THE EFFECTS OF A TECHNOLOGY-DRIVEN SCIENCE APPLICATION ON POSTSECONDARY CHEMISTRY STUDENT ACHIEVEMENT AND SELF-EFFICACY

by

Darrell Scott Byrum

Liberty University

A Dissertation Presented in Partial Fulfillment

Of the Requirements for the Degree

Doctor of Education

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ABSTRACT

The purpose of this study was to establish if distinction exists in both student achievement and self-efficacy through the application of technology-based instructional approach in the laboratory environment of undergraduate chemistry courses. The achievement of 52 college students in the southeastern region of the United States was measured through one posttest assessment. Following this assessment, students were examined through a self-efficacy scale to determine preexisting thoughts of working in an undergraduate chemistry laboratory environment, as well as peer interaction. Accordingly, three separate college chemistry I courses were used to generate data via a nonequivalent control group design. From the three courses, one class was labeled as the treatment group, while the two remaining classes were collectively labeled as the control group. The treatment group was made up of 22 participants, while the control group was comprised of 30 participants. Students in both the control and treatment groups completed the same laboratory experiments; however, the control group used traditional methods for conducting the laboratory experiments while the treatment group implemented a technology-based approach. To measure achievement, data was gathered through the administration of the *Conceptual Problems Gases Test* (*CPGT*). Self-efficacy was measured through the *College Chemistry Self-Efficacy Scale* (*CCSS*). Results from both instruments were shown through independent samples t-tests; furthermore, as reflected by p values, the technology-driven application did not have a statistically significant difference on student achievement.

DEDICATION

This dissertation is duly dedicated to those who have been major contributors throughout the process. First and foremost, all credit is given to God and his son Jesus, for their blessings of physical, emotional, and spiritual strength. In the moments when I felt I could go no longer, His grace was always sufficient. Thank you for your precious promise that in our darkest times, we will never be left alone. To Amber, my wife and best friend, words cannot justify my thanks to you for your loyalty during this journey. Your constant support and provision of belief that I could achieve this goal carried me onward. I am the man that I am today because of you. You have never doubted me. You are my rock and I love you with all that I am. To my kids Skye, Zeta, Sawyer, and Asia, thanks for being understanding of all the hours that dad was missing in action. I thank you for all the things you have done to help out. I am PROUD of each and every one of you and hope you will always keep God close to your heart. Only He has the power to give each of you the best life imaginable. To my parents, thank you for the foundation without which none of this would have been possible. Your support throughout my life has been unyielding and steadfast, and for that I am grateful.

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CHAPTER ONE: INTRODUCTION

Chapter one is a description of the use of a technology-enhanced instruction method and its effect on undergraduate chemistry students enrolled at a rural community college in the southeast United States. Included within this description is the problem statement, rationale for completing the study, and the significance that the study may bring to educational theory. The research questions as well as supporting hypothesis will also be discussed.

Background

Before the 1960s, science education and technology did not coalesce; however, due to the Science, Technology, and Society movement spurred by science instructors who felt that these venues belonged together, the separate content areas meshed (Avraamidou, 2008). Before this movement, content was delivered to students of all ages through traditional lecture format- with the teacher standing in front of their respective pupils while information was delivered. Succinctly described in the *National Science Education Standards*, "The goal of science is to understand the natural world, and the goal of technology is to make modifications in the world to meet human needs" (National Research Council, 1996, p.24). These modifications have centered much of their attention on the need to improve science education through the infusion of technology-based learning. Due to the causal relationship found between the use of technology in mathematics and science education and the procurement of developing higher-order thinking skills, many educational systems have placed priority on providing the necessary tools to achieve such a goal (Boujaoude & Jurdak, 2010). In June of 2003, the *American Chemical Society Committee on Education* called for a meeting to examine how chemistry was being taught at the undergraduate and graduate levels. Their findings conveyed that instruction in chemical education should place more emphasis on the inclusion and use of computer-aided assistance.

Furthermore, the need for the implementation of research technology in the field of chemistry was deemed necessary (Xiufeng, 2006).

Therefore, from the melding of both science education and technology, science instructors across the nation saw an opportunity to further engage science learners. To enhance science education, these instructors began to explore the various methods by which science content could be delivered at the hands of technological devices. To better understand how technology could assist in the delivery of science instruction, it is vitally important to both define and understand how technology is used in the context of science education. A closer examination of technology in the science classroom or laboratory would yield terminology such as: technology-enhanced applications, technology-driven science, technology-enhanced tools, technology-based instruction, data acquisition systems, digital tools, and probeware. Consequently, technology in this case is a narrower connotation than simply labeling any electronic device as technology because here it pertains to science education. Hands-on science, as it is commonly referred, has been defined in various ways dependent upon the context in which it is being used. For the purposes of this research study, hands-on science has been defined as the student involvement in a laboratory setting with the use of technology-aided equipment via hands-on use. Therefore, the application of a technology-driven approach to teaching science within a laboratory setting is geared toward the use of digital tools to experiment, collect, and analyze data. It is imperative that a distinction be drawn between the traditional laboratory format and one centered on the inclusion of technology-based tools. According to the National Research Council (1996), "Historically, laboratory experiences have been disconnected from the flow of classroom science lessons. Because this approach remains common today, we refer to these separate laboratory experiences as 'typical' laboratory

experiences" (Interactive Educational Systems Design, 2012). Again, it is crucial that the word *technology* in this case be understood to represent many different tools that both teachers and students use to gather data such as time (stopwatch), temperature (probe), and pH (meter), and that the integration of these tools as a technology-based approach.

As examined, additional examples of such technology include microcomputer-based systems (commonly referred to as MBLs), data acquisition systems (Vernier LabQuest), and a range of probeware, meters, and sensors that collect prescribed data. These systems take information that is being generated during a laboratory experiment and records and analyzes it (Probeware, 2005). Accordingly, the use of the term *technology* in this research study refers to any electronic device that is developed in order to allow students to collect and analyze data within a science-learning environment; moreover, it is crucial that a distinction between hands-on science and science as inquiry be made to understand the role technology places in this specific research design. In the book *Inquire Within* (2002), the author conveyed that inquiry was a way science students could conduct scientific investigations and experiments outside of the normal recipe-style facilitation. In other words, scientific inquiry within the classroom or laboratory would allow students to design their own investigations and collect data through the process of discovery. In this case, teachers would only help to facilitate the process of inquiry, but the students would actually plan their own investigations and carry them out. While hands-on science refers to students becoming engaged in experimentation through a literal hands-on approach, it is important to discern that even though inquiry may be hands-on, not all hands-on science is inquiry. For this research study, students enrolled in college chemistry I conduct hands-on science, yet it does not fulfill the role of inquiry because the instructor both supplied the needed materials, as well as gave straightforward procedures to conducting the prescribed

laboratory experimentation; hence, a cookbook style approach at conducting science was used (Llewelyn, 2002).

The first investigation to identify if probeware, a technology-driven tool, would affect student achievement was conducted by Tinker and Barclay in the early 1980s. Their research indicated that the presence of probeware was a positive experience within the classroom as it helped children be able to grasp abstract concepts. Evidence from their research provided that the use of probeware was the "first indication of the power of kinesthetic real-time interactions to lead to understandings of abstract representations" (Park, 2008, p. 35).

In 1987, Brasell reiterated the notions of Tinker and Barclay by stating that increased student learning through the use of probeware in a physics classroom. As stated in the article *The Effect of Real-Time Laboratory Graphing on Learning Graphic Representation of Distance and Velocity* (1987) evidence was given that the use of a microcomputer-based laboratory implementation provided students with a greater comprehension of distance and velocity within only one class period (Brasell, 1987). After these initial studies were conducted, other researchers placed precedence on the investigation of technology-based tools for learning in the science classroom. Russell, Lucas, and McRobbie (2003) stated that the inclusion of probeware enabled students to make more sense of the data they were gathering. Furthermore, the display that was generated by the probeware provided the students an opportunity for learning enhancement. While most applications of probeware were aligned with recipe-style experimentation, Royuk and Brooks (2003) also described not only an increase in student learning from the use of probeware, but also a greater significance when used with inquiry-based science investigations (Park, 2008). Another study including Tinker in 2004 examined the use of hands-on science through the use of handhelds as well as probeware. The findings from that

study pointed toward an increase in student achievement with inclusion of this type of technology in the hands of both trained teachers as well as students (Metcalf & Tinker, 2004).

Therefore, from the melding of both science education and technology, instructors across the nation saw an opportunity to further engage science learners. To enhance science education, instructors began to explore the various methods by which science could be delivered at the hands of technological devices. To better understand how technology could assist in the delivery of science instruction, it is important to compare the newer, more modern technology approach with that of the traditional science instruction format.

As defined, traditional teaching or the delivery of science instruction by traditional means includes the use of lecture and laboratory sessions. Class sessions between instructors and students were designed so that the instructors delivered content knowledge to the learner and the learner used supplementary tools such as textbooks to reinforce what the instructor had taught (Pursell, 2009). This idea resonated not only in chemistry courses but other science classes; moreover, stand-and-deliver instruction was a norm among most facets of science education. However, with the influx of technology into science education in the 1960s, instructors began to reassert teaching tools and with the help of industry, began infusing technology-driven applications into science education. Early notions of technology in science education included such items as a video documentary, slide presentations, and even computer-aided formats to deliver content (Champion & Novicki, 2006). Computer-aided instruction was also made famous during the 1960s as the field of education welcomed this new, valuable tool for gathering data in mathematics and physics (Culp & Castleberry, 1971). However, useful though these primitive forms of technology might have been, they did not include learning through the

perspective of students fully engaging in content through the use of hands-on tools to collect and process real-time data.

Appropriately, an article published by the Department of Chemistry at Brown University, recognized that students enrolled in chemistry courses would increase in performance if the science they were being taught was made relevant to either their past experiences or the present world. This notion of making the learning meaningful helped instructors begin molding their instruction in the classroom and laboratory to give students a sense of real-world application. Therefore, given the correct instruction coupled with appropriate collection tools, chemistry laboratories could offer students the opportunity to delve into pure research (Klara et al., 2013).

Though most universities and colleges across the nation still employ cookbook style instruction within their science laboratories, some middle and high school level institutions have undergone a paradigm shift from the older traditional teaching pedagogy to a newer, more modern approach. The new approach stems from the call for reform in formal science education due to declining test scores as a nation, as well as shortages of qualified technicians in science-related jobs. As described, current science education executes its aim upon the inclusion of technology-driven components such as microcomputer-based systems (MBLs), calculator-based systems (CBLs), and an array of probeware and sensors for data collection. These data collection devices afford students the opportunity to play the role of a scientist within school settings. Because of the nature of data collection systems, students are able to gain real-time data from current laboratory experimentation that each student or laboratory group collects. Data collected is then matriculated into the form of tables and graphs whereby students can make general inferences about the science being conducted. This new form of technology allows students to focus their attention on the extrapolation of the data rather than being caught up in the

actual construction of graphs and tables. Therefore, because much of the tedious note-taking and graph construction is integrated within these new forms of technology-driven peripherals, students are presented with conditions that lead to a more thorough and personal learning experience. Within inquiry-based science instruction, students are given even more flexibility as they not only collect and analyze prescribed experiments, but also have a hand in design of the experiment (Trumper & Gelbman, 2001).

From an educational perspective, students of science must not only be given rigor in the classroom so that they will be prepared to meet the challenges in real-world scenarios, but they must have the tools in hand to overcome those challenges. The intent of this research was to examine the effects of those tools on student learning in postsecondary science environments. In this context, technology and tools again must both be clearly defined as the scientific instrumentation such as probeware and sensors that are used by students to conduct research and carry out principles of learning within various science classes.

The theoretical framework of the proposed research design is predicated upon the sociocultural theory and postulates of Lev Vygotsky. Vygotsky's idea of learning was based upon the concept that for learning to occur, a social experience would be necessary for cognitive development; moreover, through an amalgamation of social and cultural experiences, a person would have the tools to gain knowledge (Ramdass, 2012). Thus, the interaction of student groups within a science laboratory setting will not only place significance on the interaction between each individual and prescribed science application, but also between the groups interacting with the science.

Sociocultural theory will also assist in the vision of the research design because student learning will not only hinge upon meticulous peer interactions, but also on the interactions

between each student and the technology. In an article examining the influence of sociocultural theory in science education, it was made clear that even though the awareness of sociocultural theory was present, the implementation of the theory's aspects in science teaching was limited. For students to learn through a sociocultural lens, teachers would need to shift the ideas of the theory into practice within the classroom setting (Sungmin & Sung-Jae, 2012). In an article on learning science in a virtual setting, it was described that students should be presented with a framework of sociocultural theory. This framework would provide structure, often referred to as scaffolding (Ramdass, 2012).

The sociocultural theory originated from the works of Vygotsky, as he believed that individuals learn from their social environments. Furthermore, as children grow and learn they are not only influenced by societal factors, but also place influence upon the society in which they live. Examining sociocultural theory will help to understand how student interactions foster cognitive growth or disconnect (Hsi, 2007). Furthermore, as students work collaboratively to conduct laboratory investigations at the undergraduate level, they will be required to draw from their prior funds of knowledge in order to scaffold new learning experiences. In an article published in the journal of *Higher Education Research and Development*, the authors noted that Vygotsky believed that the way in which people learn is not derived from mere social interaction but how individuals respond to the social interaction that they come into contact with. The outcome of these learning experiences would afford individuals more opportunity for critical thinking (Wass, Harland, & Mercer, 2011).

This study proposes a quantitative approach whereby a quasi-experimental design was implemented through simple parametric analysis. The plan for this study was to examine the impact that a technology-driven application may have on student achievement and self-efficacy.

Problem Statement

Clearly, research has shown that the incorporation of science-based technology has received positive findings. From scientific probeware and handhelds, to other forms of data-collection instrumentation, instructors now have a better opportunity to further engage students' learning experiences in the science setting. At the present, multiple research studies have been conducted on the infusion of technology-based instructional tools and the baseline data from those studies has revealed that student engagement in experimentation as well as overall academic performance received promising comments (Lapp et al., 2000; Pullano, Garofalo, & Bell, 2005; Brunsell & Hrejsi, 2010). However, the research has also shown that additional in-depth work should be completed, as there have only been a limited number of studies surrounding the use of technology-based instruction within the science classroom as well as the actual nature of laboratory awareness (Thomas, Man-wai, & Po-keung, 2004; Higgins & Spitulnik, 2008). Accordingly, educational institutions have agreed that the role of the undergraduate chemistry laboratory is imperative to student learning; however, current research has shown that it may not be the agreement that the laboratory is important but how effective the laboratory is in creating a positive learning experience (Brewer & Cinel, Harrison & Mohr, 2013).

The majority of the research that has been completed on the inclusion of technology in science education has taken place within classrooms ranging from elementary to high school. Most colleges and universities still maintain the trend of the instructor delivering content while students work to scaffold learning. Undergraduate science classrooms have had little to no experience with the inclusion of a modern science education platform, namely technology-enhanced learning within science laboratories. This does not give reference to the general use of

technology, as one would define it in a general sense. More general technologies such as email, cell phones, and computers, are used effectively on a daily basis by students of all ages; however, highly savvy as students are, there remains a large variation when it comes to students using science-labeled technologies (Kennedy et al., 2008). A need for more in-depth studies is necessary to not only ascertain the effect that the infusion of technology has on the undergraduate levels of science education, but also how those involved in the delivery of content might gain support in their use of technology (Ruthven, Hennessy, & Brindley, 2004). Therefore, it is crucial that additional research be conducted at undergraduate levels of science.

Purpose Statement

The purpose for this research study was to examine the effects that may exist when a technology-enhanced teaching method is used with college chemistry students within a laboratory context. The discernment of the effects that may be found from the inclusion of a technology-driven science application was examined through the implementation of two validated research instruments. The first instrument is designed to extrapolate any differences that may exist in student achievement. The instrument that will be used is the *Conceptual Problems Gases Test* (CPGT). All students in enrolled in college chemistry I also completed the *College Chemistry Self-Efficacy Scale* after the completion of the gases posttest. Since the focal point of this research is centered on differences that may come from the application of a technology-driven methodology within the chemistry laboratory, it is important to reiterate that this study was not designed to investigate the classroom; therefore, normal classroom practices such as lecture and discussion were outside the boundaries of this research study.

As per research design, community college students enrolled in college chemistry I had the opportunity to work with scientific instrumentation to gain first-hand knowledge of what

science is, what science is not, and to expand their understanding of how science happens outside of the school parameters. As the goal of science education is to prepare individuals to be productive citizens of tomorrow, it is vitally important that science students be given the opportunity to interact in such learning environments to bridge the gap between science instruction and the principles of real-world applications of science. Obviously, it is not enough to place technology in the hands of students without a clear guideline of how the technology should be used effectively (Papanastasiou, Zembylas, & Vrasidas, 2003). Moreover, the motive behind the inclusion of technology in science education is to help students succeed in understanding science content rather than simply pushing technology for the sake of technology (Wan & Gunstone, 2003). Thus, the purpose within this research study will be to provide any evidence for either the inclusion or exclusion of a technology-based instructional approach to an ever-expanding body of knowledge in science education; moreover, evidence will provide both administrators and instructors the opportunity to adjust their curricula accordingly.

