my notes to ensure my transcription is accurate. Is that okay? May I tape record our conversation?

Great and thank you. I will begin recording our conversation now, and we can continue the interview.

Interview Questions

1. Describe why you chose to take this CTE/Scientific Visualization course.
2. Tell me about a lesson or project in Scientific Visualization that you have done so far this semester.
3. Will you share with me some insights about Scientific Visualization you have learned from being a part of this class?
4. Could you describe any thoughts you may have about how you have learned and visualizations and the possible outcomes that will transpire from being in the class (the experience)?
5. Is there something you feel I haven’t asked you that you wished I had asked? What would that be? Would you share your thoughts on that?

Wonderful and thank you for sharing.

Conclusion

Thank you very much. I appreciate the time and information you have shared with me. I want to honor our time schedule. Before finishing, is there anything else you would like to say that you did not get to say earlier?
[Dialogue]

Thank you for your time. I will be in touch soon and have our conversation typed up for your review.
Appendix D: Interview #2 Guide

Directions

The interviewer will ask the interviewee the six questions given below. The interviewer may ask follow-up questions from remarks provided by the interviewee (for clarification, trigger of thought, etc.). The interview will take approximately 10 to 15 minutes to complete.

Introduction

Thank you very much for agreeing to participate in the study. This is our second interview of two. Your time is very valuable, and we going to keep this to 10 to 15 minutes. Again, I appreciate your time and willingness to participate in the study.

Before we go further, I would like to gain your permission to tape-record this interview. I will use the recording only to create an accurate account of what we have conversed about here. Once all interviews are finalized, I will type up the dialogue. I will hand the typed text to you and have you assess my notes to ensure my transcription is accurate. Is that okay? May I tape-record our conversation?

Great and thank you. I will begin recording our conversation now, and we can continue the interview.

Interview Questions

1. Could you describe the process of the Civics and Economics Activity in your own words?
2. How would you describe the visualization you created during this lesson? How were you able to create your visualization?
   - What does this visualization tell me about gas prices?
   - How did you show change in gas prices?
   - Who was your audience and what message were you communicating? Do you think it worked?
3. What techniques did you implement to make and complete your project? (Did you use techniques from a previous lesson in this class or a different class, did you do any drawings before you got on the computer, did students interact when working, what was the structure of discussion, etc.)
   - How did you select your color scheme?
   - Does your drawing support the gas price explanation?
4. Explain the circular flow of economic activities and how those interactions determine the prices of good and services, like gas prices.
5. Could you share with me some insights that you had from being a part of the experience?
6. How has the experience affected you personally or how you might understand Civics and Economics? Could you give me some examples?

7. Can you tell me about your thoughts on how this experience of working with this subject matter contrasts with other activities you have done before?

Wonderful and thank you for sharing.

Conclusion

Thank you very much. I appreciate the time and information you have shared with me. I want to honor our time schedule. Before finishing, is there anything else you would like to say that you did not get to say earlier?

[Dialogue]

Thank you for your time. I will be in touch soon and have our conversation typed up for your review.
From: Deb Paxton, IRB Administrator
North Carolina State University
Institutional Review Board

Date: June 29, 2011

Title: Understanding Student Experiences: A Case Study in Scientific Visualization and Civics & Economics

IRB#: 2112-11-6

Dear Ms. Jesse,

The project listed above has been reviewed by the NC State Institutional Review Board for the Use of Human Subjects in Research, and is approved for one year. This protocol will expire on May 17, 2012 and will need continuing review before that date.

NOTE:
1. You must use the attached consent forms which have the approval and expiration dates of your study.
2. This board complies with requirements found in Title 45 part 46 of the Code of Federal Regulations. For NCSU the Assurance Number is: FWA00003429.
3. Any changes to the protocol and supporting documents must be submitted and approved by the IRB prior to implementation.
4. If any unanticipated problems occur, they must be reported to the IRB office within 5 business days by completing and submitting the unanticipated problem form on the IRB website.
5. Your approval for this study lasts for one year from the review date. If your study extends beyond that time, including data analysis, you must obtain continuing review from the IRB.

Sincerely,

Deb Paxton
NC State IRB
Appendix F: Approval Letter

October 18, 2011

Emily G. Jessoo
912 East Ivy Valley Drive
Fayetteville, NC 27526

Re: 111210

Dear Emily Jessoo,

The Research Review Committee has concluded that your proposal Understanding Student Experiences: A Case Study in Scientific Visualization meets the requirements of state legislation and the current research policy of the

Committee approval does not guarantee access to schools or to individuals, nor does it imply that a study can or will be conducted. School principals have the final decision regarding the participation of the school in any research project. Teachers, parents, and students decide independently whether they wish to participate. The committee expects that identities of individuals, schools, and the district will be kept confidential at all stages of the project.

