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# Effects of Hands-On Experiences on Student Achievement, Interest, and Attitude in Chemistry

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# EFFECTS OF HANDS-ON EXPERIENCES ON STUDENT ACHIEVEMENT, INTEREST, AND ATTITUDE IN CHEMISTRY

by

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## ABSTRACT

This study examined the effect of hands-on experiences on student achievement, interest, and attitude in chemistry. The researcher gathered data from 82 students enrolled in an East Texas high school chemistry course for the 2019-2020 school year. Historical data from five-unit tests were used to assess differences in mean achievement scores between test items aligned with hands-on laboratory experiences and test items aligned with computer-simulated experiences. An independent t-test and a paired t-test were used to statistically evaluate the data. The independent t-test showed no statistically significant difference. However, the paired t-test did indicate a statistically significant difference. To assess attitude and interest in chemistry, focus group interviews were conducted with one student from each of the seven participating classes. Transcripts of the interviews were quantized to analyze keywords and frequency of codes. Codes were cross-tabulated to find themes in the discussions. Analysis of the data revealed that students' interest in and positive attitude toward science increased after participating in hands-on laboratory experiences, while computer simulated laboratory experiences increased negative attitude and decreased interest in chemistry. Meanwhile, students perceived learning from both hands-on and computer-simulated laboratory experiences.

Key words: Hands-on laboratory experiences, computer-simulated laboratory experiences, attitude toward science, interest in science, high school chemistry

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# CHAPTER I

## Introduction to the Study

### The First Science Standards

Before the mid-1800s, science education in the United States was largely unregulated and disorganized. However, interest in science greatly increased near the end of the 1800s (Bybee, 2010), as the industrial revolution brought advances in science and technology. Relatedly, student enrollment in high schools more than doubled in the last decade of the 19th century to meet the growing need for skilled workers. In response to these changes, the National Education Association (NEA) formed the Committee of Ten on Secondary School Studies in 1892 (Spring, 2014). The Committee of Ten's final report established guidelines for the goals of science education, stating that all students should participate in science classes which included a laboratory component. Charles Eliot, who was the Chairman of the Committee of Ten and the President of Harvard, wanted to develop a specific list of the type of laboratory experiments that secondary students would be expected to perform. He employed the help of the Harvard physics department to develop an entrance exam that emphasized the list of laboratory skills as part of high school courses (Bybee, 2010). In 1889, the Harvard list, and a compilation of information from other universities, became the first set of national science standards (Bybee, 2010; Richardson, 1957).

**Standardization**

The 1900s brought a shift toward standardization and scientific management in schools (Spring, 2014). Cost-efficiency became a focus of administration, with the result being that science became a set of facts to be learned, rather than experiences to be understood (Bybee, 2010). This paring down of the curriculum neglected the teaching of science processes and resulted in students who had little to no understanding of the foundational principles behind the "facts" of science.

Progressive education is a theory that emphasizes learning by doing. John Dewey, who was a well-known proponent of progressive education, believed that human beings learn through a 'hands-on' approach. Dewey's pragmatic philosophical view holds that reality must be experienced. In 1910, Dewey discussed the role of scientific process at an American Association for the Advancement of Science meeting. Dewey (1910) proposed that science "has been taught too much as an accumulation of ready-made material with which students are to be made familiar, not enough as a method of thinking, an attitude of mind, after a pattern of which mental habits are to be transformed" (p. 122). Dewey goes on to say that, "surely if there is any knowledge which is of most worth it is knowledge of the ways by which anything is entitled to be called knowledge instead of being mere opinion or guess work or dogma" (Dewey, 1910, p. 125). Dewey believed that people need to experiment and use scientific process in order to understand.

**National Science Foundation**

“In the early 1950s the school curriculum, in particular, came under intense scrutiny and became an important ideological battleground on which partisan groups clashed as the nation’s survival seemed to hang in the balance” (Rudolph, 2002, p. 10). At the end of World War II, the National Science Foundation (NSF) was established to initiate, support, and promote basic scientific research and education (Mazuzan, 1994). However, science education gained more national importance when Dwight D. Eisenhower called upon Congress to increase funding to the National Science Foundation by five times. This act was intended to increase the quality of science education and the quantity of science and technology workers in the United States after the Soviet Union successfully launched the first satellite (Sputnik I) into space in 1957 (Eisenhower, 1958).

Jerrold Zacharias, a member of the United States Office of Defense Mobilization’s Science Advisory Committee, and a physicist at MIT, created a group that began the process of improving curriculum and instruction in science education. Even though the group’s ideas about education were considered radical at the time, the ideas have become integrated fully in all modern science education pedagogies (Spring, 2014). Zacharias believed science should not be presented as a body of unchanging facts to be memorized, but as a living discipline with which students engage. Although one goal was that students would learn science content, the other goal of the course emphasized the process of reasoning from empirical evidence. “The questions Zacharias hoped to get students to ask themselves at all times were: “How do you know? What was your ‘basis for belief’ in any assertion about how the world works?” (Rudolph, 2002, p. 122). These questions formed the most important lesson for any student leaving a science course: Students should understand that knowledge of the world is based on evidence.

**Laboratory Component of Science**

Zacharias asserted that students must understand that evidence drives knowledge. He believed evidence could be gathered by using a variety of materials, including films, slides, textbooks, ancillary reading, and laboratory apparatus (Haber-Schaim, 2006). The merging of laboratory activities and other materials would "enable students to develop a deeper understanding of the dialectical march from experiment to theory and back again" (Rudolph, 2002, p. 130). The National Science Teaching Association (2014) released a statement on the Next Generation Science Standards adoption in K-12 classrooms. The NSTA reports that forty-four states have science standards that have been influenced by the Framework for K-12 Science Education and the Next Generation Science Standards. Twenty states and the District of Columbia have adopted the Next Generation Science Standards. Relatedly, twenty-four states have developed their own standards based on recommendations in the NRC Framework for K-12 Science Education. The Texas Education Agency (2017) developed state science standards that contain statements specifying that students from kindergarten to upper-level secondary courses should act like a scientist, using laboratory materials to determine evidence and construct arguments from the evidence.

**Modeling Instruction**

Malcolm Wells, a high school physics and chemistry teacher, and David Hestenes, a theoretical physicist and physics education researcher at Arizona State

University began the modeling instruction method in the early 1980s (Wells, Hestenes, & Swackhamer, 1995). Wells became a “hands-on” teacher, always eager to build his own apparatuses that provided simple demonstrations (Wells et al., 1995). Wells decided to improve his teaching practice, so he went back to school to get his doctoral degree. While pursuing the degree he created Modeling Instruction.

Wells was already using a student-centered inquiry approach based on the learning cycle of exploration, invention, and discovery that was popularized by Robert Karplus (Wells et al., 1995). When Wells’ students did not perform well on a skill inventory, he decided to implement Hestenes’ theory of instruction with modeling as the central theme (Wells et al., 1995). Wells’ version of Modeling Instruction evolved into a laboratory-based method that was adapted to scientific inquiry. He used models to describe and explain phenomena rather than solve problems, teaching modeling skills as the foundation for scientific inquiry. Eventually, he blended the learning cycle and modeling into a systematic Modeling Cycle that is best described as cooperative inquiry with modeling structure and emphasis (Wells et al., 1995).