According to the *National Science Education Standards (NRC,* 1996), students should be given the opportunity to use technology to practice science through collecting data, learning to calculate functions such as range, median and mode values and analyzing evidence (Bull & Bell, 2008). The proficiency with which science students utilize laboratory equipment may be directly proportional to their overall learning experience. With little research having been conducted on the effects of technology-enhanced instruction through the manipulation of hands-on tools at the undergraduate level, this study will become paramount in its efforts to collect significant data to further support or refute a technology-geared pedagogy. Certainly, educators will want to provide learning in the form that is most conducive to the student. Creating an environment of

learning will hinge upon students' responses to a more real-world approach to conducting laboratory investigations.

Significance of the Study

For a research study to gain merit within its respective field of study, that research study must be able to provide empirical evidence that either validates or refutes a specific concept. This study is worth examination because today's students are technology-driven. Earmarked as digital natives, students presently enrolled in colleges and universities possess the understanding of general technology found in computers and various peripherals; therefore, the opportunity exists through highly specialized collection tools in the background of science education. Days of traditional stand and deliver modes of instruction are no longer as effective, as students require an almost entertainment style of instruction in order to compete with fast-paced marketplace technology. Consequently, this study is of importance due to the fact that possible outcomes may prove which pedagogical methods may be more effective within the undergraduate chemistry classroom. This study is also significant because there have been a limited number of formal investigations on the use of hands-on science and its effect on student achievement and self-efficacy at the community college or undergraduate level (Higgins & Spitulnik, 2008). Furthermore, this study provides a quantitative view of how current community college chemistry students immersed in present-day instruction perform with the inclusion of hands-on science. Because of the results of the study, college administration and faculty can make adjustments to instruction for the betterment of both instructor and learner.

Research Questions and Null Hypotheses

RQ1- Is there a difference in the achievement scores between college chemistry students who use a technology-based application to conduct laboratory experimentation, and college

chemistry students who do not?

HO_1 - There will be no statistically significant difference in the means of *Conceptual Problems Gases Test* (*CPGT*) scores for the treatment group, which used a technology-based application in laboratory, and the control group, which did not use the technology-based application.

RQ2- Is there a difference in self-efficacy scores between college chemistry students use a technology-based application to conduct laboratory experimentation, and college chemistry students who do not?

HO_2 - There will be no statistically significant difference in the means of *College Chemistry Self-Efficacy Scale* (*CCSS*) scores for the treatment group, which used a technology-based application in laboratory, and the control group, which did not use the technology-based application.

Identification of Variables

In research question one the dependent variable was identified as student achievement as measured by a posttest that was given after two laboratory experiments have been completed. Final achievement scores were ascertained through one distinct, research-validated posttest. The *Conceptual Problems Gases Test* measured student achievement for the gas laws content area. The instructor involved in the study provided the posttest at the appropriate time in the research plan. The posttest was a formal assessment, as it encompassed each of the two different laboratory experiments that were given after lecture had been completed; furthermore, the posttest was delivered in multiple-choice format through the college's Blackboard system. The independent variable identified in research question one was the method in which the students carry out laboratory experimentation. Furthermore, the independent variable for this research

plan was the implementation of the treatment through the use of technology-based laboratory equipment. Students in the treatment group conducted each of the two laboratory experiments using a technology-based design, whereas students in the control group conducted each of the two laboratory experiments without the inclusion of technology but through traditional laboratory methods. Students represented the control group always used traditional equipment throughout the research study. Likewise, students represented the treatment group always used the technology-enhanced equipment. Therefore, the manipulation of the method by which the students conducted the laboratory experiments was the independent variable. In other words, the independent variable for this research plan was the design in which the students carried out each of the laboratory experiments.

In research question two, the dependent variable was identified as the observance of self-efficacy of students toward science at the self-efficacy scale. Both treatment and control groups took the *College Chemistry Self-efficacy Scale* (*CCSS*) after the completion of the posttest to gather information. The self-efficacy or dependent variable was ascertained through the manipulation of the independent variable; in this case, how the students conducted both laboratory experiments.

Definitions

Hands-on science – as defined, hands-on science eludes students learning through their experiences coupled with the manipulation of the objects there are examining (Holstermann, Grube, & Bogeholz, 2010).

Microbased-computer laboratory (MBL) – as examined, microbased-computer laboratories (commonly referred to as MBLs), are systems that take information that is being generated during a laboratory experiment via a computer interface and record and analyze it. Also known as data acquisition systems, microbased-computer laboratories utilize probes to gather information being generated by scientific experimentation (Probeware, 2005).

MKO – acronym used to describe a more knowledgeable other. Specific to Vygotsky's sociocultural theory, a *more knowledgeable other* is "someone with more knowledge or a greater understanding of a particular task or process than the learner" (Cicconi, 2013, p. 58). a person that has a greater understanding of a given concept than someone else.

Probeware – refers to handheld devices that enable students to collect real-time data such as temperature, light, motion, pH, and voltage, while at the same time being able to think about the changes that are happening as they happen (Stager, 2000).

Sociocultural theory – refers to the theory developed by Lev Vygotsky in the early twentieth century to describe the cognitive development of children. Vygotsky described an intimate relationship between learning and the interactions that occur between social groups; furthermore, significance was placed not only on how society influenced the development of the learner, but also on how the learner influenced society (Mahn, 1999).

Technology-enhanced instruction – as it pertains to the science laboratory format, refers to the application of technology-based equipment such as microcomputer-based systems and

probeware. It is an attempt made by students to engage directly with scientific experimentation through an educational setting; students' direct involvement would include manipulation of certain objects in order to procure knowledge (Ates & Eryilmaz, 2011).

Traditional laboratory – as it pertains to the science laboratory format, the term refers to the application of typical laboratory equipment to conduct experimentation without the use of technology-enhanced applications such as microcomputer-based systems and probeware (Interactive Educational Systems Design, 2012).

Zone of Proximal Development – the zone of proximal development is "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers" (Vygotsky, 1978, p. 86).

CHAPTER TWO: LITERATURE REVIEW

This chapter will begin with an analysis of the current perspective of science education and the need for reform. Afterward, a short history of the science laboratory will be investigated followed by an examination of a technology-based approach to the instruction of science in laboratory settings. Next, the format of the science laboratory will be examined through the lens of both traditional and modern applications as described from a review of the literature; furthermore, both the positives and negatives of each format will be discussed. Then, the theoretical parameter of sociocultural theory will be discussed and its implication on this research effort. Finally, the chapter will end with an observation of future pedagogy in science education.

Current Status of Science Education

One of the mainstays of science education has been its prime directive: to create learning that inculcates scientific literacy. In other words, the focus of science education was developed to create well-rounded, well-informed citizenry steeped in scientific understanding. For years, the objectives of the scientific community including the role of education have outlined that for science to become a dominant part of society it must commence from the level of the learner. The push for science literacy resonated within educational institutions as the field of education became more in tune with the needs of its constituents. Clearly, the *National Science Education Standards (NSES,* 2012) have provided a coherent plan for the implementation of science education at all levels of learning. The guiding principles that have been set forth within these standards have not only assisted teachers in aligning with contemporary science pedagogy, but has also given an opportunity for students to construct new learning in order to achieve science literacy (National Research Council, 1996). Additionally, the efforts of science literacy have

emphasized that science should be treated as a process rather than a list of facts given to memorization (Jonassen, 2006). In efforts to achieve scientific literacy, science teachers have placed great precedence both on the quality of their instruction within the classroom, as well as the necessity for students to gain important skills in the science laboratory such as following a procedure, observation, including measurement, data collection, and data analysis

As stated in the *American Association for the Advancement of Science* (2001*),* "Achieving scientific and technological literacy for all students is a goal of recent science education reform efforts" (Dana et al., 2001, p. 377). Certainly, this call for reform is based on the premise that technology has brought about change. This transformation has come about due to the increase in scientific know-how and has had an enormous impact on society as well as classrooms. As evidenced in the literature, students of today are media-immersed in uploading and streaming videos to downloading music and blogging; today's students have never known a world without the Internet, and therefore are referred to as digital natives (Parks, 2008). However, as technologically savvy as they may be, research has also shown several gaps that will be the foci of this proposed study (Higgins & Spitulnik, 2008; Hudgins et al., 2003; Parr, Jones, & Songer, 2004; Kim, Hannafin, & Bryan, 2007; Klopfer, Yoon, & Perry, 2005).

One of the primary gaps derived from current science education research is why certain areas that incorporate hands-on science still lag behind on nationwide assessments. The *National Assessment of Education Progress* (NAEP) measured the proficiency of science learning from a sampling of 122,000 eighth grade students from 7,290 schools across the nation. The examination assesses students' comprehension in the three distinct areas of earth and space science, life science, and physical science. Final scores from the assessment were matriculated

into a report known as the *Nation's Report Card*. The data analyzed from the assessment revealed several interesting facts about the current standing of our science education system.

First, scores in 2011 were higher than in 2009 when compared across the board in all areas measured except for the highest-performing students. The rationale as to why the higher-level students did not make gains was not reported. The results also yielded that educators were able to close the achievement gap among both Black and Hispanic students between 2009 and 2011. Students from all socioeconomic levels scored higher than in 2009. Specific to the assessment was a questionnaire that examined teachers on their use of hands-on activities in the classroom. They were asked about the frequency of hands-on projects; furthermore, there was a direct correlation between the frequency of projects and achievement posted by students. The more frequently teachers provided a hands-on learning environment for their students, the higher the students scored on the assessment (*National Center for Educational Statistics*, 2012). Even beyond the United States, other countries, such as Korea, have shown downward trends in the implementation of science learning. According to a research study conducted on the efficacy of science laboratories within high school level science classes in Korea, researchers reported that the science laboratory was inconsistent with prescribed curricula (Fraser & Lee, 2009).

Reasons have been given as to why gaps exist between instruction and achievement. Barnes et al. (2010) stated that for students to learn effectively, the perceptions that they carried must change. In other words, students must be able to recognize that the inclusion of technology would serve to deepen their understanding of scientific concepts; moreover, their readiness to use technological applications in the classroom and laboratory must reflect a positive attitude thereby closing the gap between how students live outside the school and how they learn within the school. In the article *The Effects of Problem-Based Learning Instruction on University Students'*

Performance of Conceptual and Quantitative Problems in Gas Concepts, the author described that students' performance in the classroom is sometimes due to motivation, and at other times it is because students do not have the ability needed to examine science with a deeper understanding than simple factual information; therefore, the use of technology has been an area in which educators hope to deepen students' understanding (Bilgin, Senocak, & Sozbilir, 2009). Irving (2005) included that in the use of technology among first year chemistry teachers over half of teachers during a five year time period did not receive any training in the use of technology. Therefore, the lack of professional development was directly proportional to the lack of learning achievement of their students. The infusion of technology into the classroom has been hinged upon not only the teacher's knowledge of the technology, but also the efficacy with which the teacher is able to incorporate learning that is effective. Therefore, for hands-on learning and the use technological tools to be effective in science instruction the teacher not only needs to know how to use technology, but also know when to infuse technology into the science curriculum. With the teacher having the necessary preparation for using technology, the foundation for integrating technology into science education will have been laid. Teachers must receive proper training for the use of technology to have beneficial results within the classroom alongside becoming an integral part of the educational experience (Dani & Koenig, 2008). Another reason that has been given as to why a technology-based approach to science education may be limited is found in the fact that not all students have equal access to the tools needed to conduct experimentation (Hudgins, et al., 2003). Furthermore, because of technical errors and malfunctions associated with some devices, researchers have become wary that the tools designed for increasing student comprehension may confound teachers' efforts (Kim et al., 2007).

Science Education Reform

As both national and local reform movements have been made in how science education delivers its content, teachers have had to undergo a shift in their respective teaching methods to acclimate to these new standards. Perhaps, many teachers that have had to refocus their instruction were those who carried the notion that being able to use technology was too complex. Furthermore, teachers were intimidated to depart with normal pedagogical practices and shift toward a more technology-based approach to classroom instruction (Higgins & Spitulnik, 2008). With national science standards incorporated into science educators' teaching, those instructors had to adapt to the arrival of not only calls for reform, but also an influx of new, technologically savvy efforts to deliver science to all students. This shift was paramount, as more prominence was placed on science students becoming models of what the field of science recognized as science professionals in the workplace. Many teachers were asked to implement laboratory on a regular basis with technology-driven applications being the standard. Before the incursion of technology, many science instructors delivered most content within the classroom; however, some students never received any real science laboratory experience at all. Students who received science laboratory experience were given outlines of the actual laboratory experiment and asked to follow a step-by-step method of completing the experiment. The aims of this type of laboratory pedagogy were constructed to give students time to work in a laboratory setting as well as confirm theoretical content that had been delivered prior in the classroom (Reid & Shah, 2007).

Therefore, until the paradigm shift in pedagogy, science laboratories were simply checkpoints where students fulfilled course requirements by completing cookbook-style laboratory assignments. However, since the technology movement that began in the early 1960s

in education with the inclusion of computer-based instruction, teachers have undergone a transition in their teaching styles. Because prominence has been placed on student involvement in the laboratory, it is imperative that the interactions within student involvement be examined. As described in the article *The Effect of Data Acquisition-Probeware and Digital Video Analysis on Accurate Graphical Representation of Kinetics in a High School Physics Class* (2010), students must gain expertise in the application of technology in order to acclimate to current notions of being science literate (Struck & Yerrick, 2010).

In *Media and Methods (*2005), the authors conveyed that for students to be successful in the 21st century they must possess the proper knowledge of their subject matter alongside enhanced skills. Therefore, the incorporation of scientific technology into their curricula would serve to better prepare students for life outside of school because students are more motivated and according to research, have achieved higher test scores (Lento, 2005). Thus, the responsibility has been given to administrators and teachers to examine the benefits that technology brings to education, adapt to pedagogical and technological changes, and incorporate effective strategies into learning environments conducive for today's students.

However, specific to a technology-driven approach in science, one body of research as stated by Yarnall, Shechtman, and Penuel (2006) acknowledged that in the use of handheld computers there had been insufficiency in the creation of assessments to truly examine the learning that was taking place within classroom setting. They further added that if assessments were not made appropriately, then the goal of the inquiry process would be destabilized in its implementation. Therefore, this research stated that if assessments do not correlate with what is being taught then there is a misalignment of their application. Voogt (2008) included that there

needs to be a clear connection between the how technology is used and how it is interpreted by their students.

As mentioned previously, progress has been made in science education according to statistics generated and published by the *National Center for Educational Statistics* (2012). Nevertheless, there are still areas of concentration described in this review of literature that warrant a deeper examination of why the achievement of some students, such as the case in Alabama, still lags behind the nation (*National Center for Educational Statistics*, 2012). Tyler-Wood (2000) included on a larger scale that the United States when examined through the lens of the *Third International Math and Science Study* (TIMSS) failed to meet a high standard of performance by only outcompeting 2 of the 21 countries in mathematics and science. The comparison used to complete this sample was the best science students that the United States had to offer.

As noted in the article *What Faculty Interviews Reveal about Meaningful Learning in the Undergraduate Chemistry Laboratory* (2013), there has been a widespread consensus of undergraduate chemistry faculty that the role the laboratory plays in student learning is pivotal in their final outcome (Bretz et al., 2013). Noted as agents of change, instructors have been assigned the responsibility of deciding what strategies are needed to help reform or even replace older science education pedagogy. Furthermore, research has clearly conveyed that before science education can change, the teachers of science must change (Mansour, 2010). As current science reform pushes for the inclusion of technology within science laboratories to increase scientific literacy, new pedagogical practices must be infused to meet those challenges. In the article *Using a Personal Response System as an In-Class Assessment Tool in the Teaching of Basic College Chemistry*, the authors noted,

> Instructors across varied disciplines are realizing the pedagogical value of these systems, including greater student engagement with lecture content, interactive participation in presentations, increased student understanding of and motivation toward learning course material, higher class attendance, enhanced subject interest, and improved examination performance. (Chen & Lan, 2013, p. 33)

Consequently, scientific literacy provides not only a gateway to scientific advancement within specific niches of academia, but also affords the opportunity for job growth in the economic infrastructures of the world (Oludipe & Awokoy, 2010).

Historical Summary of the Science Laboratory

The use of the laboratory as a supplementary feature of science teaching began in the early 1800s. Instructors felt it was necessary to provide laboratory experimentation to students because they would eventually occupy highly skilled occupational roles in industry (Reid & Shah, 2006). Hands-on science and the activities that students have completed within this type of instruction mode is not a new teaching method. Historical records have indicated that students have engaged in hands-on activities since the 1860s with the movement of various educational systems such as the Russian system and the Sloyd system (Sianez, Fugere, & Lennon, 2010). In the late 1960s and early 1970s, hands-on science was found to exist in more simplistic forms; however, the dynamic in which hands-on science took place then compared with now is much different as technology has provided great advancements (Ates & Eryilmaz, 2011).

By the 1980s, advancements in computer technology had surfaced and made it possible for scientists to engineer equipment that would be able to collect data using equipment made at a lower cost. More costly equipment was already available but schools systems could not afford to purchase such items, especially to complete minimal laboratory assignments (Stager, 2000). The

advent of cost-friendly equipment afforded schools the opportunity to shift from hands-on science activities that were in nature simplistic and made from common everyday gadgets, to real-world scientific collections that would mirror instrumentation used by real scientists.

By the turn of the 21st century, technology had become so highly developed that several companies were now responsible for producing laboratory equipment that would log, record, and analyze data for student use. This became beneficial to teachers and students alike because it gave them a powerful means of implementing hands-on learning into their classrooms as evidenced in a statement by Bigler and Hanegan (2010), that the heart of learning is located within hands-on learning. From elementary to college-level science, research has shown that learning takes place when advancements in technology flourish.