Please present this letter upon initial contact with principals. We hope that the project is successful in helping to achieve your goals. Please feel free to contact me at 919-370-2146 if you have any questions.

Sincerely,
Appendix G: Letters of Invitation & Informed Consent Forms for Participants

North Carolina State University
INFORMED CONSENT FORM for RESEARCH
This consent form is valid May 17, 2011 through May 17, 2012

Understanding Student Experiences: A Case Study in Scientific Visualization and Civics & Economics

Emily G. Jessee  Dr. V. William DeLuca

You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. The purpose of research studies is to gain a better understanding of a certain topic or issue. You are not guaranteed any personal benefits from being in a study. Research studies also may pose risks to those that participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above.

The purpose of this study is to see if scientific visualization improves students understanding of civics and economics. Scientific visualization has been proven to link higher-order thinking skills with deeper understanding of graphics. The reason to conduct this study is to understand student experiences when scientific visualization is incorporated into a civics and economics lesson. This study is reporting experiences of participants as well as reporting any themes and patterns that emerge in the data.

If you agree to participate in this study, you will be asked to take part in two interviews (one before the lesson begins in class and one after the lesson in conducted in your class) as well as a lesson that will be conducted in your scientific visualization class over a period of two days. The first interview will last 5 to 10 minutes. The second interview will take 10 to 15 minutes. The lesson will occur over two 90-minute class periods. The total time required during the duration of the study is 205 minutes. The research will take place in the scientific visualization II classroom at school. During the lesson, you will produce a graphical representation on the computer. The researcher will access this graphical representation for research purposes, as well as the score you receive on it.

There are no risks involved with this research. If you are uncomfortable at any time during the study, you are free to withdraw.

If there is no direct benefit expected to the subject, but knowledge may be gained that could help understand scientific visualization and/or civics and economics.

Transcripts of your interview will be provided to you for review, through your teacher. Transcripts will be sent to your teacher so s/he can deliver them to you for review. Data will be stored securely. Audio recording will be collected using a digital recorder and transferred to the researcher’s personal computer for transcription, and backed up the researcher’s personal hard drive. The data on the digital recorder will be deleted after the research is complete. Transcriptions and any notes will be stored securely when they are no longer needed for writing the dissertation. All data will be password protected. No reference will be made in oral or written reports which could link you to the study. Direct quotes from the interviews may be used in reports about the research results, but your identity will be masked by a fake name.

You will not receive anything for participating in this study.

If you have questions at any time about the study or the procedures, you may contact the researcher, Emily G. Jessee at 912 E. Ivy Valley Drive, Fuquay-Varina, NC 27526 or 919.762.8906.
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 Deb Paxton, Regulatory Compliance Administrator, Box 7514, NCSU Campus (919/515-4514).

"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 choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled."

Subject's signature ________________________________ Date ____________

Parent/Guardian’s signature __________________________ Date ____________

Investigator’s signature ______________________________ Date ____________
**Guardian/Parent Research Consent Form:** To be completed by the parent/legal guardian of a school-aged participant under 18 years.

Project Name____________________________________________________________________________

Sponsoring Organization______________________________________________________________

Principal Researcher_____________________________________ Telephone_____________________

Project Location(s)_____________________________________________________________________

Student’s Name_______________________________________________________________

Home Address_________________________________________Telephone _________________________

Student’s School________________________________________ Grade ___________ Age ___________

**Participants/Parental Rights and Assurances**

I have received a copy of the approved Guilford County Schools Research Application Form for the aforementioned research project. Having read the application I am familiar with the purpose, methods, scope and intent of the research project.

____ I am **willing** for my child to participate in this research project.

____ I am **not willing** for my child to participate in this research project.

If I am willing for my child to participate in this research, I understand that during the course of this project my child’s responses will be kept strictly confidential and that none of the data released in this study will identify my child by name or any other identifiable data, descriptions or characterizations. Furthermore I understand that my child may discontinue his/her participation in this project at any time or refuse to respond to any questions to which he/she chooses not to answer. My child is a voluntary participant and has no liability or responsibility for the implementation, methodology, claims, substance or outcomes resulting from this research project. I am also aware that my child’s decision not to participate will not result in any adverse consequences or disparate treatment due to that decision.

I fully understand that this research is being conducted for constructive educational purposes and that my signature gives consent for my child to voluntarily participate in this project.

Parent’s Signature____________________________________________Date_______________

Student’s Signature____________________________________________Date_______________

(When Age Appropriate)
Appendix H: Diagram of the Classroom

*Illustration not to scale*