## Theoretical Foundation

The general notion of learning through experience is ancient. Sometime around 350 BCE, Aristotle wrote, “Anything that we have to learn to do we learn by the actual doing of it” (Aristotle, 2004, p. 91). In the 1970s, David A. Kolb developed a successful, four-stage theory of learning which begins with the concrete experience of actively experiencing an activity. Kolb’s research was largely based on the work of John Dewey, who believed in the unity of theory and practice (Kolb, 2013). Dewey believed sound

educational experience involves continuity and interaction between the learner and what is learned. According to Dewey, all principles by themselves are abstract, they become concrete only in the consequences which result from their application (Dewey, 1938).
In its latest report on science standards, the NRS asserts that by the time they reach Grade 12, students should be capable of conducting their own scientific investigations, forming a hypothesis, and constructing models or theories (NRC, 2012). The Next Generation Science Standards (NGSS, 2013), were developed by the National Academy of Sciences, Achieve, the American Association for the Advancement of Science, and the National Science Teachers Association. The standards are based on the Framework for K-12 Science Education and set forth the science skills and concepts every K–12 student needs to know. The K-12 Next Generation Science Standards were completed and released to the public in April 2012 after numerous state reviews and two public comment periods. The standards are not meant to replace a state's curriculum, but rather to serve as a guideline. While adoption of the standards is not mandatory, implementing the NGSS or at least using the guidelines as a reference, can help schools better prepare high school graduates for the rigors of college and careers. In turn, employers will be able to hire workers with strong science-based skills—not only in specific content areas, but also with skills such as critical thinking and inquiry-based problem solving (NGSS, 2013).
Doing science, rather than reading about it in text, or listening to it in lecture, engages students and allows them to test their own ideas and build their own understanding (Ewers, 2001). Labs provide student-centered activities for problem solving, inquiry, and exploration of phenomena. Based on these findings, it is difficult to understand why

science educators would implement teaching programs without integrating laboratory experiences. Hands-on science can be defined as physically doing something to learn (Satterthwait, 2010). Hands-on science is the best tool for teaching problem solving, offering real context, and making the neural connections that enhance creativity and critical thinking in a way that improves long term success (National Research Council, 2000).

Hands-on science is mainly used in classrooms as an instructional approach that involves activity and direct experience with natural phenomena or as an experience that actively involves students in manipulating objects to gain knowledge or understanding. One important pedagogical value of laboratory classes is that they facilitate students' learning in moving from the concrete facts and situations which they observe, to the abstract understanding of the principles or theories that are derived from the observation of these phenomena (Bates, 2015). Another reason laboratory instruction is pedagogically sound is that it introduces students to the crucial cultural aspect of science and engineering that all ideas need to be tested in a rigorous and particular manner for them to be considered 'true' (Bates, 2015).

Studies have been carried out to determine the learning approaches that will provide students with the means to acquire a deeper understanding of science concepts and equip them with the ability to apply that new knowledge in their daily activities (National Research Council, 2000). Inquiry-based, hands-on learning requires students to be engaged in activities that reflect methods of scientific investigation. The effective implementation of an inquiry-based learning method requires the active involvement of students in a learning environment where they make their own decisions and organize their own work. Not only do the students need to think critically, but they must also reflect and reason scientifically. According to the U.S. National Science Education Standards (National Academy of Sciences, 2012), students should have minds-on and/or heads-on experiences during hands-on activities. According to the Texas Essential Knowledge and Skills (TEKS), which were developed by the Texas Education Agency (TEA, 2017), high school students enrolled in a science class should use "scientific processes" in those classes.

> (1) Scientific processes. The student, for at least 40% of instructional time, conducts laboratory and field investigations using safe, environmentally appropriate, and ethical practices.
>
> (2) Scientific processes. The student uses scientific practices to solve investigative questions.
>
> (3) Scientific processes. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom (Texas Education Agency, 2017).

Appendix B is a complete list of all TEKS for high school Chemistry. The state of Texas mandates that students spend at least 40% of instructional time conducting laboratory and field investigations. Appendix C is a list of frequently asked questions and answers compiled by Texas Education Agency to address common concerns pertaining to laboratory and field investigations. This document is particularly useful when deciding whether activities meet the criteria to be considered laboratory and field investigations and specifically allows for the use of computer simulated lab experiences but stresses the importance of active participation in inquiry (Texas Education Agency, 2017). Science for All Americans, from AAAS Project 2061, states that schools and teachers do not need to teach more and more content but should focus instead on the essentials to science literacy and teach those concepts more effectively (AAAS, 2013). Participation in relevant hands-on science activities not only helps students make connections between science content and involves students in real-world science activities, but it is mandated by state and national guidelines.

The following studies show a relationship between hands-on student activities and student interest. The first study was conducted with eleventh-grade biology students to show whether performing hands-on activities in biology classes can influence students' interest in these activities. Analysis of the collected data showed that laboratory experience significantly and positively influenced interest in many biology topics (Holstermann, Grube, & Bogeholz, 2010). Sadi and Cakiroglu (2011) used experimental research with 140 sixth-graders. The results of this study showed an overwhelming increase in student achievement when hands-on activity enriched science instruction was used as opposed to traditional science instruction. Yet another study employed a mixed method of qualitative and quantitative research to examine the effectiveness of hands-on experiments in learning science using 22 fourth-year students at an international school. The study focused on evaluating the students' academic development and identifying students' intrinsic motivation to learn. The results showed that a number of students scored higher and remembered better when hands-on experiments were used. Using hands-on experiments also increased the overall level of participation and intrinsic motivation shown by students (Dhanapal & Wan Zi Shan, 2014). Relatedly, Townsend (2012) used surveys and questionnaires over a five-month period to assess the attitudes and understanding of the 26 fifth graders in her class. She found that using hands-on approaches to learning science caused a noticeable increase in her students' interest and understanding of science.

The philosophical assumptions involved in the approach to this research are largely grounded in post-positivism. The worldview of the research conducted in this study would be considered the scientific method and the research itself was science research. Post-positivism, unlike positivism, recognizes that we cannot be certain about our claims of knowledge when we are studying the behavior and actions of humans (Creswell, 2013). Post-positivism seeks to identify the cause or determinant of an outcome or effect. The intent is to narrow the ideas into a testable, definable set. Knowledge developed through a post-positivistic lens is based on observations and measurements of the real world (Creswell, 2013). Therefore, numerical measurements were taken using multiple-choice tests. Behaviors of individuals also were measured using a focus group composed of seven randomly selected students.

Post-positivism embraces the idea that the theories or laws which govern the world must be tested to be able to understand the world (Creswell, 2013). The theory being tested in this research is that hands-on experiences will improve students' assessment scores and their attitude and interest. The researcher collected experimental data that either supported or refuted this theory. However, since knowledge is conjectural, absolute truth cannot be found (Creswell, 2013). Therefore, the research either rejected or failed to reject the hypothesis. The knowledge gathered during the research described the causal relations of interest. Staying true to the philosophical underpinnings of post-positivism, high standards of reliability and validity were upheld in the research methods and conclusions in order to maintain the objectivity of the researcher and eliminate bias wherever possible.

## Problem Statement

The emphasis on standards across the United States has changed the dynamic in classrooms today for both students and educators. The primary focus in traditional classrooms today centers on preparing students for passing standardized exams and state assessments. As a result, many schools in the state of Texas are not holding teachers accountable and enforcing the state-mandated law that states, “The student, for at least 40% of instructional time, conducts laboratory and field investigations…,” (Texas Education Agency, 2019, Subchapter C). The problem was that science teachers may not be providing students with direct laboratory experiences for 40% of instructional time as outlined in state and national guidelines.