However, these efforts have been dampened as educational reports have shown various groups of students in the US still continue to severely lag behind in educational progress. Older assessments, such as the *National Assessment of Educational Progress*, reported that the scores of 13 year-old students enrolled in science courses were the same in 1994 as they were in 1970 (Sutman et al., 1997). More current assessments of science instruction have revealed that science students are still behind in their retention of core scientific concepts. The *TIMSS*, or *Trends in International Mathematics and Science Study*, found that in 2011, US students enrolled in the fourth grade saw no statistical difference in their learning between 1995 and the 2011 assessment. Furthermore, the same assessment on US eighth grade students found little improvement as well (Provasnik et al., 2012).

Due to such disheartening results, both national and local reform movements have been made in how science education delivers its content. Current reform has highlighted the need for teachers to realign many of their classroom practices to become better prepared to provide

instruction that mirrors the new standards. This overall shift in teachers' respective pedagogical practices has also been called for in order to produce a nation of scientifically literate citizens. In order to produce vitally functioning students of science, research has clearly outlined that providing students with more meaningful instruction not only in the classroom, but also in the laboratory was crucial. Hence, the effectiveness of an individual school or school system is dependent upon the educational measures that are taken (Highfield, 2010). Some teachers that have been called upon to reorganize their instruction were also those who were taught in teacher education courses, as well as professional development sessions, that science education was about teaching science to the general school populace without focus on real-world applications. The notion of *science for all* was instilled within the hallmarks of content delivery but also with it came scientific literacy. The goal of public education has been and will continue to be to provide educational constructs for the betterment of all constituents. The ideology of educating the masses has been the framework upon which educational philosophies have been constructed.

However, in order to construct a framework by which all science students would become scientifically literate, it became paramount that science instruction be delivered through the lens of discovery. Accordingly, a case study conducted with urban elementary students that were labeled at-risk, provided feedback that even though students have the ability to learn, if they were not provided a suitable framework on which to construct underpinnings of larger science concepts, they would not be successful in developing the critical thinking skills needed to become literate. However, students who were given freedom to devise their own learning strategies were able to understand science concepts with some success. Allowing students to become engaged in science discovery learning has shown promise that students can learn more difficult concepts if allowed to engage in learning where they possess the tools to explore (Lee-

Pearce, Plowman, & Touchstone, 1998). The creation of a more meaningful learning environment has conveyed that scientific practices that are found outside brick and mortar institutions must be reflected within these institutions to create learning that is logical. Students have rarely been given the opportunity to interact with experiments from the guise of a researcher. On an even more rare occasion have science students been allowed to critique the efforts of peers within a scientific setting. Thus, students have been limited not only with developing new ways of critiquing their own work, but from that self-inspection the comprehension of abstract thought (Shen, 2010).

With national science standards incorporated into science educators' teaching, those instructors had to adapt to the arrival of not only calls for reform, but also an influx of new, technologically savvy tools to deliver science to all students. Data provided through the *National Center for Education Statistics* (2012) has reported that the presence of the computer in both homes and schools are commonplace. In addition to computer presence, the Internet has been made readily available where most computers are located (Capobianco & Lehman, 2006). The presence of this general form of technology has provided the field of science education an opportunity to realign its standards to reflect contemporary applications. Furthermore, because the current generation of learners grew up alongside the birth and growth of the Internet, the skills needed to use Internet-based applications does not require much additional training. This generation has been referred to as digital natives.

This shift was paramount as more prominence was placed on science students becoming models of what the field of science recognized as science professionals in industry and also the workplace. Many teachers were asked to implement laboratory experiences on a regular basis with technology-driven applications being the standard. Before the incursion of technology,

many science instructors delivered most content within the classroom; furthermore, some students never received any real science laboratory experience at all. Even though school curricula for various science classes called for the implementation of hands-on learning within a laboratory setting, many teachers shunned the notion either because of lack of professional development, shortage of tools, or even constraints placed by standardized testing (Klopfer, Yoon, & Perry, 2005). Students who received science laboratory experience were given outlines of actual laboratory experiments and asked to follow a step-by-step method of completing the experiment. The role of the teacher became minimal, as their role and responsibility was to just provide laboratory equipment and limited instruction. The aims of this type of laboratory pedagogy were constructed to give students time to work in a laboratory setting as well as confirm theoretical content that had been delivered previously within the classroom (Reid & Shah, 2007). Therefore, until the paradigm shift in science pedagogy, science laboratories were simply checkpoints where students fulfilled course requirements by completing cookbook-style laboratory assignments. The focal point of these laboratories was not for students to gain an in-depth understanding of the abstract concepts embedded within the lab, but to learn to correctly manipulate equipment in order to produce results that would be deemed acceptable for the prescribed experiment.

However, professionals began to notice that students were not progressing at the same rate as technology, In Thomas Kuhn's *The Structure of Scientific Revolution* in 1962, he brought forth the concept of change in that scientific advancement was "a series of peaceful interludes punctuated by intellectually violent revolutions" (Zapata, 2013, p. 779). Until this time, students received direct instruction and were asked to find the answers to the questions with which they were presented. But with the technology movement that began in the early 1960s alongside

Kuhn's book, the field of education for the very first time saw the inclusion of technology in the form of computer-based instruction. Teachers at the forefront of their profession began to notice the benefits of providing students with alternate methods of learning; moreover, their teaching styles became a subject of transition from stand-and-deliver methods to ascertaining the role of a facilitator in their students' learning experiences. Teachers then became responsible for building a platform that would align the newly found standards with the influx of technology (Parr, Jones, & Songer, 2004). Because prominence was now focusing on student comprehension in the science laboratory, it became a priority for teachers to examine their teaching strategies, procure those that were effective, and eliminate unproductive ones. Consequently, teachers began to elucidate cause and effect relationships surrounding various forms of instruction. Through analysis of trial and error attempts to identify pedagogy that would increase student comprehension, instructors realized that students would acclimate to the expectations of the teacher. Hence, the achievement level of students enrolled in science coursework was directly related to the expectations of the teacher (Lawrenz et al., 2009).

The use of a technology-minded approach to laboratory investigation according to a review of current literature found that the use of technology-driven methodologies in science-based applications has brought a new way of exploring abstract ideas. Through the use of hands-on tools, instructors have been able to supplement their lectures with quality laboratory experience. Within the confines of the science laboratory, students have been given the opportunity to assume the role of a scientist by using tools that are reflective of those found in scientific occupations. In addition, the application of these tools, such as microcomputer-based systems, have not simply been infused into science coursework for the aim of replicating real-

world settings only, but also purpose of enhancing and supplementing classroom instruction (Siew Wei & Hussain, 2011).

As discussed in the literature, research has shown that the use of technology-driven methodologies in science-based applications has brought a new way of exploring abstract ideas. By providing hands-on tools, instructors have been able to replicate the role that scientists play in real-world settings. Specifically within laboratory settings, students have been given the opportunity to assume the role of a scientist by using tools that are reflective of those that are found in scientific occupations. However, students engaged in scientific learning at the hands of technology have not done so alone. Research has shown that students who work together in groups are more likely to have success at reaching a threshold of comprehension than if they were to work alone. The social interaction among peers has been shown to be a productive feature of laboratory group work. Once placed in groups either by chance or directive, students conducting science experimentation have been indirectly asked to socially interact to perform intellectual functions. Krusberg (2007) referred to this arrangement of social as well as cultural blends as social learning. In social learning, students have been required to become a team to carry out exercises and complete higher-order thinking constructs; moreover, the success of a member of the team may depend upon input from each member. Therefore, if an individual has participated within a group, that individual has played a vital role as a group member or societal figure. From this stance, the theoretical framework of this research study has been identified as the sociocultural theory. The goal of science education is to prepare individuals to be productive citizens of tomorrow. Thus, the theoretical framework of sociocultural theory has been chosen as the construct upon which student learning and self-efficacy within the science laboratory setting has been chosen.

Therefore, Lev Vygotsky's the educational constructs of sociocultural theory are founded upon the premise that learning is further stimulated and knowledge facilitated when students are given time to interact in social niches. Consequently, science teachers have been directed to prepare lessons that are conducive to hands-on learning and would provide an opportunity for peer collaboration. Because teachers have changed their approach to teaching laboratory, group interaction has become an integral role in the way students conduct investigations. Simply put, laboratory experiments have begun the acclimation of new science standards by allowing students to work within social constructs whereby knowledge can be facilitated through interaction. Furthermore, research has shown that in instances where students are allowed time to collaborate with peer groups, an increase in not only student attentiveness but also achievement has been found. Accordingly, as individuals were given the opportunity to interrelate topics with group collaboration, each member of the team had the opportunity to construct a new learning experience via participation within their social faction (Mahn, 1999). As the focus of this research study has been placed on student learning and their respective self-efficacy in the laboratory setting, emphasis will not be placed on normal classroom procedures.

Theoretical Framework

The theoretical framework of this research study is based on the theory of sociocultural theory. Particular to this study, the sociocultural theory will be examined through the lens of educational construct.

Sociocultural theory.

With the aspects of the social member taken together with each member possessing their own cultural identities, the sociocultural theory emerged in the early twentieth century due to the contribution of Lev Vygotsky, a Russian developmental psychologist. Now recognized as the

father of the sociocultural theory, Vygotsky described an intimate relationship between learning and the interactions that occur between social groups; furthermore, significance was placed not only on how society influenced the development of the learner, but also on how the learner influenced society (Mahn, 1999). As the core of this theory centers on social interaction for the betterment of the learner, researchers have begun to revisit the notions of Vygotsky as traditional pedagogical practices within science education has proven deficient for many years (Struck & Yerrick, 2010).

Vygotsky's sociocultural theory was based on the premise that children learn from their social and cultural interactions. These interactions have been ascribed to children interacting not only with peers, but also with people who are more knowledgeable than them, or a *more knowledgeable other* (MKO). Ergo, an overemphasis on the role of social interaction in cognitive development became the backbone for the theory. Sociocultural theory has become the basis for educational directives in learning. Vygotsky believed that children do not learn because they have developed; however, they develop because they have learned. It is only when children are directly involved with the social aspects of learning that they develop. The sociocultural theory was grounded on three main principles. The first principal was that children must learn in a cultural setting. The second principal was that specific mental structures and processes could be traced to our interactions with others. From this second principal, Vygotsky believed that these interactions were either interpsychological or intrapsychological. The interpsychological interaction was one in which children were able to interact with those in their environment or group. Through this interpsychological interaction, children were able to learn tasks and abilities from those within the group that were more advanced. Once learning had taken place within the group setting, children were automatically moved into the intrapsychological interaction mode.

In this form of interaction, children were given independence as the learning they received in the interpsychological interaction was then internalized. The third principle of Vygotsky's sociocultural theory was the zone of proximal development, or *ZPD*. As defined, the zone of proximal development is "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers" (Vygotsky, 1978, p. 86). In the zone of proximal development, children learn by interaction with more advanced peers, as the more knowledgeable other (MKO) provided the groundwork for reaching full understanding. As described by researchers involved with the use of sociocultural theory to assist in the instruction of organic chemistry, the zone of proximal development was described as, "the distance between what students can do by themselves and the next learning level that they can be helped to achieve with competent assistance" (Livengood et al., 2012). Furthermore, a *more knowledgeable other* is "someone with more knowledge or a greater understanding of a particular task or process than the learner" (Cicconi, 2013, p. 58).

In general, the zone of proximal development has been divided into four phases or steps. The first step in the zone of proximal development has been labeled as the assistance step. In this step, the learner receives assistance from a significant figure to acclimate to a level of learning that may be deemed out of their reach. Through scaffolding, the learner is able to pass through the zone of proximal development as they move from an area of their own understanding to a new area of cognitive development with the help of such figures as teachers and peers working in the role of a more knowledgeable other (MKO). The second step in the zone of proximal development has been identified as the independence phase where the learners grow more independent of societal interaction and therefore, they look within themselves for

information to promulgate growth. The third phase of the zone of proximal development is automation. Automation has been described as the area where children no longer need assistance as learner has matured and internalized. The last step of the zone of proximal development is de-automatization. In this phase, children have forgotten how to complete tasks and no longer have the ability to construe their own learning without help; thus, the recurrence of learned tasks is no longer present and the learner will return to an early phase. The phases of the zone of proximal development have been explained; however, when viewed through an educational context the zones are more narrowly viewed as the first two steps listed.

Another tenet of Vygotsky's sociocultural theory was the concept of scaffolding. Vygotsky believed that in order for children to learn a task that they seemed to struggle with, assistance would be needed to help them construct learning. This notion, known as scaffolding, provided the necessary dialectical processes needed for a child's learning to internalize. If tasks were deemed too easy, then the child would become bored. Additionally, if the tasks being presented were too hard, then the child would become frustrated. Therefore, when children were presented with tasks that were considered just beyond their grasp, the instructional level application of scaffolding would assist them in reaching higher cognitive development.

Relationship of theory to study context.

Within science laboratories, students are afforded the opportunity to work together in peer groups. The arrangement of students working with each other on conceptual tasks may create occasion for students to undergo social interaction in order to internalize their learning. Students have always shown positive increases in learning when given the opportunity to collaborate. Vygotsky believed that these social processes were rudimentary to a child, or student in this case (John-Steiner & Mahn, 1996). In a comparative analysis report on the

implementation of education technology, Klopfer et al. (2004) conveyed that the social arrangement of learners should reflect a sense of interactivity. As described in the report, implementation of various forms of technology-driven methodology could provide a framework for social constructivism. Another corollary of sociocultural theory and its impact on science education was described in the article *The Use and Evaluation of Scaffolding, Student Centered-Learning, Behaviorism, and Constructivism to Teach Nuclear Magnetic Resonance and IR Spectroscopy in a Two-Semester Organic Chemistry Course* (2012). Within the article, researchers conveyed that the use of scaffolding was beneficial in that the, "students participate in activities that are initially beyond their skill and knowledge" (Livengood et al., 2012).

As science education reform has called for the creation of a rich, technology-enhanced environment to assist in student learning, the pillars of Vygotsky's sociocultural theory have provided a framework for change. Clearly, attempts to convey the importance of social interaction in a science education setting have been conveyed. In the article "*Brown Paper Packages'? A Sociocultural Perspective on Young Children's Ideas in Science* (2005), the author delivered the idea that the relationships among people interacting within a community are vital to cognitive development. Through the integration of social relationships, students are given the chance to use technology-driven tools to interact not only with each other, but also interact with the science through each other (Robbins, 2005).

Powell and Kalina (2009) stated that social interactions were vital to the success of the learning process and that for a classroom to be effective the interaction among students must be present. Furthermore, they reiterated the notions of Vygotsky in that students must be able to negotiate their surroundings before any type of curricular learning could commence; thus, without the interaction within their social niches, students would not be able to participate in

discovery learning within laboratory groups. Therefore, evidence has been provided that many skills such as critical thinking, inquiry-based learning, discovery learning, extrapolation of data, and reasoning may only come to fruition within the parameters of group communication (Lavonen et al., 2003).

Vygotsky believed that learning occurred in two phases. As described in his 1978 work *Mind in Society,* a child's development occurred first on the social level as children interacted among society in what he referred to as interpsychological interactions. The second development among children would become identified as intrapsychological as a child would begin to maturate internally. Upon completion of both stages, a child may learn according to their cognitive abilities (Vygotsky, 1978). Wang (2006) stated that joint communication within groups afforded students the opportunity to collaborate and share knowledge; moreover, in what is known as equal participation, students actively become engaged not only in each other but their assignment at hand. By doing so, knowledge is constructed as each member of the group contributes their expertise.

In addition, the theory also supported the idea that humans lived and actively participated in cultural settings through the language and art they were accustomed to using. Sociocultural theory defined members within a group as those who learn from each other while interacting socially. The significance of interactivity and learning, specifically within the cognitive and social processes of learning can have a powerful effect on whether students become better learners. The sociocultural theory supports active involvement within peer collaborative groups.

Accordingly, these ideas formed the basis for learning in a socially rich environment; hence given the time and nurture, children and students in collaboratively working niches could help foster knowledge not only among the group, but also among each individual of the group

(Vygotsky, 1978). This theoretical framework supports the practice of students working in groups to solve a task. Hsi (2007) included in sociocultural theory as a framework among different disciplines; hence, students can learn through multiple perspectives. Xu (2012) stated that providing students multiple standpoints such as hands-on science, would serve as catalysts for stimulating interest and encouraging students to reach for higher goals.

Technology-Based Instruction in Science Education

A technology-based instructional approach has been defined in various ways dependent upon the context in which it is being used. For the purposes of this research study, technology-based instruction has been defined as the student involvement in a science laboratory setting with the use of technology-aided equipment via hands-on use. Other terminology, such as technology-enhanced instruction, hands-on science, and technology-assisted instruction, have also been used to describe the process of using hands-on tools to conduct science. As defined, *hands-on science* promotes student learning through their experiences coupled with the manipulation of the objects there are examining (Holstermann, Grube, & Bogeholz, 2010). Again, it is important to note for the framework of this research study, precedence has been placed on the word *technology*. In this case, *technology* has been used to represent many different tools that both teachers and students use to gather data collection such as time, temperature measurements, and pH readings. These tools are often used when a specified laboratory assignment has been given. Furthermore, various systems that have been present in the assistance of gathering information have been referred to as micro-based labs (MBLs), calculator-based labs (CBLs), probeware, handhelds, and data acquisition systems; however, these tools may have been assigned formal names respective to the companies that developed and manufactured them. In general, technology-driven science methods or hands-on science has

proven that it contains the necessary ingredients to bring positive learning experience to fruition. Regardless of the formality, these systems have been developed to collect information that is being generated during a laboratory experiment and record and analyze it (Probeware, 2005). Through the use a computer interface, these devices are programmed to collect and analyze various components of data at the user's discretion. Ates and Eryilmaz (2011) stated that hands-on science was more clearly defined as an attempt made by students to engage directly with scientific experimentation through an educational setting; students' direct involvement would include manipulation of certain objects in order to procure knowledge.