## Purpose Statement

The purpose of this research was to examine the relationship between hands-on laboratory experiences, interest in science, and scores on end of unit assessments of students enrolled in a Chemistry course taught in a rural high school. The study investigated the use of a hands-on laboratory program as a means of increasing student achievement and improving attitude toward science.

**Research Questions**

The essential questions this research sought to answer were:

1. How does students' performance on unit test assessments after participating in hands-on laboratory-based experiences compare to students' performance on unit test assessments after participating in computer-simulated laboratory experiences?
2. What impact does participation in hands-on laboratory experience have on students' attitude toward and interest in science?
3. What impact does participation in computer simulated laboratory experience have on students' attitude toward and interest in science?

**Significance of the Research**

This study allowed the researcher to draw conclusions regarding the use of hands-on laboratory experiments and establish whether or not this factor causes a change in the students' attitude toward and interest in science, and performance on unit assessments. Since other variables were controlled, the researcher could say with some confidence that the manipulation of the independent variable caused the changes in the dependent variables. The research was a rigorous, experimental design that was conducted using a sample of over 100 students. Hofstein & Lunetta (2004) stated that since 2000, there has been a plethora of research published that discusses the necessity of reform in science education. Relatedly, the effectiveness of inquiry-based instruction in science education has been widely investigated in the research literature for both experimental studies (Furtak, Seidel, Iverson, & Briggs, 2012; Minner, Levy, & Century, 2010) and correlational studies (Cairns & Areepattamannil, 2019; Jerrim, Oliver, & Sims, 2019).

However, the literature showing the correlation between the use of inquiry-based learning and the actual improvement of student achievement in science is scarce (Larkin, Seyforth, & Laskey, 2009). In chapter two, other research that has been done in this area is presented. However, most of the research has been quasi-experimental, done on a smaller scale, performed over a shorter period of time, or done by researchers rather than Chemistry teachers. The results of the current research of this study could add to the body of research done on the significance and importance of incorporating hands-on laboratory experiences into high school Chemistry classes.

**Assumptions**

The researcher presented both hands-on and simulated curriculum within Chemistry units without bias. The curriculum was the same for every student in every aspect. The sample size was adequate to assume an equitable representation of Caucasian, African American, Hispanic, and other ethnicities within each group as well as an equitable representation of males and females. The rural East Texas high school where this research was conducted has a demographic make-up of 30% African American, 22% Hispanic, and 47% Caucasian students. Fifty-two percent of the student population is economically-disadvantaged and 47% of the students are female. Each group had a similar composition of students of varying interests, skills, and performance levels.

**Limitations**

Because the research was done in a controlled classroom environment, the test subjects' reactions may not have been true indicators of their behaviors in a nonexperimental environment. Human error may also have played a role in the validity of the project results since eliminating all bias of the researcher and students is not realistically achievable. Additionally, controlling all extraneous variables may not be possible. Particularly, the health, mood, and life experiences of the test subjects may have influenced their reactions and those variables may not even have been known to the researcher. The researcher was also the teacher of the students in this study. Therefore, students may have reacted differently to the tests because they knew they were part of a research study. Furthermore, whereas experimental research is a powerful tool for determining or verifying causation, nonetheless, the research cannot specify "why" the outcome occurred.

**Delimitations**

Internal validity was produced by the strict adherence to procedures and methods used in quantitative experimental research, but those results may not be generalizable to the larger population since populations of both students and teachers, available resources, and classroom settings will vary. Adhering to a written and pre-planned curriculum and research design decreased bias and improved control over internal variables. Since all groups were of similar composition and size, extraneous variables of mood, life experiences, and health of the test subjects occurred somewhat equally across each group. Additionally, the sample size was large enough to accurately represent the general population of students at this school. Participation or non-participation in the research did not impact the students' grades, attitude of the teacher, or progress in the class.

## Definition of Terms

The purpose of defining the following conceptual terms was to set the foundation for the reader to understand the conceptual terms that were used in this study.

### Chi Square.

A chi-square independence test evaluates if two categorical variables are associated in some population. The test is used to try to refute the null hypothesis that two categorical variables are (perfectly) independent in some population (Laerd, 2019).

### Correlation.

Methods of correlation and regression can be used in order to analyze the extent and the nature of relationships between different variables. Correlation analysis is used to understand the nature of relationships between two individual variables (Creswell, 2013).

### Dependent variable.

A variable whose value depends on that of another (Creswell, 2013). The dependent variables in this study consisted of test results and attitudes toward science.

### Descriptive coding.

Descriptive coding is applied with reviewer generated descriptive codes. After generating descriptive codes, a reviewer can determine the frequency of Descriptive Codes by utilizing tools such as Word Cloud, a graphical representation of content analysis software programs or computer-assisted qualitative data analysis software programs that facilitate the counting of words or codes. Examining descriptive codes might help a reviewer to identify "key words" to explore the topic (Saldaña, 2016).

**Focus group.**

A group composed of six to ten participants, that is led by a moderator, for the purpose of discussing one topic or issue in depth (Atkeson & Alvaraz, 2018).

**Generalizability.**

The extent to which the findings of a particular study can be extended to, or are representative of, the larger population from which subjects were sampled (Creswell, 2013).

**Hands-on learning.**

The most common and accepted definition is that hands-on learning is learning by doing. It involves enabling the child's ability to think critically in a total learning experience (Bates, 2015).

**Hypothesis.**

A testable statement about the relationship between variables (Creswell, 2013)

**Independent variable.**

The variable that is changed or controlled in a scientific experiment or the variable the experimenter changes to test their dependent variable (Creswell, 2013).

**Mean.**

An arithmetic average calculated by adding scores together and then dividing this sum by the number of scores added (Laerd, 2019).

**Nonparametric tests.**

It is not advisable to rely on assumptions about the shape or parameters of the underlying population distribution based entirely on nonparametric tests (Laerd, 2019).

**Normal curve.**

A probability distribution of scores on a variable in which scores are symmetrically distributed about a sample mean (Laerd, 2019).

**Null hypothesis.**

The tested statement in which the independent or manipulated variable tested is presumed to have no effect on dependent or responding variable (The AP Biology Development Committee, 2001). In a particular study, for example, sample data, usually in the form of experimental and control group means, are evaluated against the null hypothesis that there is no difference between population group means. In experimental studies such as this one, the null hypothesis and hypothesis have parallel sentence structure.

**Null hypothesis significance testing (NHST).**

A procedure whereby the null hypothesis is either rejected or accepted according to whether the value of a sample statistic yielded by an experiment falls within a certain predetermined "rejection region" of possible values (Creswell, 2013).

**Parametric.**

Quantities such as means, standard deviations and proportions are all important values and are called "parameters" when describing a population. Since it is usually difficult to get data from the whole population, the exact values of the parameters for that population are unknown. It is possible, however, to calculate estimates of these quantities for samples. When they are calculated from sample data, these quantities are called “statistics.” A statistic estimates a parameter (Laerd, 2019).