As more laboratory-based technology such as handhelds and probeware have been produced specifically for use within the classroom, instructors from all levels of education have found much success. Organic chemists at Georgia Gwinnett College have identified in their mission of instruction that they wanted learning to take place beyond the normal confines of traditionally formatted pedagogy. Furthermore, educational technology including such devices as handheld peripherals was an integral part of their growing aim to enhance the learning process (Paredes et al., 2010). Aside from the collegiate level, The *Technology Enhanced Elementary Middle School Science Project* proposed the goal and need for inquiry-based instructional materials for elementary and middle school science education. One of the overarching questions that were examined in the project was whether or not the inclusion of probeware and materials provided by the *Technology Enhanced Elementary and Middle School Science* (*TEEMSS*) project would affect student academic achievement. Research has shown multiple times there is a significant gap in this area and warrants attention. How effective is technology when compared with student learning? The implications described in the project suggested that the implementation of science probeware in the classroom has proven to be an effective method of

teaching today's students coupled with the fact that most students have never known a world void of technology in general (Zucker et al., 2008).

Habraken (2004) stated that hands-on instruction must emulate the same conditions that real scientists are embedded in on a daily basis. Consequently, for most college students enrolled in upper-level chemistry coursework, their choice of career upon graduation will fulfill the role of scientist in some aspect. Whether it is engineers, chemists, or even pharmacists, research has indicated that priority should be placed on the replication of professional work within the classroom before formal training is finished. In the article *Effective Learning Environments for Computer Supported Instruction in the Physics Classroom and Laboratory* (2008), the author examined the effectiveness of handheld equipment in teaching and conveyed that students are able to learn conceptually when active engagement in the classroom was present (Thornton, 2010). Educators have proven that the implementation of science laboratory will help to frame students for life outside of the school parameter; furthermore, the production of science conscious individuals will further catapult science education to the general public. In order to accomplish this, teachers must ensure that the lessons that are integrated within the curriculum are essential to students' level of comprehension; furthermore, lessons designed must infuse technology to enlighten students' understanding. Millar (2005) included that students who participate in the use of data acquisition systems would more clearly feel connected to the learning and that both quantitative and qualitative measures during a laboratory procedure could be ascertained (Millar, 2005). Generally, students who have had the opportunity to engage in hands-on learning not only become engaged within the learning dynamic of science, but they also are excited about doing so (Lee-Pearce, Plowman, & Touchstone, 1998). By providing students a platform on which learning can be assimilated, the excitement within laboratory

environments have given students a feeling of school support; moreover, high motivational factors have been somewhat proportional with student career choice (Shores & Smith, 2010).

In science contexts where hands-on opportunities have been provided, students feel more connected in three distinct ways. First, in support of Vygotsky's sociocultural theory, students have felt more engaged as members of a team and are willing to work toward a common goal. Second, they have displayed a greater understanding of the objectives within each experiment. Third, students who may have been reluctant to apply technology such as a handheld device or sensor, gained confidence in using a science tool to gain knowledge about their subject matter (Lyublinskaya & Zhou, 2008). For example, a group of students in the Netherlands engaged in hands-on activities by using MBL technology to create images of the heart. By doing so, the students were placed in a semi-professional context whereby their learning spawned discussions about their content that was seen as fruitful (van Eijck, Goedhart, & Ellermeijer, 2005).

Schrand (2008) stated that the literature describes the process of active learning as having the qualities of student engagement that includes higher-order thinking and exploration. Many students that have enrolled in science courses have done so with the anticipation of lofty goals at the post-secondary level; hence, their informal education was a place to begin a challenge of their cognitive abilities as well as social adaptability. However, not all students that have found their way into science classrooms have had high expectations of a science-related career, but attended because of state requirements to fulfill science credits. Madden and Madden (2005) included that hands-on science and the activities that students complete within the classroom have offered at-risk students essential skills for being able to build on prior knowledge and improve on new concepts. Soloway (1994) stated that for science to become what it should be in classrooms, we should adopt a learn-by-doing principle. The National Association of Biology

Teachers has stated that conducting laboratory investigations within the classroom, laboratory, or even in the field is highly recommended; therefore, the installation of technology-laden applications will expedite the rigor of science learning (Holstermann, Grube, & Bogeholz, 2010). One specific type of hands-on technology has described a wireless system that would collect student data and give instantaneous feedback openly to the class (Keng, Hong, & Fui-Hoon Nah, 2006).

Gado, Ferguson, and van't Hooft (2006) included that the use of hands-on activities through the use of technology-driven methodology also enhanced the students' abilities to inquire about content as well as engage in the subject matter. In a quantitative study of the application of hands-on science, a pretest-posttest revealed that when students were allowed to use probeware to conduct science their achievement scores improved by a factor of 19% (Metcalf & Tinker, 2004).

Voss et al. (2011) reported that in certain areas around Illinois, the demand for professional development for teachers in middle and high school grades for hands-on science was high. This need originated from the overwhelming response that teachers received from their students. Hands-on science provided students a place to engage in charismatic learning; therefore, instructors demanded more. At the collegiate level, the need for professional development has not received the same enthusiasm.

In the article *Using Data-Collection Devices to Enhance Students' Understanding* (2000), the authors conveyed the benefits of using technology in laboratory settings as it gave students the opportunity to construct more meaningful concepts with the science they were conducting (Lapp & Cyrus, 2000). One study conveyed that students' conceptual understanding of chemistry was predicated upon their metacognition. Thus, as students were given an

opportunity to generate data through probeware collection, instantaneous results in the form of tables and graphs provided a deeper understanding. Furthermore, the use of data-logging also facilitated social interactions among student groups (Feng et al., 2011). Because of the nature of collecting and analyzing data in a laboratory setting, these data-collection devices relieved students of the duty of manually entering data into notation as the device translated all received information into an electronic form. The opportunity was then provided for students to further extrapolate information about their experiment with a high degree of certainty. This was accomplished because the confusion and drudgery surrounding student-made graphs were kept under control as the devices constructed accurate graphical information automatically (Mokros & Tinker, 1987). Another research study has shown that when students are able to make a meaningful connection to the learning environment, in this case a laboratory, they were able to gain more insight and quality from the classroom (Burleson & Myers, 2013).

Appropriately, multiple research efforts have been made to validate the use of a technology-driven methodology within the science laboratory. From the body of research that has focused on this pedagogical application of technology, it has conclusively been shown that student performance has increased with the inclusion of a technology-based instructional approach. Even more, one study has shown student performance improvement after just a single application of hands-on science (Brasell, 1987).

The infusion of this type of technology into the general science laboratory has reduced the efforts of students to collect data while also conducting the experiment. In the article *Palm-Based Data Acquisition Solutions for the Undergraduate Chemistry Laboratory* (2003), researchers found that the accessibility and portability were benefits of incorporating such tools (Hudgins et al., 2003). One evaluation of students using a hands-on approach to conduct an

undergraduate chemistry analysis of an organic dye stated that they felt they had gained new and valuable skills from the experience (Salman, Rauf, & Abdullah, 2012). As students have conducted laboratory work, not only is the needed information gathered and stored within a computer-aided handheld device, but also students are able to understand the outflow of information; therefore, students are able to refine skills that may be later reflected in real-world applications as their generated data becomes meaningful.

However, it has been proven that the use of technological tools, in a more hands-on approach to conducting laboratories, has provided a framework for conceptual understanding through visual representations. As data-collection devices are designed to display real-time data, students no longer are immersed in the confusion of bridging the gap between the science they are conducting and being able to conceptualize abstract ideas embedded within the science. These innovative tools have addressed the problem that has faced educators in providing instruction whereby students are able to construct new learning from abstract ideas (Kelly & Kennedy-Shaffer, 2011). In the article *Science 2.0* (2010), the authors described that when students are given the opportunity to engage in proactive learning by the means of digital sensors, then students not only acquire science content more effectively but also better understand principles of science (Brunsell & Hrejsi, 2010).

Research has shown that implementing hands-on science with a technology-based approach into science classrooms versus traditional pedagogical methods is beneficial. The dynamic of a hands-on, minds-on learning milieu alongside digital tools has allowed students the ability to conduct laboratory investigations in less time. Furthermore, the technology-based instruction has also provided students a better opportunity to better perform on standardized examinations (Probeware, 2005).

One basis of research emphasized the possibilities that science probeware brings to the classroom; moreover, the use of data acquisition systems gives teachers the opportunity to develop a classroom environment that is centered on inquiry-based methodology (Millar, 2005). Toth, Morrow, and Ludvico (2008) described inquiry learning as a type of methodology whereby students gain insight from their instruction and apply it to real-world relevance; furthermore, hands-on learning activities was given as a way to incorporate this type of learning into the classroom. Another methodology discussed in the literature was the use of technology to guide students through the process of an experiment, yet they use the nature of discovery to find for themselves ways to think and logically extrapolate their own findings. This type of methodology contained implications that were relevant to current ideology with the use of scientific probeware in that the more hands-on students are, the more dependent they are on themselves and each other and not the teacher; consequently, research has shown higher achievement scores due to this inclusion of technology to the science classroom (Millar, 2005).

Hisim (2005) stated that technology in the form of hands-on science has enabled students to quickly gather data for examination of graphical and numerical information. Data gathered is more accurate than most traditional methods; therefore, students know that their results are dependable. Students who use probeware can conduct extensive studies for long periods of time because the technology would allow them to save their information until completion. Rationale for implementation of probeware was given in that today's students are tech-savvy; moreover, the probeware seems to fit their lifestyles and offers them a modern way of doing science.

Another benefit of hands-on science is the implementation of tech-savvy techniques that would allow students to become scientists rather than just play science. The use of probeware in the science laboratory has helped students become engaged in scientific role-play rather than

following a prescribed list of procedures. Accordingly, science probeware has enabled students to collect real-time data such as temperature, light, motion, pH, and voltage, while at the same time being able to think about the changes that are happening as they happen; moreover, students are more likely to gain meaningful understanding of science and the work that scientists perform if they role-play and perform hands-on, minds-on scenarios (Stager, 2000). In the article *Using Probeware to Improve Students' Graph Interpretation Abilities* (2005), the author stated that probeware afforded students the opportunity to engage in real scientific collections in time settings that are appropriate for the school life, and that student participation was directly proportional with academic success. The article described how the use of probes in mathematics helped students to visually encompass some of the harder concepts such as contextual graph interpretation that require extrapolation. Accordingly, the use of probeware was supported due to the fact that students are able to instantly gain feedback on a number of dynamics such as temperature and motion. Consequently, students being able to visualize science as it occurred were considered important as other aspects such as recognizing how their efforts affect the outcome of the investigation. Better student awareness and higher achievement were the pillars of this research (Pulano, 2005). Kelleher (2000) stated that the use of certain forms of hands-on technology helped to transform the relationship between instructors and their students, as well as their interactions within the community.

As numerous research analyses have investigated the advantages of students conducting laboratory work, it has been made evident that the traditional, lecture-based platform contained flaws. For example, the traditional laboratory design has not been proven effective in helping students to understand the concepts behind such things as graphs and tables. Students are asked

to perform cookbook-style investigations and yet have no understanding of what their findings mean at the conclusion of their respective experimentation (Kozhevnikov & Thornton, 2006).

In general, technology such as email, the Internet, and cellular devices, have seen not only a sharp rise in their use among technological-savvy users, but also a widening participation in the total amount of people subscribing to their services. Vast research has shown that almost every classroom in the US has computers and those computers connected to the Internet. There has also been a shift in the delivery of state mandated examinations as instructors have begun to administer these tests via computers. Therefore, the existence of technology has created an opportunity for growth, both in the world and within educational parameters (Zucker, 2009).

As new designs and innovations such as wireless connectivity have been developed and dispensed to educational institutions, both administration and faculty are aware of the future opportunities that will go along with having and maintaining the presence of all forms of technology within their establishments. As described in *Science 2.0* (2010), science education has been brought alive due to the implementation of technological approaches within the classroom. Opportunities to further deepen the understanding of scientific concepts have been instituted through the applications of hands-on science (Brunsell and Horejsi, 2013).

Summary

Overall, many benefits to the inclusion of hands-on applications in science education have been shown. Research has proven that for teachers to be effective in a technologically driven classroom, much time and energy must be invested in achieving success at effectively implementing technology in the curriculum (Gado et al., 2006). In the Proceedings of *Society for Information Technology & Teacher Education International Conference* in 2009, it was made clear that for educators to be able to successfully incorporate solid pedagogy into the classroom,

teachers would be required to be fluent at the use of technology (Forssell, 2009). Scientific literacy can be infused into the science curriculum through the infusion of digital technologies via hands-on learning. The choice of technology has been dependent upon the knowledge of the instructor and the method of instruction that has been most conducive to the situational learning for a particular class.

Reasons for incorporating probeware, as well as other forms of technology, have been to help build communities of learners and promote reflection. Technology that is content-driven and infused with a hands-on, minds-on design will invite more students to become active learners, hence higher achievement. If students are to be given a science education that is meaningful; the curriculum that is conveyed must contain an approach that reflects the role that scientists play in the real world (Dani, & Koenig, 2008).

Therefore, it is the vital role of the teacher to ensure that science education is coupled effectively with sound pedagogical and technological practices. Teachers must narrow the learning gap between their content knowledge and how student's best learn in today's world.

Yet, with national science education reform serving as a catalyst for change, teachers must adapt to become better suited for their respective environments; however, if change does not occur, the use of technology will never bring out the best children have to offer. This apathy was best described in the article *Meeting the Needs of Middle Grade Science Learners Through Pedagogical and Technological Intervention* (2009), "If a science teacher's epistemological orientation toward science is a collection of facts, then the computer is likely going to become a tool that collects, organizes, and repeats facts more efficiently" (Yerrick & Johnson, 2009, p. 282).

CHAPTER THREE: METHODS

The objective of this study is to examine the impact that a technology-based teaching application will have on the achievement and self-efficacy of community college students in Chemistry courses. Based upon the review of relevant research in the field of college science education coupled with the inclusion of a technology-driven teaching model and its effect on student academic achievement within classrooms, this section sets forth to establish a description of the methodology that is proposed for such a research effort. Therefore, included in this section is a description of the overview of the study, the design of the study, data gathering methods, instrumentation, sampling procedures, and data analysis.

Research Design

The research design is a static-group comparison design. In the static-group comparison design, one group is labeled as the treatment group, while the other group represents the control (Gall, Gall, & Borg, 2007). Students in the treatment group are given an experimental treatment, while those in the control are not. After manipulation of the treatment, both groups are measured through a posttest. This particular design was utilized due to the groups already being placed into respective sections prior to the onset of research (Dickson, 2006). Furthermore, the design is non-equivalent because the chemistry classes under investigation did not undergo randomization; in other words, the participants of the study were already placed within each of their respective chemistry classes at the onset of data collection. A non-probability sampling procedure was utilized. Specifically, convenience sampling framed the general method of data collection. The plan of the study is quantitative in nature with a quasi-experimental focus. Quasi-experimentation is much like experimental design research; however, quasi-experimental design is distinguished from experimental because of the mode of selection of participants being either

randomized or not. Therefore, the design employed a non-randomized experimental design. Within the college, the chemistry classes under investigation were examined on the basis of whether a technology-based approach to laboratory work influenced student achievement and/or self-efficacy. Because the population from the college was considered statistically the same based on demographics, the total sample size of 52 was divided into two sections: the treatment group and the control group.

The rationale behind choosing this community college was based on the pre-existing infusion of technology-assisted instruction, a significant amount of technology on hand for implementation, and instructor preparedness via professional development. The reduced sample size is explained by the fact that there is a limited number of students on average that enroll in this type of coursework as well as the inclusion of technology at the college level being a relatively new research venture; however, both a treatment and control group supported the reliability of the study. Regardless of treatment, all chemistry classes earmarked for the study were given a posttest. The posttest design produced data to determine if students who use a technology-based approach within the laboratory setting to conduct laboratory investigations have significant achievement when compared to students who only use traditional methods.

The purpose of the study was not to gauge students on their effectiveness of the use of the technology, but how technology may or may not be directly proportional to their academic achievement and self-efficacy when discerned through data analysis. Therefore, every member of the treatment group must have a basic understanding of how to use selected instrumentation prior to the laboratory so that internal validity is not jeopardized. Therefore, a session between the instructor and each member of the treatment group was vital so that any student who did not fully understand the basic operations of chosen instrumentation was given time to ask questions

to gain insight; furthermore, the instructor may have been able to detect if a student is reluctant to ask questions and ensured that all members of the treatment group have equivalence training prior to experimentation. To further support the validity of the study, it was imperative that the instructor was prepared to deliver the technology effectively. This notion refers to the level of knowledge and professional response that the instructor will supply in their teaching; furthermore, the instructor will need to possess both the educational background and experience to successfully implement chosen technology. The individualized instruction on the use of any hands-on science application can prevent students from misunderstanding assignments and furthermore skewing data on posttest analysis.