**Relationship.**

From a research perspective, means that an individual’s status on one variable tends to reflect his or her status on another variable (Creswell, 2013)

**Reliability.**

The consistency or stability of a measure, the extent to which an item, scale, test, etc. would provide consistent results if it were administered again under similar circumstances. Types of reliability include test-retest reliability, internal consistency, and interrater reliability (Creswell, 2013).

**Statistical inference.**

The act of drawing conclusions about a population based on observed sample statistics (Creswell, 2013).

## Organization of the Study

The study was conducted during the 2019-2020 school year at a rural East Texas High school. The study involved between 100-125 Chemistry students and one Chemistry teacher who was the researcher. Letters explaining the research were sent home for signature by the parents or guardians of each student (See Appendix A). Students were not required to participate in the research. Participation was completely voluntary and students were not penalized in any way if they chose not to participate. All students participated in the same learning activities throughout the study.

A focus group composed of a random sample of students from each group discussed interest and attitude at the end of each unit. Every participant also took five multiple-choice tests created from an archived database of questions. The questions addressed the specific TEKS covered by the units of study in the research and were chosen from released STAAR Chemistry tests and the DMAC data base of test questions (explained further in Chapter Three). Results were statistically tested for differences that in order to analyze the extent and the nature of relationships between using hands-on computer laboratory experiments versus computer simulated laboratory activities and the effect on student test scores, attitude, and interest in science.

**Summary**

The researcher was a Chemistry teacher in a rural, East Texas high school. The participants were volunteers from the population of students enrolled in Chemistry classes for the 2019-2020 school year. The problem was that science teachers may not provide students with direct laboratory experiences for 40% of instructional time as outlined in state and national guidelines. The purpose of this quantitative, experimental study was to show a comparison of the effects of hands-on laboratory experiences to computer simulated laboratory experiences on student performance on assessments, and increased interest in and attitude toward science. Historical data from five, unit tests was used to compare academic achievement. A focus group was used in the Spring semester of 2020 to assess student attitude about science. The sample size of 120-125 students was large enough to be statistically valid and increase the generalizability of the study.

# CHAPTER II

## Review of Literature

### Introduction

Improving science participation and performance has received attention as a national priority for many years. For over 20 years, extensive federal funding of science and mathematics programs has occurred in an attempt to solve the problem of U. S. students lagging behind their international counterparts (PCAST, 2010). Educators and employers throughout the U.S. demand that science education produce a science-literate public capable of fulfilling the job needs in our increasing Science, Technology, Engineering and Math (STEM) fields (Adkins, 2012; Gates & Mirkin, 2012; Vargas, 2016).

Many states now include performance-based science assessments in their student assessment programs to determine the extent to which students can apply and use science knowledge (Finn, Julian, & Petrilli, 2006). These accountability initiatives are being implemented at the same time student attitudes towards science are steadily declining from elementary to high school (Ravitch, 2016). In 1996, the National Research Council (NRC), a division of the National Academy of Science, published National Science Education Standards to assist school systems in designing and implementing effective science programs in order to spark scientific literacy interest and enhance learning for all K-12 students. That document specifies learning and skills which all students need to be scientifically literate. National Science Education Standards called for major changes in science education programs. The National Science Education Standards are centered on the theory that science is an active, inquiry process that involves the dynamic involvement of students in activities that require scientific thinking and reasoning. French and Russell (2002) write

> Inquiry-based instruction places more emphasis on the students as scientists. It places the responsibility on the students to pose hypotheses, design experiments, make predictions, choose the independent and dependent variables, decide how to analyze the results, identify underlying assumptions, and so on. Students are expected to communicate their results and support their own conclusions with the data they collected (p. 1037).

These findings are important to science teachers because they show that using activity-based instruction improves student achievement.

However, activity-based instruction requires more instructional time, planning, and resources. Educators must create a different type of classroom environment for instruction to be effective. Additionally, administrators must be convinced that the changes seen in classroom structure and management are supported by research on improved science achievement for students. Activity and inquiry-based classes look different. Active participation involving physically doing experiments, recording data, discussing results, and inferring outcomes are integral parts of this type of learning.

Furthermore, different types of material are covered during lessons. Yet Turpin states that many studies have provided evidence that activity-based instruction is worth the instructional time needed and will improve student performance in science. (Turpin, 2000).

**State and National Requirements**

The Next Generation Science Standards contain verbs to indicate active, inquiry learning. Throughout the standards, students are directed to develop models and plan and conduct investigations. These activities require students to engage in hands-on, inquiry learning (Next Generation Science Standards, 2013). In Texas, the Texas Education Agency (TEA), with extensive input from educators and other stakeholders, developed a set of Texas Essential Knowledge and Skills (TEKS). TEKS detail the curriculum requirements for every course and are the state standards for Texas public schools from kindergarten to twelfth grade (Texas Education Agency, Curriculum Standards, 2017).

The process standards in the Texas Essential Knowledge and Skills (TEKS) for science describe ways in which students are expected to engage with the content. The student expectations addressing scientific processes are an integral part of the TEKS for science. In the State of Texas Assessments of Academic Readiness (STAAR) science assessments, which is the state's student testing program, there is not a separate reporting category for process skills. Instead, these skills are incorporated into at least 40% of the test questions from the content reporting categories. The main process skills included in the scientific processes strand of the TEKS are listed below (for a complete list see Appendix B):

(1.) Scientific processes. The student, for at least 40% of instructional time, conducts laboratory and field investigations using safe, environmentally appropriate, and ethical practices.

(2.) Scientific processes. The student uses scientific practices to solve investigative questions.

(3.) Scientific processes. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom (Texas Education Agency, 2017).

The science process skills form the foundation for scientific methods. These basic skills are integrated together when scientists design and carry out experiments or in everyday life when we all carry out experiments that yield accurate and reliable results. In practice, science process skills are an integral part of the conceptual understanding involved in learning and applying science. Identifying and discussing the skills which can apply to different subject-matter because of their central role in learning with understanding, is important for education and for life. The inquiry process takes advantage of the natural human desire to make sense of the world. This attitude of curiosity permeates the inquiry process and is the fuel that allows it to continue (Ash, 2000). However, process skills are not used discreetly. They are integrated into the content material. These skills strengthen and deepen the level of understanding and function as a link between previous knowledge and current knowledge. Learners utilize their senses during investigations by observing and gathering information. They also use higher level thinking in questioning and performing tests, and in inquiry and problem-solving as well as in gathering and interpreting data. Other methods of inquiry can also help them understand content. As students use these skills, they build new conceptual understandings. They experience the content of science.

**How People Learn**

Knowledge concerning human learning and development has grown rapidly, but much of what we know from research on learning and instruction has yet to affect the design and enactment of everyday schooling in the form of curriculum, instruction, and assessment (Goldman & Pellegrino, 2015). Suggestions for improving school and classroom practices have emerged from a consensus about the science of learning and development, outlined in a recent synthesis of the research (Cantor, Osher, Berg, Steyer, & Rose, 2018).

When the review is put into the context of a developmental systems framework, evidence can be synthesized from the learning sciences and several branches of educational research regarding critically examined strategies that support the kinds of relationships and learning opportunities needed to promote children's well-being, healthy development, and transferable learning (Darling-Hammond, Flook, Cook-Harvey, Barron & Osher, 2019). The developmental systems framework makes it clear how children's development and learning are shaped by interactions among the environmental factors, relationships, and learning opportunities they experience both in and out of school. These factors, along with the child's physical, psychological, cognitive, social, and emotional processes can either enable or undermine learning (Fischer & Bidell, 2006; Rose, Rouhani, & Fischer, 2013).