Research Questions and Null Hypotheses

RQ1- Is there a difference in the achievement scores between college chemistry students who use a technology-based application to conduct laboratory experimentation, and college chemistry students who do not?

HO_1 - There will be no statistically significant difference in the means of *Conceptual Problems Gases Test* (*CPGT*) scores for the treatment group, which used a technology-based application in laboratory, and the control group, which did not use the technology-based application.

RQ2- Is there a difference in self-efficacy scores between college chemistry students use a technology-based application to conduct laboratory experimentation, and college chemistry students who do not?

HO_2 - There will be no statistically significant difference in the means of *College Chemistry Self-Efficacy Scale* (*CCSS*) scores for the treatment group, which used a technology-based application in laboratory, and the control group, which did not

use the technology-based application.

Participants

The participants of this study stemmed from students enrolled in multiple general college chemistry courses. The total population that was involved in the study was approximately 52 students, all enrolled in college chemistry. Due to the fact that the students were not randomly assigned to different groups but were considered pre-existing, assignment of a non-randomized, quasi-experimental research design best fit the study's plan. Further evidence provided that the proposed students were non-randomized because the students came from the same college and many factors that influence one's decision to attend a specific college such as the cost of tuition, location to home, and type of degrees offered were not decided by the researcher. For many students, completion of a college degree will represent the first time a member of their respective families have completed such a goal.

The proposed participants in this study were entered into a non-randomized, quasi-experimental approach. Students enrolled in general chemistry coursework were non-randomly selected from a community college in the fall semester of 2014. The community college represented the entire sample size of the study. The sample for this study was drawn from chemistry students enrolled in three sections of college chemistry I. In other words, participants all stemmed from one of the three, college chemistry I courses offered within the semester. Therefore, two sections or individuals classes of college chemistry I functioned as the control group with a sample size of 30, while the remaining section served as the treatment group with a sample size of 22. Therefore, sampling was accomplished by labeling one of the college chemistry courses as the treatment group, while the remaining two classes were combined to function as the control group. The total sample size that stemmed from all three college

chemistry I classes was 52. All participants represented an even distribution of socioeconomic status, age, and gender. One difference that was clear among the participants is that they all belonged to schools whose enrollment was predominately white. Class scheduling in the chemistry classes in the college was designed so that each chemistry class spent 150 minutes per week in lecture alongside an additional 150 minutes in laboratory. Accordingly, ample time was allotted to the completion of both general coursework as well as laboratory work

Setting

The proposed location of this research was centered at a community college that was located in a state in the southeastern portion of the United States. The school was nestled among the lower extensions of the Appalachian mountain chain. The area surrounding the school was classified as very rural area with little diversity. Members of the various communities and surrounding areas find work in different suburban and metropolitan locations both around and away from the school. However, a few residents have stayed close to home as they have gained employment through local businesses such as local supermarkets, cabinet shops, and a plethora of agricultural jobs in the cattle, poultry, and crops industry.

The college offers various two-year degree opportunities as well as transfer options to larger four-year institutions. The total population that was involved in the study is approximately 52 students, all enrolled in college chemistry. There was one instructor responsible for instruction. The instructor represented a valid point of insertion for the research, as they not only fulfilled the role of the science department chairperson for the college, but they also received training on the implementation of prescribed technology prior to the beginning of research. The demographic information for the school revealed approximately 87.7% white, 5.5% Hispanic/Latino, 3.8% Native American, 1.8% African American, 0.7% Asian, and 0.5%

other. The distribution of gender in the school reflected 39.3% male to 60.7% female. The socioeconomic status of the residents in the surrounding college communities showed that on average, 61.1% of the student body receives some type of financial aid or assistance (Anonymous, 2014).

Instrumentation

Two instruments will be implemented into the research study to gather data. The first instrument was the *Conceptual Problems Gases Test* (*CPGT*). In the article "*The Effects of Problem-Based Learning Instruction on University Students' Performance of Conceptual and Quantitative Problems in Gas Concepts*," the use of the *Conceptual Problems Gases Test* (*CPGT*) was implemented to assist researchers in assessing whether or not the inclusion of a treatment would affect the conceptual learning of students enrolled in a university chemistry course. The Cronbach's alpha reliability for the instrument was found to be 0.77 (Bilgin, Senocak, & Sozbilir, 2009).

Therefore, utilized as a posttest, this instrument was integrated into the research study to evaluate for academic achievement differences within the chemistry topic of gas laws. Furthermore, students who had been subjected to a technology-infused laboratory experience via hands-on tools were compared with those who had completed the same experiments in a traditional laboratory setting. The *Conceptual Problems Gases Test* (*CPGT*) consisted of a 19 question, multiple-choice examination whereby the posttest questions probed students for information contained within the context of each laboratory experiment respectively. Each question had five answer choices, A, B, C, D, and E. Students were given the *Conceptual Problems Gases Test* (*CPGT*) through Blackboard, an online educational platform. The instructor or their designee both administered and proctored the test. To administer the test, the

instructor reserved a computer laboratory on campus. Students were given a specific timeframe in which the test had to be completed. Access to the test was limited to only those students enrolled in college chemistry I. Furthermore, the integrity of the test results was maintained, as student identification was required to take the test. Consequently, the instructor or their designee checked for photo identification if a student was unknown. The instructor scheduled a time when the students could take the test. When students arrived to take the *Conceptual Problems Gases Test* (*CPGT*), they were given access to the test upon signing in to their Blackboard account. This helped prevent students from taking the test away from supervision and disseminating the test's content to other students. The posttest should have taken no longer than 45 minutes for students to complete.

There was an individualized posttest for all students under investigation. Thus, all students enrolled in college chemistry I took the same posttest. The posttest for the chemistry courses *Conceptual Problems Gases Test* (*CPGT*) came from validated, research-based material designed to examine achievement from laboratory material taught at the time of collection; therefore, the posttest was administered to both the treatment and control group. The posttest was administered after both of the laboratory experiments have been completed. Once all students completed the *Conceptual Problems Gases Test* (*CPGT*), they were given *College Chemistry Self-Efficacy Scale.* This instrument gave insight as to how students perceive their environment within a science laboratory. Specifically, this provided important insight on how students not only view the laboratory as a whole, but also how they perceive themselves as an integral part of the science that takes place within the lab. The instrument was also used to extrapolate data to reflect student self-efficacy in the science laboratory. Consequently, if students are confident of themselves as laboratory researchers, they may in turn become better

researchers through the inclusion of a technology-driven laboratory design. Uzuntiryaki and Aydm (2008) stated that the self-efficacy of students enrolled in chemistry, as well as other sciences, was a predictor of how well those students would perform academically. Because the *College Chemistry Self-Efficacy Scale* (*CCSS*) was examined through the lens of self-efficacy, the formation of this instrument was examined for validity. Researchers examined self-efficacy through three points: self-efficacy for cognitive skills, self-efficacy for psychomotor skills, and self-efficacy for everyday applications. From this, each point was assigned a Cronbach's alpha reliability. Respectively, the self-efficacy for cognitive skills was found to have a Cronbach's alpha reliability of 0.92, the self-efficacy for psychomotor was given a Cronbach's alpha reliability of 0.87, and a Cronbach's alpha reliability of 0.82 was given to self-efficacy for everyday applications. Hence, the overall average Cronbach's alpha reliability for the *College Chemistry Self-Efficacy Scale* (CCSS), based on the three prior reliabilities, yielded a value of 0.87. Therefore, this instrument gauged how students enrolled in first-year college chemistry courses might perform on all three facets of self-efficacy (Uzuntiryaki and Aydm, 2008). Consequently, the *College Chemistry Self-Efficacy Scale* will pinpoint both strengths and weaknesses students may have perceived through themselves. This instrument helped to identify trends among college chemistry students working in a laboratory setting. Students completed the scale by indicating how they felt about statements that discussed their academic backgrounds in chemistry as well as how well they believed they could collect data within a laboratory setting. Information from this instrument was coded and the appropriate quantitative results extrapolated.

Procedures

To align with research protocol, an official university International Review Board (IRB) approval was requested and received before formal data collections were entered into. Also,

permission to use a population, eliciting participants, and conducting any type of pilot studies that were needed was all secured before the onset of interaction between the researcher and research individuals. Accordingly, formal requests to implement research treatment such as gathering and recording data were granted before formal phase of research begins. Furthermore, permission from instrument authors was also obtained before instruments are delivered to participants.

Data such as posttest and self-efficacy scores will remain confidential information to only those who have been granted access by formal permission; namely, the research individuals, accessory statistician, and researcher. Compliance with the Family Educational Rights and Privacy Act (FERPA) law was upheld, as all identifiable information, including student name, teacher name, and other class information was removed or hidden. Once all official research permissions were granted, the researcher initiated the study by examining the college in which data was to be collected. The researcher also met with the chemistry instructor to explain that their role is to remain unbiased and to conduct research in its purest form.

Students began fall semester of 2014 by settling into their classes for the semester. Afterward, research began for treatment groups after the administration of the onset of classroom instruction. Students in all chemistry courses at the college conducted their respective laboratory experiments concurrently. All groups took the posttest and self-efficacy scale at approximately the same times. The researcher then collected data from the posttest and survey from both treatment and control groups to perform the appropriate data analysis to determine if the presence of a technology-based teaching application had an effect on student achievement and/or self-efficacy.

Data Analysis

In the study, two different types of instruments were used to measure the effect of a technology-based approach in laboratory on student achievement and self-efficacy. Before the laboratory experiment was conducted, all students received classroom instruction as normal. The research study did not focus on the effects of classroom instruction, but the effect that the inclusion of a technology-driven approach may have on students' understanding within the laboratory setting. After students completed the laboratory investigation within their assigned group, the posttest and self-efficacy instruments were administered respectively. It was important that the instruments be administered to each member of both the treatment and control groups as soon as the laboratory experience was finished to prevent cross-contamination of methods; moreover, accuracy of posttest depended on keeping confidentiality among groups. Internal validity was also stronger by conducting the posttest at the completion of experimentation, as it did not allow for maturation variables to interfere with student input.

Gathered data from all instruments was coded and entered into *SPSS* software. An independent t-test was used to calculate any achievement differences that may have existed between both groups (treatment and control). The independent t-test was appropriate for this research design due to the fact that the participants throughout the study did not change; thus, the analysis examined any changes that may have occurred due to application of a treatment. Therefore, the application of the independent t-test showed if any differences existed between the treatment and controls groups of college chemistry I. The posttest examined any differences that could have been found after the application of the treatment; in this case, the application of a technology-based instructional approach within the undergraduate chemistry laboratory. The alpha level for this research design was set at .05 ($\alpha = .05$). The alpha level is the probability of

rejecting the null hypothesis assuming that the null hypothesis is true. In social sciences, the alpha level is $p < .05$ (Brace, Kemp, & Snelgar, 2009). To fully understand the significance of whether the manipulation to the treatment group is relevant, the question of variability must be taken into account. Certainly, it is not enough to examine the differences in means to determine significance, but with taking under account the effect size from the distribution of scores that will be extrapolated from parametric methods, the null hypotheses can be rejected or accepted. Therefore, the statistical power of this research study assisted in determining the nature of the null hypothesis (Faul et al., 2007). The use of parametric analysis as a data analysis tool in this research study made it easier to detect if there was a true difference between instruction modes between the groups being tested; moreover, a much more precise reflection of the data was generated because of the control over the effect of the covariate. The independent variable was instructional method with two levels (technology-based laboratory method versus traditional laboratory experiments). In research question two, the dependent variable was student self-efficacy toward science at posttest. The independent variable was instructional method with two levels (technology-based laboratory method versus traditional laboratory experiments).

At the conclusion of the posttest instrument in college chemistry I, students took the *College Chemistry Self-Efficacy Scale.* This instrument was used to examine the extent to which students related to their skills and personal performance in the context of the chemistry laboratory. The self-efficacy scale was analyzed using an independent t-test. The results that stemmed from the data analysis of the *College Chemistry Self-Efficacy Scale* (*CCSS*) scores indicated if students that are part of the treatment group felt differently about their self-efficacy while working in a laboratory setting than the students who made up the control group. The *College Chemistry Self-Efficacy Scale* (*CCSS*) provided students with questions such as how well

they view themselves as problem solvers, or even how well they can interpret data that is generated during a given experiment. The *College Chemistry Self-Efficacy Scale* (*CCSS*) was administered after the completion of both prescribed laboratory experiments on the gas laws. Consequently, students who were members of the treatment group already had interaction with the technology-based approach, whereas members of the control group had only come into contact with traditional means of collecting and generating data. The analysis of the *College Chemistry Self-Efficacy Scale* (*CCSS*) provided insight as to whether the technology-infused experimentation had any effect on student self-efficacy.

CHAPTER FOUR: FINDINGS

The purpose of this study was to examine the effectiveness of a technology-enhanced teaching method used with college chemistry students within a laboratory context. Days of traditional stand and deliver modes of instruction are no longer as effective as students require an almost entertainment style of instruction in order to compete with fast-paced marketplace technology. Consequently, this study is of importance due to the fact that possible outcomes may prove which pedagogical methods may be more effective within the undergraduate chemistry classroom. Moreover, there have been a limited number of formal investigations on the use of technology-enhanced instruction and its effect on student achievement and self-efficacy at the community college or undergraduate level (Higgins & Spitulnik, 2008).

The discernment of the effects of the inclusion of a technology-driven science application was examined through the implementation of two validated research instruments. The first instrument, the *Conceptual Problems Gases Test* (*CPGT*), measured student academic achievement within the chemistry topic of gas laws. The other instrument, the *College Chemistry Self-Efficacy Scale (CCSES,* assessed how students perceived their ability to perform tasks within a science laboratory context. The instruments were administered through Blackboard, an online educational platform.

Data collection transpired during the spring semester of 2014 after obtaining the required approvals and permissions. Research began for treatment groups after the administration of the onset of the classroom instruction. Students in all chemistry courses at the college conducted their respective laboratory experiments concurrently. All groups took the posttest and self-efficacy scale at approximately the same times. The researcher then collected data from the posttest and survey from both treatment and control groups to perform the appropriate data

analysis. Demographic data on the students were obtained through SurveyMonkey®, an online data collection tool. Data were entered into four excel spreadsheets, which imported into SPSS and subsequently merged for analysis.

Chapter four is organized by the introduction, sample demographics, descriptive statistics and data screening, research questions and hypothesis testing, and conclusions. The following provides a discussion of the sample demographics.

Sample Demographics

There were 52 students who participated in the study; 42.3% (n = 22) were in the treatment group and 57.7% (n = 30) were in the control group. Relative to age, 90.4% (n = 47) were 18 to 24; 7.7% (n = 4) were 25 to 34; and 1.9% (n = 1) were under 18 years of age. Three-fourths of the students (75%, n = 39) were males and one-fourth (25%, n = 13) were females. Approximately 10% (n = 5) of students had completed two years of college; 47% (n = 24) had completed one year of college; and 43% (n = 22) had graduated from high school or had a General Education Diploma (GED). Seventy-six percent (n = 38) were employed outside of school. The chemistry course was not the first college science course for 96.2% (n = 50) of students; and 76.5% (n = 39) of students considered their first choice of college major to be science-based.

Descriptive Statistics and Data Screening

Raw scores on the *CPGT* could range from 0-190. However, scores on the sample of students ranged from 30-100 (M = 63.27, SD = 17.35). Scores on the *CCSS* could range from 1-10. Scores for the sample of students ranged from 4.62 to 9.05 (M = 6.98, SD = 1.02). The data were screened for normality with skewness and kurtosis statistics and histograms. In SPSS, when the absolute values of the skewness and kurtosis coefficients are less than two times the

standard error, the distributions are considered to be normal. As indicated in Table 1, the skewness and kurtosis coefficients are within normal ranges.

Table 1

Skewness and Kurtosis Coefficients

Variable	*N*	Skewness		Kurtosis	
	Statistic	Statistic	Std. Error	Statistic	Std. Error
CPGT score	52	.292	.330	-.557	.650
Chemistry Self-Efficacy	52	-.202	.330	-.334	.650

Next, the distributions were examined with histograms, which further supported the normality of the distributions. The histogram for the *Conceptual Problems Gases Test* scores is presented in Figure 1.