Critical information garnered from the science of learning and development asserts that the brain and the development of intelligences and capabilities have a capacity for adaptive change, and the "development of the brain is an experience-dependent process" (Cantor et al., 2018, p. 5). When people have experiences, new neural connections are made that create different ways of thinking and performing. The National Research Council's review (Pellegrino, Hilton, & National Research Council, 2012) indicates that the kind of learning that supports higher-order thinking and performance skills needed for the 21st-century is best developed through inquiry and investigation, application of knowledge to new situations and problems, production of ideas and solutions, and collaborative problem-solving. Students need an important and relevant activity that scaffolds on their prior learning and experiences and actively engages them in differentiated tasks that facilitate an integrated and functional grasp of concepts that the student can apply in new contexts.

Since the goal is to have students understand conceptual knowledge at a depth where they can facilitate its use and application beyond the classroom, the material should be organized and learned in the context of a conceptual framework. Teachers must structure the objectives to be learned in meaningful ways so that students can assimilate the learning and transfer new skills to new situations. The teaching strategies that allow students to do this require careful integration of direct instruction, integrated with hands-on activities that kept students engaged in working with the material, built a level of increasingly complex problem solving, and assessed understanding to guide revisions. "Rich environments" that support brain development provide numerous opportunities for social interaction, direct physical contact with the environment, and a changing set of objects for exploration (National Research Council, 2000, p. 119).

**Experiential Learning Theory and Inquiry**

When considering experiential learning theory, David Kolb is ubiquitous. His work has been cited at least 95,000 times (as measured by a Google Scholar, as of February 23, 2020), and has been incorporated into many experiential programs. Kolb drew on the ideas of Jean Piaget, Kurt Lewin, and John Dewey when he developed his seminal work, *Experiential Learning* (Kolb, 1984). In his experiential learning theory, Kolb synthesized what he called "a holistic integrative perspective on learning that combines experience, perception, cognition, and behavior" (Kolb, 1984, p. 21). He asserted that learning is "the process by which knowledge is created through the transformation of experience, [and] knowledge results from the combination of grasping and transforming experience" (Kolb, 1984, p. 41). A crucial principle of Kolb's experiential learning theory is comprised of concrete experience, reflective observation, abstract conceptualization, and active experimentation, where a learner "touches all bases" (p. 41) in a cycle (see Figure 1).

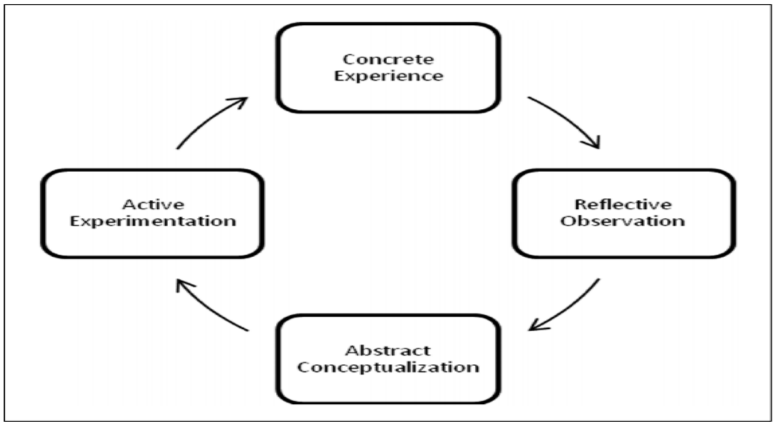


*Figure 1* Kolb's Experiential learning theory, (Kolb, D.A., 1984).

Another renowned work compiled by a group of experts in the fields of learning, psychology, and science, asserts that "people learn to do well only what they practice doing" (American Association for the Advancement of Science, 1989, "People Learn To Do Well," para. 1). They continued with, "Students cannot learn to think critically, analyze information, communicate scientific ideas, make logical arguments, work as part of a team, and acquire other desirable skills unless they are permitted and encouraged to do those things over and over in many contexts" (AAAS, 1989, para. 2). The argument that student inquiry is critical to transferable learning is based on insights from cognitive theories about how people learn and the importance of students making sense of what they are learning and processing content deeply so that they truly understand it (Bransford, Brown, & Cocking, 2004).

Inquiry approaches to learning require students to take an active role in knowledge construction to solve a problem or probe a question. Inquiry lessons vary in length, design, and implementation, but share the critical component of provoking active learning and student agency through questioning, consideration of possibilities and alternatives, and applications of knowledge (Darling-Hammond, Flook, Cook-Harvey, Barron & Osher, 2019). For epistemologically authentic inquiry in schools, the learner is immersed in a collaborative learning environment where problem-solving is connected to real science, alternative strategies are formulated, concepts are questioned, and problem-solving approaches are debated (Lave, & Wenger, 1991).

Leaders in science education must confront the persistent confusion that an inquiry orientation lacks intellectual rigor. Faultfinders may ignore the content and process of science and reduce science inquiry to its simplest form. Inquiry can become dubious and may not be aligned with viable and connected conceptual and factual understandings that should be an integral part of this method. Critics may contend that inquiry methods are inappropriate because the process requires more time than traditional classroom methods. Science teachers must clarify what the education community means by scientific inquiry. Inquiry centers on content goals, on the student understanding scientific inquiry and developing cognitive abilities, and on the instructional approaches that are instrumental in achieving these outcomes (Bybee, 2010).

Inquiry has been a clear aim of science education for 50 years (Bybee, 2009). In *A History of Ideas in Science Education*, George DeBoer states, “If a single word had to be chosen to describe the goals of science educators during the 30 year period that began in the 1950s, it would have to be inquiry” (DeBoer, 1991, p. 106). Inquiry provides a unifying goal that forms a social connection among advocates. Examples of inquiry in the science curriculum are one way to make abstract concepts more concrete (Bybee, 2010).

A clear and explicit use of inquiry is found in the Biological Sciences Curriculum Study (BSCS) 5E Instructional Model which purports to bring coherence to different teaching strategies, provide connections among educational activities, and help science teachers make decisions about interactions with students. The five phases are: engagement, exploration, explanation, elaboration, and evaluation (Bybee, Taylor, Van Scotter, Powell, Westbrook & Landes, 2006). H. J. Muller, a Noble laureate and BSCS steering committee member said, “The trouble is not that there is too much science but too much short-sighted application of it, too little dissemination of its deeper meanings, and too little appreciation of the need for proceeding by its method of free inquiry” (Muller, 1957, p. 252). Scientists Bentley Glass, H. J. Muller, Bruce Wallace, and John Moore have all supported the inclusion of inquiry, but Joseph Schwab actually implemented the theme of science as inquiry and wrote a foundational statement for curriculum development (Bybee, 2010).

BCBS programs linked the text with inquiry, replaced the rhetoric of conclusions with a narrative of inquiry, and organized laboratory work so that it conveyed the fact that science is inquiry. Students investigated questions for which the text provided no answers. Some labs included in the texts, supplemental laboratory blocks, and the research problem series were examples of inquiry, but inquiry is primarily implemented through the labs. Teaching science as inquiry became associated with doing labs where the overarching goal was learning concepts of science. By the early 1980s, the science professional lost sight of Joseph Schwab's rich inquiry theme. Science teachers began equating inquiry with doing a few labs. At the same time, new research was emerging to support the efficacy of teaching science as inquiry (Shymansky, Hedges, & Woodworth, 1990).