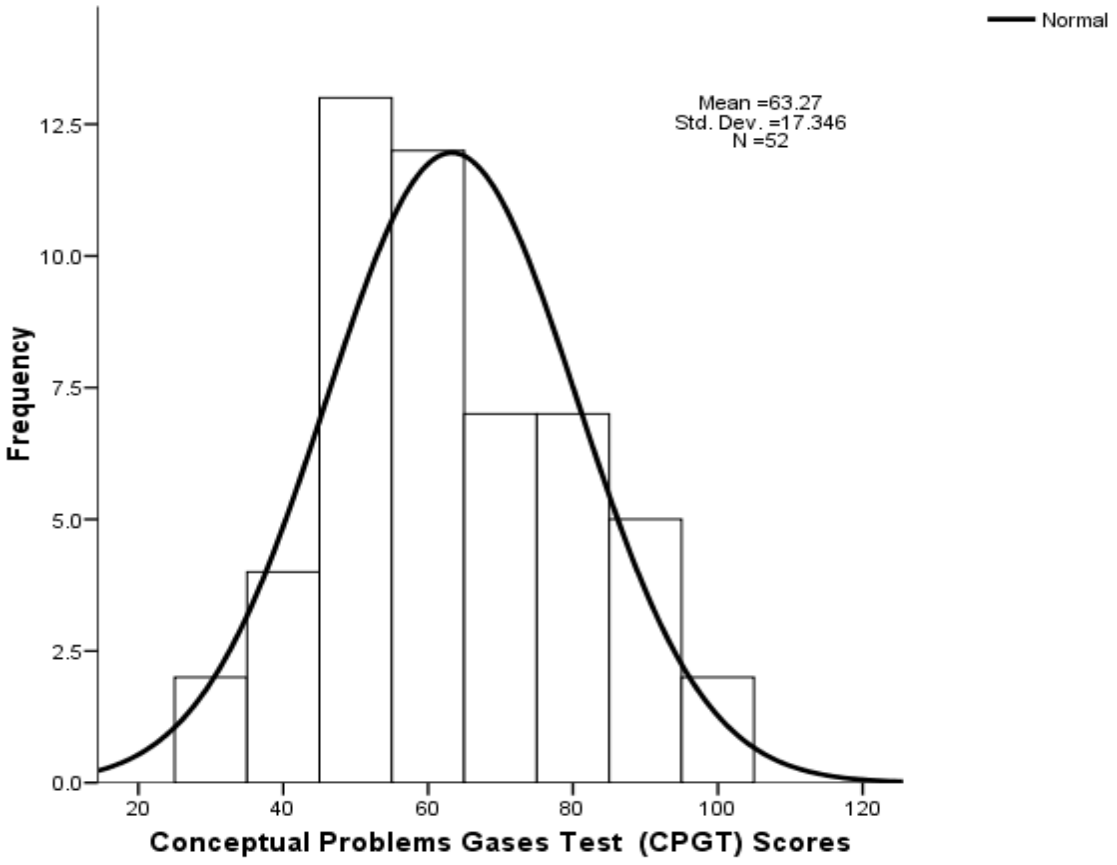

Figure 1. Histogram of Conceptual Problems Gases Test Scores

The distributions of scores on the College Chemistry Self-Efficacy Scale were examined on the basis of normality. As given below, it was found that the scores were considered normal. The histogram for chemistry efficacy is presented in Figure 2.

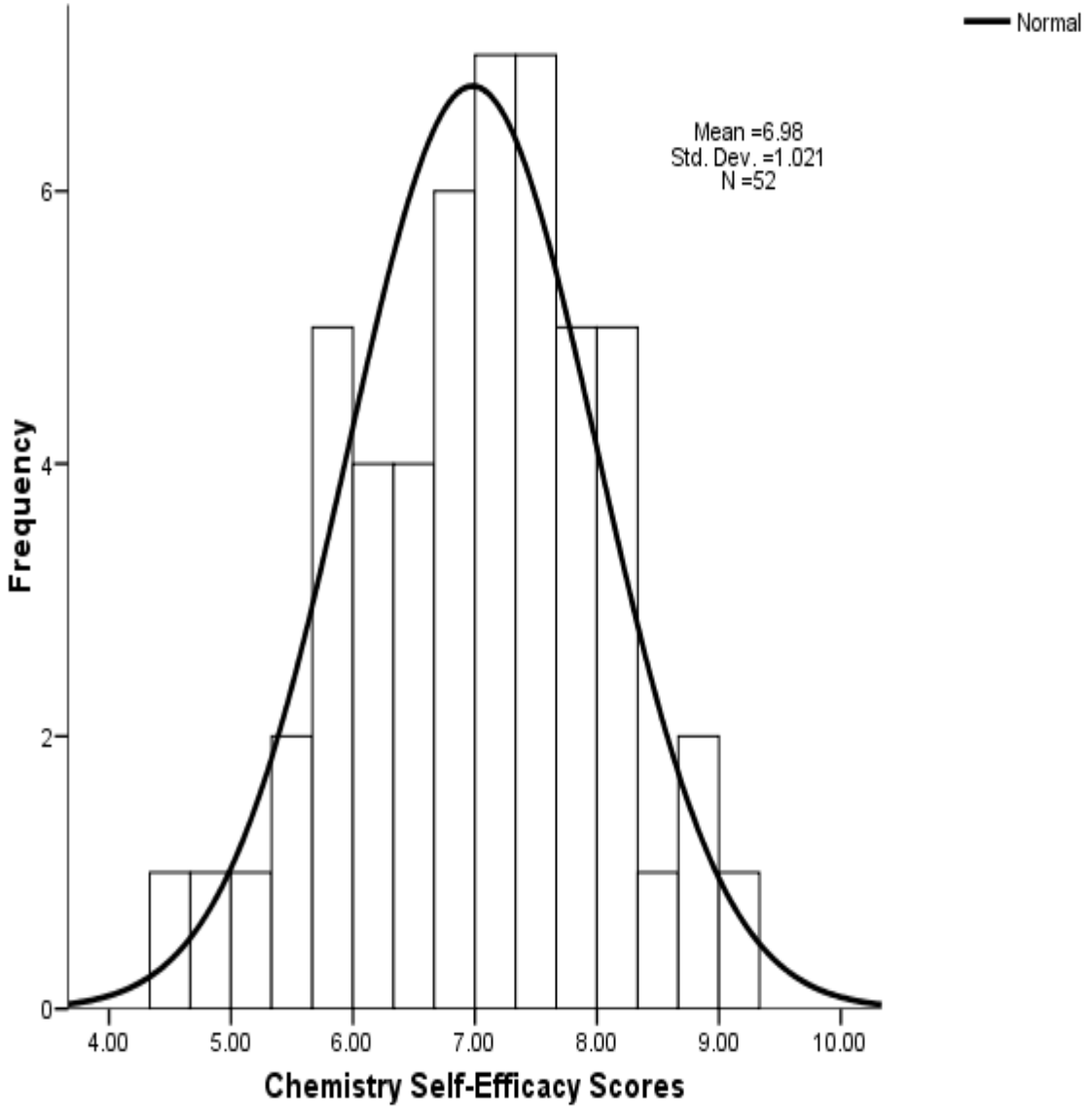

Figure 2. Histogram for College Chemistry Self-Efficacy Scores

Histograms were also generated for the dependent variables by group (treatment versus control group). When the scores on the *Conceptual Problems Gases Test* (*CPGT*) are compared

between students in the treatment group, and those in the control group, evidence is provided that the distributions of scores between the groups were normal. The histogram representing this finding is presented in Figure 3.

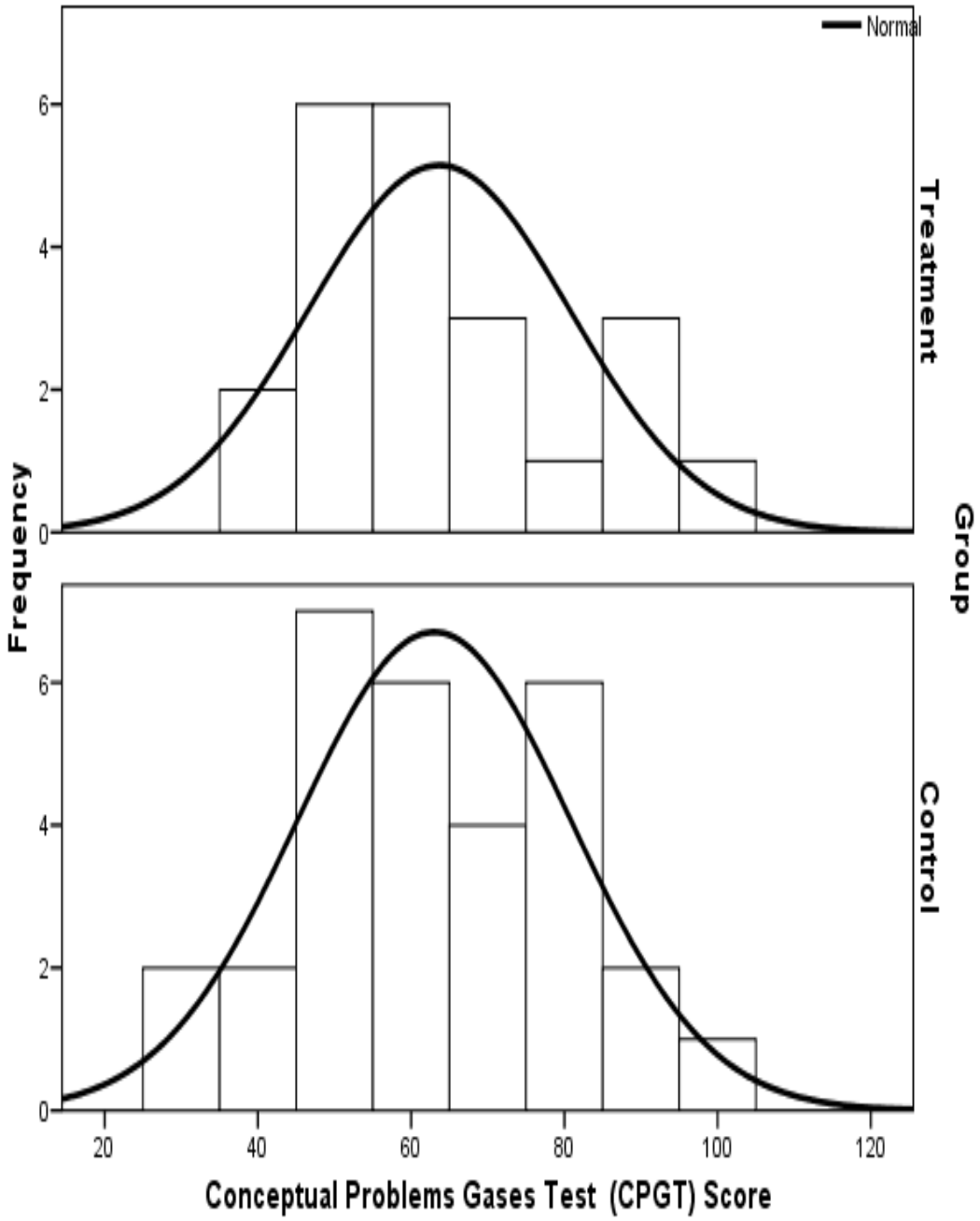

Figure 3. Histogram of Conceptual Problems Gases Test Scores by Group.

The histogram for chemistry efficacy scores by group is presented in Figure 4.

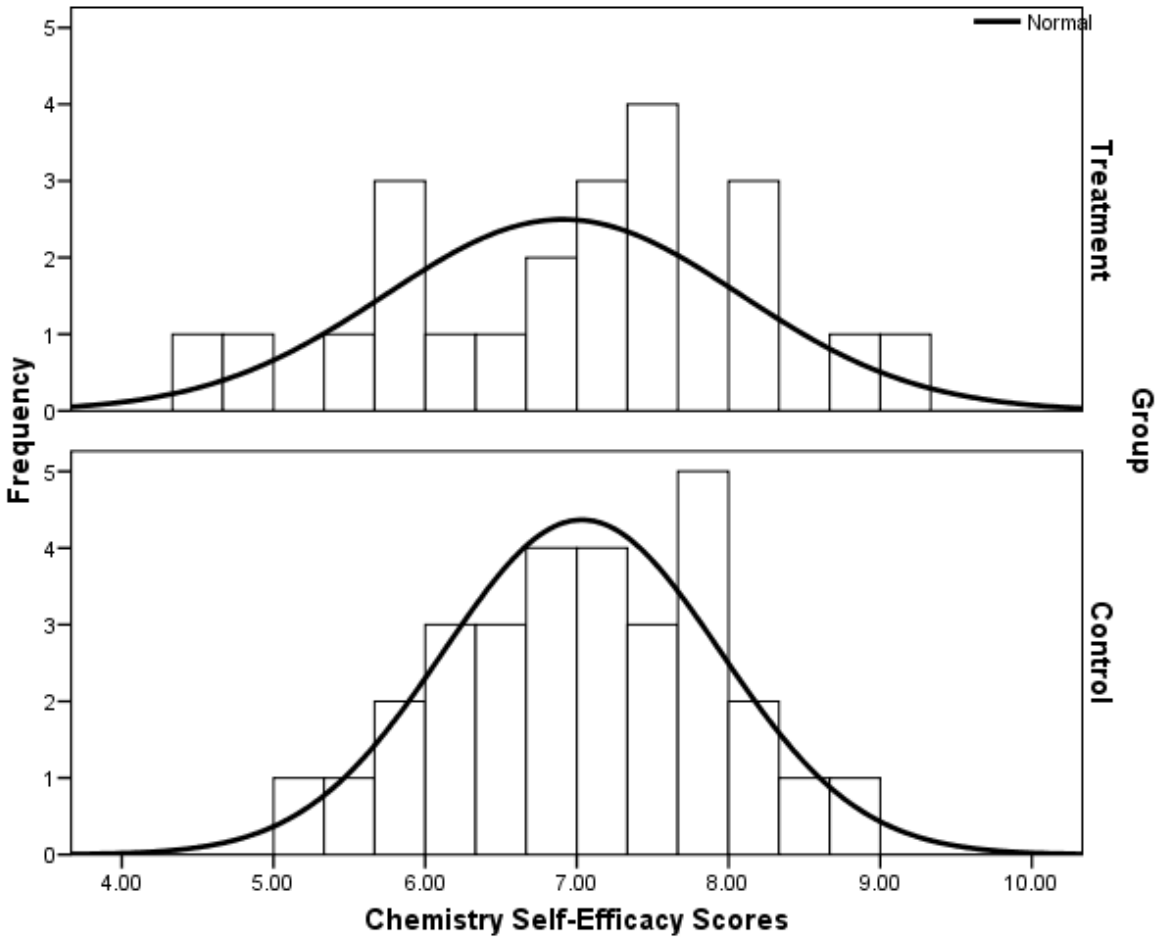

Figure 4. Histogram of Chemistry Self-Efficacy Scores by Group

Null Hypotheses

Null Hypothesis One

Null hypothesis one was investigated to determine if the presence of a technology-based approach in the chemistry lab would have any effect on student achievement. From the analysis, the Levene's Test for Equality of Variances was not statistically significant, $p = .711$. This information helped to form the assumption that there was no statistical variance between the treatment group and the control as measured by the posttest. HO_1 stated that there will be no

statistically significant difference in student achievement by college chemistry I students, based on the inclusion of a technology-based science application versus a traditional approach in the laboratory, as measured and shown by the by the *Conceptual Problems Gases Test* (*CPGT*). The technology-based laboratory instructional method (treatment group) (M = 63.64, SD = 17.06) did not significantly differ from the traditional laboratory method (control group) (M = 63.00, SD = 17.84), $t(50) = 0.13$, $p = .898$, two-tails. Based on the results from the t-test, therefore the researcher failed to reject the null hypothesis. The t-test results for the *Conceptual Problems Gases Test* are given in Table 2.

Table 2

Means, Standard Deviations, and t-tests (*Conceptual Problems Gases Test*)

Group	n	M	SD	t	p =
Treatment	22	63.64	17.06		
				.129	.898
Control	30	63.00	17.84		

Null Hypothesis Two

Null hypothesis two was examined to discern if the presence of a technology-based approach in the chemistry lab would have any effect on student self-efficacy. From the analysis, the Levene's Test for Equality of Variances was not statistically significant, $p = .242$. This information helped to form the assumption that there was no statistical variance between the treatment group and the control as measured by the self-efficacy scale. HO_2 stated that there will be no statistically significant difference in the means of *College Chemistry Self-Efficacy Scale* (*CCSS*) scores for the treatment group, which used a technology-based application in laboratory, and the control group, which did not use the technology-based application. The technology-

based laboratory instructional method (treatment group) (M = 6.91, SD = 1.17) did not significantly differ from the traditional laboratory method (control group) (M = 7.03, SD = 0.91), $t(50) = -0.43$, $p = .669$, two-tails. Therefore, the researcher failed to reject the null hypothesis. The t-test results for the College Chemistry Self-Efficacy Scale are given in Table 3.

Table 3

Means, Standard Deviations, and t-tests (College Chemistry Self-Efficacy Scale)

Group	n	M	SD	t	p =
Treatment	22	6.91	1.17		
				-.430	.669
Control	30	7.03	.913		

Conclusions

Two research questions and two related hypotheses were formulated for investigation. The outcome of each was non-significant. For student achievement, as measured by the *Conceptual Problems Gases Test* (*CPGT*), the technology-based laboratory instructional method did not significantly differ from the traditional laboratory method. Similarly, in student self-efficacy in chemistry, as measured by the *College Chemistry Self-Efficacy Scale*, the technology-based laboratory instructional method did not significantly differ from the traditional laboratory method. A summary of group statistics is given in Table 4.

Table 4

Summary of T-Test Results

Research Question	Variable	*T*	*df*	*P*
1	Conceptual Problems Gases Test	.129	50	.898

2	College Chemistry Self-Efficacy	-.430	50	.669

Therefore, based on the t-test values, the researcher failed to reject both null hypotheses. From this, the technology-based laboratory instructional method had no discernible impact on student achievement or student efficacy. Implications will be discussed in Chapter Five.

CHAPTER FIVE: DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

This chapter provides a thorough explanation for the results of the research study. The following sections give a summary of the research findings: discussion, conclusions, implications, limitations, and recommendations for future research.

Discussion

The purpose of this research study was to investigate if the presence of a technology-based instructional approach within the postsecondary chemistry laboratory setting would have any effect on student achievement, as well as student self-efficacy while working in a laboratory setting. This research study included a total of 52 college chemistry I students enrolled in a small community college in the southeastern United States. The research study was a nonequivalent, control group, posttest only design. The results showed that the inclusion a technology-driven approach within the undergraduate chemistry laboratory had little effect on student achievement and self-efficacy.