**Hands-On Laboratory Experience**

The American Association for the Advancement of Science (AAAS) reported in *Science for all Americans: A project 2061 report on literacy goals in science, mathematics, and technology* (1989), that progression in learning usually starts with the concrete and advances to the abstract. People learn most easily about things they can observe using their senses—visual, auditory, tactile, and kinesthetic. As their ability to grasp more abstract concepts grows, they can manipulate characters, use logical reasoning skills, and apply specifics to broader concepts. These abilities mature gradually, however, and most people continue to require concrete examples of new ideas for their entire life. Furthermore, concrete learning experiences are most successful when they occur in some closely connected context of the concept. Several studies in the literature show that hands-on activities help students to outperform students who follow traditional, text-based programs (Bredderman, 1983; Freedman, 1995; Glasson, 1989; Shymansky, 1989; Staver & Small, 1990; Stohr-Hunt, 1996; Turpin, 2000), to enhance their understanding and replace their misconceptions with the scientific ones (Coştu, Ünal & Ayaş 2007; Ünal, 2008), and to develop positive attitudes toward science (Bilgin, 2006; Bredderman, 1983; Bristow, 2000; Jaus, 1977; Kyle, Bonnstetter, & Gadsten, 1988; Schibeci & Riley, 1986). Additional literature shows that hands-on activities encourage learners' creativity in problem-solving, promote student independence, and improve skills in reading, math, and communication (Haury & Rillero, 1994; Staver & Small, 1990). Lebuffe (1994) emphasizes that children learn better when they can touch, feel, measure, manipulate, draw, make charts, record data and when they find answers for themselves rather than being given the answer in a textbook or lecture (Ates & Eryilmaz, 2011).

Science education includes process skills as an essential component of the curriculum. The AAAS determined that educators must engage students actively through numerous and varied opportunities for collecting, sorting and cataloging; observing, note taking and sketching; interviewing, polling, and surveying; and using tools such as hand lenses, microscopes, thermometers, cameras, and other common instruments. They emphasized measurement, including what to measure, how to measure, how to determine whether measurements are correct, and how to make sense of the results, as being vitally important to learning science. Since measurement is a hands-on skill by nature, it is considered best learned through hands-on activities (Allen, 2001). Additionally, the AAAS stressed the necessity of properly using tools (American Association for the Advancement of Science, 1989).

**Theoretical Rationales for Effect of Hands-On Science on Student Achievement**

A set of theories has been proposed to explain how hands-on science benefits student learning of science. Since scientific knowledge is often complex and abstract, physically manipulating objects can help bridge the gap between the concrete and the abstract (Ruby, 2001). Developmental theory posits successive stages of development through which humans progress. Since thinking during the second stage of development depends on concrete matters and advancement to the third, abstract stage, is facilitated through interaction with the environment, hands-on activities must help students progress to the final level (Darling-Hammond, Flook, Harvey, Barron, & Osher, 2019).

Relatedly, information processing in cognitive theory designates long-term memory for storage and short-term memory for immediate use. The ability to access information stored in long-term memory depends on how the knowledge is organized and the strength of the associations. Participating in tactile experiences adds a physical component to abstract knowledge, creating additional connections and improving retrieval (Ruby, 2001).

Another component of cognitive theory purports that information is filed away in long-term memory using organizing themes called schema. When learning, students may form schema which do not correspond to the real world. However, hands-on activities that require students to use knowledge to conduct experiments and achieve outcomes reduce the likelihood of the student having misconceptions about the knowledge and consequently filing the information in the wrong schema (Ruby, 2001).

Adding to these rationales, Darling-Hammond et al. (2019) in their research on developmental outcomes and the experiences needed to support them, cited the following as necessary elements:

> Meaningful work that builds on students’ prior knowledge and experiences and actively engages them in rich, engaging tasks that help them achieve conceptual understanding and transferable knowledge and skills; inquiry as a major learning

> strategy, thoughtfully interwoven with explicit instruction and well-scaffolded opportunities to practice and apply learning; well-designed collaborative learning opportunities that encourage students to question, explain, and elaborate their thoughts and co-construct solutions; (p. 104).

Each of these can be achieved in the science classroom through the use of hands-on, engaging, collaborative, laboratory experiences.

Protagonists of the rationales for including hands-on activities in science cite studies that seem to indicate that hands-on activities may reduce learning (Bohr, 2014: Dyrberg, Treusch, & Wiegand, 2017). Today, traditional laboratory method is used widely. Concannon and Brown (2008) mention that traditional labs only focus on scientific terminology, concepts, and facts. Furthermore, Concannon & Brown (2008) note that these labs contain detailed procedures that tell students what they will observe during experiments. In this method, students follow instructions written in the lab manual step by step and the outcome is pre-determined. Students already know the scientific theory when they start doing their experiments. In this format, students only think about following the directions written in the lab manual. For this reason, students cannot develop higher-order cognitive skills.

Despite the traditional laboratory method having some advantages like conducting many experiments in crowded classes within a limited time and using limited sources, this method has many disadvantages. The following research supports the assertion that students often cannot learn effectively since they just concentrate on the lab manual and they generally do not have real-life connections. Donaldson and Odom (2001) state that in a traditional laboratory, students' ability to follow instructions has been considered instead of their questioning, designing, conducting and analyzing an experiment. According to Madhuri, Kantamreddi, & Prakash (2012), the most important negation of a cookbook-style laboratory is it does not help students translate scientific outcomes into meaningful learning. The traditional laboratory method is inadequate for supporting the development which is its aim. According to Baseya and Francis (2011) changes in lab style can help students develop scientific processing skills and understand the nature of science.

Teachers should move away from traditional lecturing and cookbook-style laboratories to active learning strategies such as problem-based learning, cooperative learning, and inquiry-based learning which help students to develop their cognitive processes and help them to become lifelong learners (Tessier & Penniman, 2006). Inquiry-based learning promotes cohesiveness and supports students' as they apply their knowledge, understand real-world situations, and discover (Ketpichainarong, Panijpan, & Ruenwongsa, 2010; Toth, Ludvico, & Morrow, 2012). Inquiry-based learning helps educators to increase students' self-confidence and learning (Wall, Dillon, & Knowles, 2015). According to Arnold, Kremer and Mayer (2014) students need to develop scientific inquiry skills while learning scientific facts and principles. In inquiry-based learning environments, students are more active and they are guiding their own learning processes.

**Virtual Laboratory Experiences in Science Classrooms**

Since the creation of Operation Frog, a virtual dissection program created by Scholastic Software in 1984, software providers have been developing a variety of virtual labs for science classrooms that do not have the funds or equipment needed for actual laboratory experience (Kloza, 2000). Technology has changed education, affecting how students acquire the skill sets needed to prepare for college and a career and how educators integrate digital technological instructional strategies to teach. In response, online education, beginning as early as preschool and enduring through terminal degree plans, has evolved and grown (Delgado, Wardlow, McKnight, & O'Malley, 2015). The availability of a technological alternative to the traditional hands-on laboratory experience raises questions as to the validity of the experience and the comparability of the results produced. Educators must be conscientious in assuring a complete and comprehensive lab experience that will prepare their students for future study and careers in the field of science.