Research Question One and Null Hypothesis One

The first research question asked: Is there a difference in the achievement scores between college chemistry students who use a technology-based application to conduct laboratory experimentation, and college chemistry students who do not? The null hypothesis one stated: There will be no statistically significant difference in the means of *Conceptual Problems Gases Test* (*CPGT*) scores for the treatment group, which used a technology-based application in laboratory, and the control group, which did not use the technology-based application. Predicated on the results of the independent samples t-test, null hypothesis one was not rejected. Thus, students in the treatment group who conducted their laboratory experiments using a technology-based approach showed no greater achievement than those in the control group. The

results given in *Figure 3* shows that there was no significant statistical difference between groups.

Research Question Two and Null Hypothesis Two

The second research question was: Is there a difference in self-efficacy scores between college chemistry students use a technology-based application to conduct laboratory experimentation, and college chemistry students who do not? The null hypothesis stated: There will be no statistically significant difference in the means of *College Chemistry Self-Efficacy Scale* (*CCSS*) scores for the treatment group, which used a technology-based application in laboratory, and the control group, which did not use the technology-based application. Based on the results of the independent samples t-test and Levene's Test for Equality of Variances, hypothesis two was not rejected. Hence, students in the treatment group saw themselves no differently than students in the control group as measured by the *College Chemistry Self-Efficacy Scale* (*CCSS*). The results given in *Figure 4* shows that there was no significant statistical difference between groups.

A review of the literature conveys that much attention has been given to the effectiveness of technology-based teaching applications within science education, especially with elementary, middle, and high school instruction being at the focal point. However, a dearth of research has been dedicated to the investigation on the effectiveness of technology-based applications in postsecondary chemistry environments. Of the published studies on the effectiveness of technology-driven applications, most have yielded favorable reports that the inclusion of such applications has led to an increase in student achievement and self-efficacy. However, most studies that have been able to produce valid results on the use of technology-based instruction have come at the hand of elementary, middle, and high school instruction. This research study

was conducted to build upon the effectiveness of technology-based practices in educational research. Furthermore, it is imperative to understand that no other educational research mirrors the design of this present study. Novel in nature, this study reaches beyond what has been done to provide results that might provide the groundwork for the successful implementation of technology-minded applications in undergraduate programs of science.

As with this research study, evidence was provided that the inclusion of technology-based applications made little difference on student achievement or self-efficacy. To better understand the impact of this study, it is cogent to compare it with other studies.

Feng et al. (2011) reported that in their study on 96 eleventh-grade Chinese chemistry students, that the level of student metacognition is heavily dependent upon their conceptual understanding in chemistry. Students were divided into experimental (DBLE) and control (traditional) groups. Students within the experimental group were given the opportunity to work with data loggers (probeware) to better understand the chemistry concepts that were being presented to them. Students in the control group were given regular lecture-oriented instruction and assigned problems from their textbook to complete. Students' answers to a prescribed instrument were measured, and the data analyzed by means of various statistical tests. The results revealed that the use of technology-based applications, data loggers in this instance, contributed to higher gains by the experimental group (Feng et al. 2011).

In the Feng et al. (2011) study, student achievement increased with the inclusion of a technology-aided device, the data logger. Like this research study, students were given the opportunity to engage in effective learning that would possibly yield conceptual understanding of content-driven themes. However, unlike the Chinese students, the students of this study did not

show that the inclusion of technology made any statistically significant difference in achievement or self-efficacy.

Avraamidou (2008) reported on a large-scale research study conducted by SRI international. From the study, 102 teachers received a grant whereby placing one handheld computer in each of their students' hands. The emphasis from the study was placed on how well the handheld computers improved student learning. From the results, it was noted that 87% of the teachers agreed that student directedness in learning was increased, and that 75% of teachers agreed that the utilization of the handheld computer also assisted in student completion of homework (Avraamidou, 2008).

In this research study, only one instructor was responsible for the implementation of the treatment. Unlike, the SRI study, this study only contained a total of 52 students for investigation. Furthermore, only one device was given to each laboratory group within this study, whereas each member of the SRI study had their own. The difference can be made that students working in collaborative groups have to share devices and might not be afforded the opportunity for autonomy with a device. In other words, some students might become more skilled in using devices than students who have one device for themselves.

Zucker et al. (2008) reported that the Technology Enhanced Elementary and Middle School Science II Project (TEEMSS), a project that received its support by the National Science Foundation, conducted a study on the efficacy of computer and probeware use in elementary and middle school grades. From the study, 15 inquiry-based units were developed and given to more than 100 classrooms made up of over 60 teachers and thousands of students. Consequently, teachers who were involved in the study completed one academic year of teaching without the use of TEEMSS materials (computers and probeware), then taught the following year with the

use of TEEMSS materials. Comparison data was only available for 8 of the 15 units; however, the results described that four of the units showed a significant difference in student learning, while the other four units did not show significant learning (Zucker et al., 2008).

The TEEMSS study provided one of the closest correlations with the present research study. In the TEEMSS study, students were asked to use probeware to extend their learning on prescribed science units, and afterward their achievement was measured. This research study had a similar design for implementation of technology; however, students involved in the TEEMSS study were enrolled in grades 3-8. Obviously, the level of cognition between primary grades and undergraduate level work is not for comparison.

Yerrick (2010) reported on the effects of introducing science-based technology into a suburban New York middle school, during the 2007-2008 school year. In the study, middle school students were supplied with MacBook computers alongside probeware. The teachers at the middle school were trained on how to effectively incorporate new technology-based standards into their present science curriculum. In collaboration with researchers from the State University of New York at Buffalo, teachers incorporated strategies that would create a technology-based environment more conducive to science learning. After one year of implementation of the program at the middle school, data was gathered through a pretest/posttest instrument, a survey, and student interviews. It was noted that the increase in technology was directly proportional to the increase in student achievement as measured by the New York State Grade 8 Science assessment. Furthermore, approximately 80% of students agreed that they were satisfied or even very satisfied with how the use of technology-based tools fit into the scheme of classroom instruction. Overall, the findings from the New York state middle school project yielded positive results in student achievement and satisfaction (Yerrick, 2010).

When compared with the outcome of this research study, the results are incongruent. Students in the middle school program made significant gains in achievement and self-efficacy. However, the college chemistry I students involved in this research study did not see measurable differences from their use of technology; hence, students using traditional or typical equipment to carry out laboratory experiments produced results that were seemingly just as good as students in the treatment group. It is important to note that the middle school students were allowed to use the technology for the entirety of their school year, whereas the students in this study were limited to less than one college semester.

The National Center for Educational Statistics (2002) stated that data from the 2000 National Assessment of Educational Progress described a trend in students' scores for those who were given the opportunity to engage in science learning through the use of probeware. Among students enrolled in science coursework as seniors, those who were given the chance to use probeware one to two times per month had scored significantly higher than students who were not given the same opportunity. Likewise, students enrolled in science coursework as seniors and who were provided computers to be able to analyze data scored higher than students who were not given computers (National Center for Education Statistics, 2002).

In comparison to the student description as given by the National Center for education statistics, students involved in this research study were given probeware in order to collect and analyze data. Whereas the NCES reported significant gains for seniors through their manipulation of probeware, the undergraduate students of this research study did not reveal that the inclusion of technology made any difference on their achievement or self-efficacy. Unlike the seniors, students within this research study were not given computers to use in the aid of data collection and analysis. Therefore, the treatment within this research study was limited to

whether students used the technology-based approach to completing gas law experiements or not.

Linn and Hsi (2000) described the effectiveness of probeware through the examination of a project referred to as the Computer as Learning Partner (CLP) project. In this project, middle school students were assigned a specific curriculum embedded with the use of computers and probeware. For eight semesters they were given science content that required them to interact with technology. When compared, the students who had undergone the treatment of the CLP project outperformed their cronies that were members of a non-CLP group (Linn & Hsi, 2000).

One striking feature of the Computer as Learning Partner (CLP) study was that students were allowed to use technology frequently and consistently. Certainly, any misconceptions that students may have had with the use of technology were stymied through their ongoing exploration of science at the hands of the technology- infused curriculum. Obviously, the more students were afforded an opportunity to interact with the technology and each other; they became more experienced in the use of the technology and could therefore focus on the objectives of the content rather than intricacies of operating the equipment. For many of the chemistry students in this research study, it might have been their first time interacting with probeware; moreover, they were more concerned with correctly using the equipment than ascertaining the overall learning process. Consequently, this limitation could ultimately interfere with not only achievement, but self-efficacy as well.

Thornton (2008) summarized that research involving three physics curricula and the implementation on the use of technology-based applications such as probeware, created an environment in which students became research-based in their mission to understand the content that was being delivered to them. Furthermore, the frequency and variation with which physics

students employed the technology led to conceptual understanding and gains in achievement (Thornton, 2008).

The curriculum for the undergraduate chemistry class involved in this research study did not contain any directives on the use of technology to complete chemical laboratory experimentation. Outside of a general course description, the instructor involved in this research study possessed full autonomy in their decision of how the course was conducted, including the choice of laboratory experiments and how they would be investigated. The looming difference between the three physics classes discussed by Thornton, and this research study, was that the physics classes had guiding directives embedded within their curricula that called for the use of technology-based pedagogy. The three college chemistry courses in this study were only directed by the decisions of the instructor.

Schneider et al. (2002) conveyed that test scores from tenth and eleventh grade students had improved through the addition of probeware use to the curriculum. The results came from a comparison that was made between students who had been afforded the opportunity to use a project-based science curriculum. The curriculum, known as the PBS curriculum, included the use of computers and probeware for students to be able to interact, collect, and analyze data (Schneider et al., 2002).

Again, the inclusion of technology within a given curriculum has provided a springboard for the use of devices such as probeware and specialty sensors in many middle and high school settings. What is not only absent from the chemistry courses of this research, but also many other undergraduate courses in science, is the provision of a curriculum with technology-based instruction. Perhaps if a technology-infused curriculum were implemented into undergraduate

science courses, the students of those courses would see their efforts come to fruition at the hands of technology.

The National Research Council (2006) noted that in a 2006 report constructed for the National Science Foundation, that previous trends in science education has found the environment of the laboratory to be disconnected from normal classroom pedagogy. Furthermore, the study brought forth the concept that today's laboratories are still not connected to the flow of classroom instruction, and almost provide a typical experience for the learner. However, with the inclusion of a technology-based approach, students would be able to develop sharper reasoning skills, increase their understanding of course content, and nurture a deeper interest in science (National Research Council, 2006).

At the undergraduate level, most science laboratory experimentation is to be carried out at a different time than lecture. From this, students enter the laboratory feeling that they are somewhere else and that what is being completed in the laboratory does not connect with the instruction they received while sitting under the lecture of an instructor. Furthermore, some postsecondary laboratory settings have a different instructor to carry out prescribed experimentation than the person who is responsible for providing classroom instruction.

Capobianco and Lehman (2006) reported that when teachers were presented with an integration of technology in a teacher methods course, their ideology of using technology changed. From this, it was stated that for teachers to become effective facilitators of technology within the classroom, it is imperative that sound teaching practices become part of their strategy when planning effective pedagogy (Capobianco & Lehman, 2006).

As for correlation with the teacher methods course, the instructor responsible for integrating technology into the chemistry courses must also be aware of what creates effective instruction at the hands of technology.

With respect to theory in this research study, students were allowed to form groups of no more than three, but no less than two, regardless of control or treatment group. With respect to research question one and whether technology would provide a statistical difference in student achievement, the sociocultural theory provided that even though student interaction would not provide a panacea for difficult concepts for the less-skilled individual, it would provide a scaffold by which conceptual development for out of reach concepts could be achieved if only taken one aspect at a time. In other words, students with a greater understanding of the content being presented could assist less-skilled students; therefore, through these cognitive interactions, the less-skilled individual within the group could grasp concepts that were once unattainable.

Working within groups in a college chemistry setting provided the opportunity for individuals to interact. For students in the treatment group, individuals that might have been more comfortable using the technology could have translated its worth to the more technologically illiterate. Not only could the application of technology been delineated among group members, but also the content in which students were covering in each of the laboratory experiments could have also been dissected. Consequently, students in the control group, even though there was no addition of technology, could still serve as more knowledgeable others in helping less-skilled group members unsure of laboratory procedures transcend their limited level of cognitive state.

With respect to research question two and whether the inclusion of technology made any difference on student self-efficacy, Vygotsky's sociocultural theory provided that group

interaction could assist in helping to develop confidence in individuals who do not assess their worth within a chemistry laboratory as significant. Moreover, by individuals assisting each other in peer groups, students who are less confident have the opportunity to gain confidence in the how and what they are learning. This in turns provides these individuals a source of self-worth and support to the individual's self-efficacy as an effectively functioning member of a social niche, a laboratory environment in this case. Unlike achievement, students develop cognitive constructs about their learning and gain self-worth in areas that before the interaction of a *more knowledgeable other* were not self-reliant.

The students found within this research study were afforded the opportunity to work in groups to conduct laboratory work in college chemistry. Members of both the control group and treatment group were treated the same at the time of experimentation; there were no differences made with respect to group formation. All groups consisted of either two or three students. The only difference between the control group and the treatment group was the application of technology. So, each laboratory group of the control had to work together as a cohesive unit to complete both gas law experiments, and all members of the treatment group worked collectively with technology to complete the same laboratory assignments as the control group.

Through the comparison of sociocultural theory and this research study, it has been noted that students who are placed within groups have a higher chance of increasing their cognitive development as well as self-efficacy. The contrast between this study and Vygotsky's sociocultural theory was that there was no statistical significance measured that working in groups help foster an increase in overall student achievement and self-efficacy; thus, Vygotsky's sociocultural theory provided a framework by which students were examined within this research study through the lens of peer interaction. Overall, the application of the sociocultural theory

provided groundwork for assisting students in reaching higher achievement in the college chemistry laboratory.

Conclusions

Currently, multiple research studies have been done which focused on the efficacy of technology-based instructional tools and their possible outcome with student learning and achievement. From those results, evidence has been revealed that student academic performance, as well as an increase in student engagement, received positive remarks (Lapp et al., 2000; Pullano, Garofalo, & Bell, 2005; Brunsell & Hrejsi, 2010). However, findings have also been provided that conveyed that additional in-depth work should be fulfilled; furthermore, there have only been a limited number of studies surrounding the use of technology-based instruction within the science classroom as well as the actual nature of laboratory awareness (Thomas et al., 2004; Higgins & Spitulnik, 2008). Accordingly, educational institutions have concurred that the role of the undergraduate chemistry laboratory is an integral part to overall student learning; however, additional research has described that the importance of the laboratory environment may be in how effective the laboratory is in providing an environment that is conducive to a positive learning experience (Brewer & Cinel; Harrison & Mohr, 2013).

Research has conveyed the perception that for instruction to be sound within a technology-driven environment, much energy and dedication must be given in order to reach attainment of effectively incorporating technology into the curriculum (Gado et al., 2006). Other research has called for teacher responsibility in successfully incorporating pedagogy that was conducive to learning; furthermore, the directive was given that for teachers to be effective, they must first show fluency in the use of technology (Forssell, 2009).

The importance of this research study is that it has taken place at the undergraduate level. The focal point of prior research studies has been centered on the effectiveness of technology-based instructional design in elementary, middle, and high school settings. Little research has been conducted to investigate how these science-based tools may or may not be effective within postsecondary settings. Perhaps one rationale to explain why more undergraduate institutions of learning do not undergo a paradigm shift to teaching chemistry through the lens of technology may lie in the fact that faculty members are not comfortable using new apparatuses, or yet they may not have received formal training on how to effectively implement such pedagogy into their curricula.

Nonetheless, the fact still remains that undergraduate chemistry laboratories tend to shy away from the inclusion of these modern, technology-based applications. Even though most students efficiently make use of other general technologies such as email, wireless devices, and computers, there remains a significant variation when it comes to students using technology-based tools to both collect and analyze data within the undergraduate chemistry (Kennedy et al., 2008).

Therefore, the heart of this research study was to gain a deeper insight on the effectiveness of technology-based tools within the undergraduate niche. The findings given within this research study have provided a basis for appropriately examining effective pedagogical practices in postsecondary chemistry laboratory environments. From the data analysis of both student achievement, as well as self-efficacy, students did not gain any statistical significance when using technology-based instructional methods to conduct laboratory investigations when compared with traditional means. For instructors, this investigation has provided evidence that traditional ways of conducting chemistry experiments will not only

suffice, but also provide results that are equal to those of technology-based methods. This may be essential information as some institutions lack the professional development and funding to fully apply a technology-based approach to preexisting curricula. As students of science move toward careers that are science-based, it is imperative that the latest technologies be used. Taking on a real-world approach to instruction within the classroom and laboratory will give students a sense of learning that is meaningful. Without proper instruction and guidance by postsecondary institutions, students of the future may find themselves in an ever-increasing competition for gainful employment in scientific careers.

Therefore, the overall priority for undergraduate programs of science should be to prepare individuals to transition from college into career-ready niches. Though the tasks students will be asked to perform in a future job setting will not be exact repetition of the activities and experimentation they are presented with at the postsecondary level, they should be offered a chance to develop critical thinking skills, with the inclusion of technology-based tools. Thereby, students will be afforded the opportunity to ascertain a foundational understanding of what may be required of them beyond the collegiate level; moreover, those skills should enable individuals to excel in all phases of scientifically based career.