Many professional organizations in the sphere of science education have published their assessments and recommended guidelines regarding the use of virtual laboratories. The National Science Teaching Association (NSTA) supports virtual lab use for blended instructional activities for Grades K-16 in its 2008 position statement (NSTA, 2008), provided the experiences are coordinated with the educational process, correctly represent the nature of science, and comprise competently designed laboratory activities.

By 2010, the College Board Advanced Placement program began to endorse the use of virtual classes primarily because they increase accessibility for schools and students in districts with fewer resources where funds and equipment may not be available. The College Board regulates the quality of these courses by requiring schools to present a detailed syllabus for both AP courses and online programs (The College Board, 2010). Since AP science courses place an emphasis on hands-on labs, this task can be quite an obstacle. One of the first providers of online AP courses, Apex Learning, offers a blend of hands-on and computer-simulated experiences for its students, with the exception of chemistry (Davis, 2011).

The National Board for Professional Teaching Standards (NBPTS), emphasizes in the Fostering Science Inquiry, that students learn best by doing and must have many opportunities to engage in hands-on activities (National Board for Professional Teaching Standards, 2013). This includes making use of available technological resources to enhance the learning experience. Several states offer virtual high school science courses including AP biology, chemistry, and environmental science; however, students are also required to participate in some lab-based courses.

For example, according to the Texas Classroom Teachers Association (TCTA), Texas students must earn one credit in Biology, AP Biology or IB Biology. The other two credits may be selected from a list of approved courses that include Chemistry, Physics, and many CTE courses; one credit must be earned from a listed laboratory-based course (https://tcta.org/node/13847-graduation_requirements). The Florida Department of Education also mandates that laboratory investigations be included in science courses and requires students to complete three science credits, two of which must have a laboratory component (FLDOE, 2011). Every state establishes a curriculum with specific requirements for science. These curricula can be examined at each states' department of education website.

The National Academy of Sciences (NAS) formed the National Research Council (NRC) in 1916 for the purpose of bringing into cooperation government, educational, industrial, and other research organizations with the object of encouraging the investigation of natural phenomena, and increased use of scientific research in the development of American industries, the employment of scientific methods in strengthening the national defense, and such other applications of science as will promote the national security and welfare (www.nasonline.org). In its latest report on science standards, the NRS asserts that by the time they reach Grade 12, students should be capable of conducting their own scientific investigations, forming a hypothesis, and constructing models or theories. The use of virtual or computer simulated labs can help educators accomplish the NRC's emphasis on providing all students with equal access to quality space, equipment, and teachers to support and motivate them (National Research Council, 2012).

Even though virtual schools can provide course access to more students than is possible in a brick-and-mortar school, students earning high school science credit through an online school would be wise to determine if these classes will meet the learning objectives required by colleges and universities. Several professional science education organizations expect high school science courses to include a laboratory component and expect that these labs provide students with opportunities to acquire process skills and meet specific objectives. Some of these required experiences can be achieved in the virtual environment, such as simulations, data manipulation, and research. However, the questions about the importance of actual hands-on experiences of using and manipulating equipment, specimens and chemicals remain (Bohr, 2014).

The University of Texas at Tyler requires science majors to have “four units of science to include at least one unit of Biology, Chemistry and two advanced sciences such as Physics, Environmental Science, or Anatomy and Physiology” and, “strongly recommends three units of laboratory science including Chemistry and Physics” (Minimum high school units, para. 1). When students are not exposed to the hands-on labs that are provided in the regular classes, they may be missing valuable learning experiences that are an integral part of comprehensive science education. Individual school districts must be more alert to this potential deficiency in the virtual science course students are taking for credit. High school science teachers who conduct online science classes or dual credit classes may be the best resource available to make this evaluation and offer input into any changes for improvement that may be needed so that all students have equal access to a comprehensive science education (Bohr, 2014).

High school students who participate in online science as a foundation for college will need to be diligent and thorough when determining whether a class will transfer to their chosen college and be beneficial to their career plans. As more high schools include virtual science courses and labs in their programs, it is vital that educators examine the quality of the lab experience so that online students have the same learning opportunities as their face-to-face counterparts (Bohr, 2014).

A study done by Tatli and Ayas (2013) examined the effect of a virtual chemistry laboratory (VCL) on student achievement among 90 students from three different ninth-grade classrooms (an experimental group and two control groups). Study data were gathered with pre and post-chemical-changes unit achievement (CCUA) test, laboratory equipment test (LET), and unstructured observations. The collected data were analyzed using SPSS [version 16.0]. Comparisons were made within and between groups. It was concluded that the developed virtual chemistry laboratory software is at least as effective as the real laboratory, both in terms of student achievement in the unit and students' ability to recognize laboratory equipment (Tatli & Ayas, 2013).

In a study which measured student attitude, motivation, and self-efficacy after using a virtual laboratory program in undergraduate microbiology and pharmaceutical toxicology classes at The University of Denmark, researchers found mixed results. Students felt significantly more confident and comfortable operating lab equipment, but they did not feel more motivated to perform the virtual experiences versus real laboratories. Teachers noted that students were able to engage in discussions at a higher level after completing the virtual labs, thus indicating that virtual labs have potential to improve pre-lab preparation (Dyrberg, Treusch, & Wiegand, 2017). However, this study did not indicate that virtual laboratory experiences should replace hands-on laboratory experiences.

In another study, Brinson (2016) reviewed literature comparing learning outcomes using traditional labs (TL) to learning outcomes using non-traditional virtual labs (NTL). Brinson concludes that "the majority of studies reviewed (n = 50, 89%) claimed that student learning outcome achievement in NTL was equal to or greater than achievement in TL" and furthermore, virtual labs can be as effective as hands-on labs in learning science (Brinson, 2016, p. 218). However, this conclusion only held true within certain parameters. In reality, he attests students' need for prior physical knowledge to aid in self-construction of abstract concepts of lower-level difficulty, but "for higher levels of complexity they need an explicit representation of the abstract objects in the learning environment" (Olympiou, Zacharia, & de Jong, 2013, p. 575).

Brinson's review also suggests that educators need to be conscious of unnecessary use of NTL since learning with physical objects is clearly needed at some point. The crucial factor is determining where along the educational process that need lies. Students who completed online courses with NTL had slightly lower average course grades as compared to students who completed courses with TL. In contrast, when data were disaggregated by subject, students who completed biology and chemistry classes in the traditional format had statistically significant higher grades in these classes when compared to students in online classes who completed NTL. This would thus support greater learning outcome achievement in TL (Brinson, 2016).

**Science Technology Engineering, and Math (STEM)**

Science, Technology, Engineering, and Math (STEM) programs are being created daily across the nation. Myer and Berkowicz (2015) define STEM as "a shift in the philosophical framework for teaching and learning" … "defined by subject integration, project-based learning, relevancy for the lives of children, and structural flexibility" (p. xv). In the United States, the 2013 report from the Committee on STEM Education stressed that "The jobs of the future are STEM jobs," with STEM competencies increasingly required not only within but also outside of specific STEM occupations (National Science and Technology Council, 2013, p. vi).