Implications

Overall, there was no evidence of statistical significance to warrant the use of technology-based tools within the undergraduate chemistry laboratory. This statement translates the idea that students can be just as effective in postsecondary chemistry experimentation given the right instruction and provision of necessary equipment. Furthermore, the extrapolation of data from the *Conceptual Problems Gases Test* (*CPGT*), as well as the *College Chemistry Self-Efficacy Scale* (*CCSS*), shows that students had equal success regardless of the presence or

absence of a treatment. From this, a generality can be made that if the research study was repeated with the treatment group becoming the control group, and the control group becoming the treatment group, the data would provide that there would still be no statistical significant difference between the groups. In other words, if all the students of each group, the control and treatment, were to exchange places, all students would have just as good of an opportunity to succeed regardless of the presence of technology.

Several reasons have been provided in the research for the gap that exists between the inclusion of technology in the classroom and achievement. Barnes et al. (2010) stated that student perceptions would need to change for them to be able to gain sufficient learning at the hands of technology in the science classroom. Students must possess the ability to recognize that the influx of technology and the changes that it brings are for their good, and to be used to further deepen their prior understanding of scientific concepts; consequently, their livelihood within a technology-based laboratory environment is directly proportional to maintaining a positive attitude toward the application of technology-based tools (Barnes et al., 2010). In the article *The Effects of Problem-Based Learning Instruction on University Students' Performance of Conceptual and Quantitative Problems in Gas Concepts,* it was described that students' performance in the classroom and laboratory were sometimes directly linked to their motivation. In this case, student performance could be ascertained as both achievement, as well as self-efficacy. However at other times, student performance was indicative of students not having the ability to examine science at a deeper level (Bilgin, Senocak, & Sozbilir, 2009).

From this research study, it has been shown that the use of technology did not provide enough stimuli to statistically change how students felt about working in the laboratory as measured by the College *Chemistry Self-Efficacy Scale* (*CCSS*), nor was there any difference

made on achievement as measured by the *Conceptual Problems Gases Test* (*CPGT*). Perhaps the lack of motivation or even unpreparedness on the part of the student stymied their success. Another reason why the gap in learning exists as presented in the research study is due to the fact that there was only one instructor responsible for utilizing the technology in a way that student learning was increased. Even though the background of the instructor was validated by their years of service in teaching chemistry, and having had received some professional development in the use of technology-enhanced tools, some students may not have responded to how the technology was presented. This could be due to disconnect between topics the instructor received in professional training, and those topics where the instructor received no prior training. In other words, instructor insecurities might have been conveyed to the students if the instructor conducted laboratory sessions before first receiving formal training specific to the experiment being given.

Irving (2005) concluded that a staggering 50% or more of first year chemistry included never received any formal training or professional development on how to effectively incorporate technology into the classroom. Therefore, some of the problem as to why students do not smoothly adhere to new pedagogical methods may be because instructors do not feel confident that the technology will be as successful as traditional methods, and this attitude is translated to the learner. Furthermore, it is important to note that student achievement or self-efficacy may not solely depend on an instructor's knowledge of technology, but also with the efficacy with which an instructor discloses technology-based approaches in the classroom and laboratory; moreover, hands-on learning and the use of technological tools in science instruction is directly linked to how well the teacher not only needs to know how to use technology, but also know when to infuse technology into the science curriculum. Obviously, teachers must receive

proper training for the use of technology to have beneficial results within the classroom alongside becoming an integral part of the educational experience (Dani & Koenig, 2008).

Therefore, the gap that exists in the use of technology-driven applications within an undergraduate chemistry laboratory and their effectiveness on student achievement and self-efficacy will remain open. By the close examination of the results of this research study, there is little evidence to purport that the treatment made any difference in the total outcome of student achievement and self-efficacy. Beyond statistical analysis, these findings translate the ideology that even though current undergraduate students are immersed in a technologically advanced world, they do not solely depend on technology for academic support and extension of learning. Perhaps the way in which the technology is used within the classroom does not closely mirror the application of various technologies, which are commonplace to the student.

Limitations

The limitations that arose in this study were participant selection, location, time constraint, and the use of a posttest-only design to measure student differences. Each of these limitations was examined in respect of their influence on the research study, as well as both internal and external validity threats that may exist.

The total sample population measured in this research study was limited to 52, of which, 22 were in the treatment group and 30 were in the control group. The low sample size was due to the investigation only being conducted at one research site; therefore, the population was gathered from students taking college chemistry I during the fall semester of 2014. Due to participant selection, a selection bias could provide a threat to the external validity from the small sample size as the population may not truly represent other sample sizes in different institution and at different times throughout the academic year. However, due to results from the

student demographics survey, the total population was noted as statistically similar. Hence, from the results of the demographics survey, 90.4% (n = 47) of students were between the ages of 18 to 24. Three-fourths of the students (75%, n = 39) were male. The examination of ethnicity provided that 88.5% (n = 46) of the participants were Caucasian. Relative to marital status, 82% (n = 41) of participants were single or had never been married. Seventy-six percent (n = 38) of the students had employment outside of the school environment. The college chemistry I course was not the first college science course for 96.2% (n = 50) of the population; furthermore, 76.5% (n = 39) of the students examined in the study considered a science-based career to be their first choice of college major. Overall, a close examination of the generalized student participant in this research study would reflect a single, Caucasian male between the ages of 18-24, who had already completed at least one college science course, was a science major, and had a job. This being said, the average college chemistry I student found within the parameters of this research study was identified as being generalized, and if the research study was repeated with a similar focus group, the results should be similar. A possible threat to the internal validity of this study with respect to a low sample size of 52 participants could be that the population does not represent a true sample when compared with a randomized design. Because students were already placed into their respective courses at the onset of the fall 2014 semester, the sampling was not random, but non-random. One could question that because the population was not selected randomly that the treatment would not have the same effect that it may have had peradventure random selection was utilized. However, this threat is reduced because all students who participated in this research study share common backgrounds as given by the demographics data. Due to the protocol in which students take courses in college, the researcher could not anticipate the same population being enrolled in college chemistry I more than one

semester. As the fall semester has the highest population of students enrolled in college chemistry I at this particular institution, it provided the highest possible sample number than any other semester during the college academic year of fall, spring, and summer.

In conjunction with the low sample size for the research study, another limitation was that the research study was location. As several studies have been conducted on the use of a technology-based instructional approach within elementary, middle, and even high school levels, few of them have focused on the postsecondary level in chemistry; therefore, this research provided a novel framework within the context of student achievement and attitude at the postsecondary level in chemistry laboratory experimentation. Because this institution only represented a small fraction of the institutions in the southeastern United States, the likelihood of the results being replicated at another location and time served as a possible threat to external validity. Perhaps the rationale behind why many studies have not been conducted at the postsecondary level is because most college chemistry courses that require laboratory have not accepted the notion of using simple probeware to replace traditional laboratory means of collecting and analyzing data. Even if multiple college institutions subscribed to using items such as gas sensor probeware, the means by which instructors both teach students to collect and analyze their findings may differ due to differences in such things as course rigor, course goals, instructor knowledge and experience in using technology, and student training. Perhaps better results may be examined if multiple institutions were examined on their use of technology-based tools through a time-series or even longitudinal studies. An identified threat to the internal validity was that the treatment results may not be accurately measured based on the prior learning of students. In other words, some students who participated in the study could have come from different backgrounds where the inclusion of technology may have been introduced.

However, most students who attend this institution come from similar public school backgrounds from the surrounding area. Therefore, students who were primed to technology may bring prior knowledge into the research study; however, as measured by independent t-tests, there were no observable difference between achievement and self-efficacy.

This research study focused on the effectiveness of the inclusion of science-driven technology at the postsecondary level. One concern is that the researcher was under a time constraint. Limited time availability reduced the efforts to examine the treatment effect over multiple topics within undergraduate chemistry. As technology-based equipment is designed to measure a world of variables such as temperature, pH, and dissolved oxygen, this research study only focused on how well students performed, as measured through the *Conceptual Problems Gases Test* (*CPGT*), or how they perceived their self-worth through the *College Chemistry Self-Efficacy Scale* (*CCSS*). Both of these instruments assessed student information within the unit on gas laws only. Because instruction at the college level is high-paced, there was not sufficient time to further incorporate extended research in various areas of chemistry such as stoichiometry, acids and bases, and bonding. This time constraint was placed upon the researcher by not only the pace of the college chemistry I course, but also due to the fact that there is so much information that is to be covered within a given semester. A possible threat to the internal validity of the study was that the results of the independent t-tests may have differed if students had been allowed to use the technology-based approach for a longer amount; hence, the effectiveness, by which students could have collected and analyzed data, may have increased as their understanding of the application of sensors and probes became more user-friendly. However, because the research study did not measure effectiveness of technology-driven applications over an extended period of time, less time was provided for students to drop out of

the research study; therefore, the mortality threat was lessened. A possible threat to the external validity because of time constraint was that the study might not have accurately portrayed treatment results if the study was replicated at a different institution within different time constraints.

The final limitation to be discussed was the choice to use a posttest-only design to gather data. If a pretest had be given prior to the onset of each of the two laboratory experiments, then student achievement data may have better reflected true learning. In other words, if students had been given a pretest before the inclusion of the treatment, the score from that pretest could have been compared against the scores of the posttest. This comparison would help to support the notion that students were ideally the same before any manipulation. Because a pretest was not given in this research study, we can only provide assumptions that all students at the onset of the research were statistical the same based on their backgrounds. This assumption is a risk to the internal validity of the study. However, the result of their true learning may not have been accurately measured due to the fact that we do not know how much they knew prior to experimentation. If the research study was repeated in other areas of the United States or even other countries, a generalization of the population may not be acceptable as different areas have greater diversities within the demographics; hence, this threat to external validity must be assumed as possible.

Recommendations for Future Research

For future research studies, there are several recommendations that should be made to better investigate the use of technology-based applications in undergraduate science courses. First, more studies should be conducted not only in undergraduate chemistry, but other science courses such as biology and physics. As most science coursework at the undergraduate level

requires a laboratory session to successfully gain semester credit hours, the platform for research in different science courses is available. Another recommendation for further research is to include more students in the total population. As this research study included a total of 52, higher sample numbers could provide more power as reflected in a statistical analysis, and therefore stronger validity to a study's impact.

Alongside a higher sample number, multiple institutions with diverse backgrounds should be investigated to assess whether technology-based pedagogy may have an effect on students of different ethnicity, geographic locale, socioeconomic status, and even gender. Additional studies within international contexts should also be investigated and compared against similar studies in the United States; consequently, if other country's methodologies provide more effective strategies for learning through technology-based designs, then a call for action should be made.

Still, additional studies may also include a different research design. Particular to this research, the use of a nonequivalent control group with posttest design was used due to the assignment of students to each chemistry course; therefore, the ideal randomization of students was not possible. Future studies may include different design strategies that would provide better blending of students to ensure true randomization. An additional recommendation for a future study would be to examine what effect a professional development program would have on preparing teachers to deliver technology-based pedagogy more effectively, and in turn the effect on student achievement and mastery of science content. Lastly, research designs including longitudinal and case studies may peer deeper into how students truly perceive learning at the hands of technology within the science laboratory. This research only focused on one unit in chemistry, the gas laws, and was measured in less than one college semester. If more units could

be examined and the effects of technology measured over a longer period of time, the results may yield a different picture than was conveyed in this research study.

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APPENDIX A

Conceptual Problems Gases Test Permission Letter

On Fri, 11 Apr 2014 16:25:40 +0000, "Byrum, Darrell Scott" wrote:
Dr. Bilgin:

I hope I am using the correct email. I tried contacting you at the university where you work; however, due to language barriers I was unable to reach you. I am currently working on my dissertation at Liberty University in Lynchburg, Virginia (USA). The focus of my work is on the effectiveness of digital probeware in the chemistry laboratory. While conducting research, I discovered that two of the instruments that I need in order to conduct my research are from your works. The two instruments needed are the Chemical Equilibrium Achievement Test (CECT) and the Conceptual Problems Gases Test (CPGT). As both of these instruments align with my writing and research, I ask your permission to include them in my dissertation. Therefore, may I have your permission to use the assessments, and if so, could you please attach them in your reply? I certainly appreciate your consideration as well as the work you are doing in the field of science education. Thank you very much for your consideration in helping me achieve my goals.

Thanks again,

Darrell Scott Byrum

From: ibilgin@mku.edu.tr
Sent: Thursday, April 17, 2014 4:48 AM
To: Byrum, Darrell Scott
Subject: RE: Permission

Dear, Darrell Scott Byrum
I am sending you Conceptual Problems Gases Test (CPGT) as an attachment file. Also I am looking for Chemical Equilibrium Achievement Test if I find it, I will send it you. I think that it will be helpful for your studies.
Best,
İbrahim Bilgin

APPENDIX B

Permission Correspondence for the *College Chemistry Self-Efficacy Scale (CCSS)*

Re: CCSS Permission Request
Esen Uzuntiryaki <esent@metu.edu.tr>
Sat 3/1/2014 8:32 AM

To: Byrum, Darrell Scott <dsbyrum@liberty.edu>;
Dear Darrell,

You can use the CCSS. Thanks for your interest. Good luck in your studies.

Esen

Sent from my iPhone

On Mar 1, 2014, at 4:44, "Byrum, Darrell Scott" <dsbyrum@liberty.edu> wrote:

Dr. Uzuntiryaki Kondakci:

My name is Darrell Scott Byrum and I am a doctoral candidate at Liberty University in Lynchburg, Virginia, USA. After looking over the College Chemistry Self-Efficacy Scale (CCSS), I have come to the conclusion that this particular instrument would be beneficial to implement in my current dissertation. Therefore, what do I need to do to gain permission to use this instrument in my current research study?

Thank you,

Darrell Scott Byrum

APPENDIX C

LIBERTY UNIVERSITY

INSTITUTIONAL REVIEW BOARD

September 19, 2014

Darrell Scott Byrum
IRB Exemption 1969: The Effects of a Technology-Driven Science Application on Student Achievement and Self-Efficacy in Postsecondary Chemistry: A Quasi-Experimental Study

Dear Darrell,

The Liberty University Institutional Review Board has reviewed your application in accordance with the Office for Human Research Protections (OHRP) and Food and Drug Administration [FDA] regulations and finds your study to be exempt from further IRB review. This means you may begin your research with the data safeguarding methods mentioned in your approved application, and that no further IRB oversight is required.

Your study falls under exemption category 46.101 (b)(2), which identifies specific situations in which human participants research is exempt from the policy set forth in 45 CFR 46:

> (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

Please note that this exemption only applies to your current research application, and that any changes to your protocol must be reported to the Liberty IRB for verification of continued exemption status. You may report these changes by submitting a change in protocol form or a new application to the **IRB** and referencing the above IRB Exemption number.

If you have any questions about this exemption, or need assistance in determining whether possible changes to your protocol would change your exemption status, please email us at irb@liberty.edu.

Sincerely,

Fernando Garzon, Psy.D.
Professor,
IRB Chair
Counseling

(434) 592-4054

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APPENDIX D

E-MAIL INVITATION TO PARTICIPATE IN RESEARCH STUDY

Date: September 9, 2014

Mr. John Doe

Chemistry Student

chemistrystudent@research.com

Dear John Doe:

As a graduate student in the School of Education at Liberty University, I am conducting research as part of the requirements for a doctoral degree. The purpose of my research is to gain insight on the effects that technology has in certain areas of chemistry. Specifically, I want to know if the use of technology within the chemistry laboratory will have an affect on student achievement and self-efficacy, and I am writing to invite you to participate in my study.

You have been chosen to receive this invitation because you are currently enrolled in college chemistry I. If you are willing to participate, you will be asked to complete a short demographics survey, two assessments about chemistry laboratory, and a follow-up scale (survey) about yourself. From the onset of the study, it should only take approximately 2 weeks for you to complete the requested items above. Your participation will be completely anonymous, and no personal, identifying information will be required.

To participate, you will log in to your Blackboard account and follow the directions of your chemistry instructor. The directions will be simple and links will be provided periodically so that you may participate. A consent document will be located under your Blackboard course. This document will become available a few days before the onset of participation. The consent document contains additional information about my research, but you do not need to sign and return it. Please complete the survey within Blackboard to indicate that you have read the consent information and would like to take part in the study.

If you choose to participate, you will be automatically entered into a drawing for 5 Wal-Mart gift cards.

Sincerely,

Darrell Scott Byrum
Liberty University Doctoral Candidate

APPENDIX E

Demographics Survey

1. What is your age?

- 18 to 24
- 25 to 34
- 35 to 44
- 45 to 54
- 55 to 64
- 65 to 74
- 75 or older

2. What is your gender?

- Female
- Male

3. What is your ethnicity? (Please select all that apply.)

- American Indian or Alaskan Native
- Asian or Pacific Islander
- Black or African American
- Hispanic or Latino
- White / Caucasian
- Prefer not to answer

4. Which of the following best describes your current relationship status?

- Married
- Widowed
- Divorced
- Separated
- In a domestic partnership or civil union
- Single, but cohabiting with a significant other
- Single, never married

5. What is the highest level of education you have completed?

- Graduated from high school or equivalent such as GED
- 1 year of college
- 2 years of college
- 3 years of college
- Graduated from college
- Some graduate school
- Completed graduate school

6. Are you currently employed outside of school?

- Yes
- No

7. Is this your first college science course?

- Yes
- No

8. Would you consider your choice of college major to be science-based?

- Yes
- No