Developing competencies in the STEM disciplines is thus regarded as an urgent goal of many education systems, fueled in part by perceived or actual shortages in the current and future STEM workforce (e.g., Caprile, et al., 2015; Charette, 2013; Hopkins et al., 2014; The Royal Society Science Policy Centre, 2014), as well as by outcomes from international comparative assessments (e.g., Organization for Economic Cooperation and Development, 2013). The comprehensive, integrated nature of STEM programs prepares students for 21st-century careers and equips them with the skills necessary to be ready for college (Myers & Berkowicz, 2015). "STEM-related disciplines are responsible for many of the societal innovations that make our world better," so it is clear that the United States needs to encourage more students to pursue STEM careers (Adkins, 2012, para. 2).

Sadly, less than one in three American college students will complete a STEM degree, even though the number of students who embark on a STEM path is closer to 40%. Many of them change majors before earning a degree (Adkins, 2012). Given increased national concern centered on student academic achievement in STEM, the number of college students pursuing degrees in STEM fields would be expected to increase. Why then have the numbers of college graduates pursuing and completing STEM or STEM related degrees not increased (Kuenzi, 2008; PCAST, 2010)?

"Why STEM?" Myer and Berkowicz (2015) offer a succinct answer, "Solutions to real problems can be developed and manufactured in classrooms, by students" (p. 19). They provide data to support their claim that STEM can solve many of our education system's biggest problems such as differentiation, nurturing critical thinking, producing students who are prepared for the global workforce, and even bringing more equity for gender, race, and socioeconomic differences. In the Report to the President, Engage to Excel, The President's council of advisors advocate and provide support for replacing standard laboratory courses with discovery-based research courses (Gates & Mirkin, 2012).

Learning theories, empirical evidence about how people learn, and assessment of outcomes in STEM classrooms all point to a need to improve teaching methods to enhance learning and student persistence. Classroom approaches that engage students in "active learning" improve retention of information and critical thinking skills, compared with a sole reliance on lecturing, and increase persistence of students in STEM majors. STEM faculty need to adopt teaching methods supported by evidence derived from experimental learning research as well as from learning assessment in STEM courses (Gates & Mirkin, 2012).

While our access to and dependence on technology grows, we continue to use outdated methods in our classrooms. STEM programs offer a potential solution to these problems with a bottom-up educational orientation. STEM models encourage student creativity and innovation. They offer "…a new way of working together, a new way to engage students, and local answer created by local leaders" (Myer & Berkowicz, 2015, p. 8). Interconnectedness and collaboration are key points in shifting educational processes and methodology with the goal of relating education to the environment of this century. Our schools are not serving the student population who will soon be our future. The message is that educators must change themselves and the system. Myer and Berkowicz offer STEM as the vehicle for change.

STEM is learner centered. Students must think critically and solve complex problems. Technology is an integral part of STEM programs; however, technology is not just a class. Advances in technology have changed the way people function and learn. STEM education involves using technology in every subject including using e-learning and blended models in flipped classrooms. In addition to this, constructivist theory, which proposes that people construct their own understanding and knowledge of the world, through experiencing things and reflecting on those experiences, is a methodology included in STEM teaching which has been proven to close gaps in learning. These methodologies are more inclusive and bring about greater student achievement for a higher percentage of students, which produces students who are better prepared for STEM careers and strengthens the economy (Myer & Berkowicz, 2015).

The National Science Education Standards (NSES), called for a shift in science teaching and learning (NRC, 1996). Traditionally science classrooms were teacher-centered, which was considered to be a less effective methodology (Johnson, Zhang, & Kahle, 2012). The NSES expressed that classrooms must become student-centered, with instructors who utilize varied instructional strategies, including inquiry, as a way to engage students in science contextually embedded in the real world (NRC, 1996). Inquiry science teaching requires students to develop researchable questions, plan investigations, collect and interpret data, and present results (NRC, 1996; Shulman, 1986). Additionally, the NSES were developed by a variety of science stakeholders who stated, "all students are capable of full participation and of making meaningful contributions in science classes" (NRC, 1996, p. 4). The integration of STEM calls for an inquiry-based classroom where students are actively engaged in the fundamental concepts of science and can "develop their understanding of science by combining scientific knowledge with reasoning and thinking skills" (NRC, 1996, p. 2). Additionally, student experience is necessary for inquiry, as stated on page 31, "inquiry into authentic questions generated from student experiences" is encouraged (NRC, 1996, p. 31).

The President's Council of Advisors on Science and Technology (PCAST, 2010) asserts that students need to be prepared for and inspired by STEM education. To accomplish this goal, schools must inspire students by engaging them in "exciting experiences... that reveal to them the satisfaction of solving a problem, discovering a pattern or phenomenon on one's own, becoming insatiably curious ..., or designing and creating an invention" (PCAST, 2010, p. 20). Furthermore, from these experiences, students need to be able to envision themselves as a "scientist, technologist, engineer, or mathematician" (PCAST, 2010, p. 20).

The National Science Teaching Association (NSTA), the leading organization for science teaching and learning, released their new position statement on STEM education and learning in February of 2020 (NSTA, 2020). NSTA released a list of recommendations for educators, administrators, parents, and all stakeholders as they develop and refine STEM education programs. National Science Teaching Association asserts that STEM education programs should be grounded in the tenets of constructivism supported by the findings of three decades of cognitive science and that integrated STEM education occurs when:

- Learning is viewed as an active, constructive process, and not a receptive one.
- Student motivation and beliefs are integral to cognition.
- Social interaction is fundamental to cognitive development.
- Knowledge, strategies, and expertise are contextualized in the learning experience (Declarations, para. 2).

The NSTA (2020) further declares that high-quality K–12 STEM education is an essential, relevant, and continual endeavor for all students. STEM education:

- enables analytical and critical thinkers;
- increases science, mathematics, and technology literacy;
- fosters the next generation of innovators and entrepreneurs;
- provides opportunities for students to engage in 21st-century skills of teamwork, collaboration, problem solving, communication, and creative thinking; and

- offers learning experiences in which students apply what they are learning in relevant, meaningful ways (NSTA, 2020, Declarations, para. 3).

**Attitude and Interest**

In a pilot study using Labster, an online learning lab platform, the researchers used a theoretical basis in motivational theories, to evaluate students' (*n* = 73) motivation and attitude towards the virtual exercises. Upon completion of the virtual laboratory activities, the students felt significantly more confident and comfortable operating laboratory equipment, but they did not feel more motivated to engage in virtual laboratories compared to real laboratories (Dyrberg, Treusch, & Wiegand, 2017).

Another significant study with 397 grade-school participants, monitored the cognitive and motivational effects within different educational instruction schemes, teacher-centered versus hands-on instruction, and hands-on instruction with and without a knowledge consolidation phase (concept mapping). The same content was covered in each scheme. A pre-test, post-test, retention test design was used both to detect students' short-term learning success and long-term learning success and to document their decrease rates of newly acquired knowledge. Intrinsic motivation was also monitored. Differences were found in short-term learning success, but after six weeks all students achieved similar learning outcomes. Scores of student interest, perceived competence, and perceived choice were high in all of the instructional schemes (Gerstner, & Bogner, 2010).

Holstermann, Grube, & Bogeholz (2010) conducted a research study to compare student interest when involved in hands-on activities versus students without hands-on experience. Twenty-eight hands-on biology activities using experimentation, dissection, work with microscopes, and classification were included in the research. A total of 141 students enrolled in 11th grade classes completed questionnaires on interest in the hands-on activities, their experience with each activity, and the quality of the respective experience. Students' interest in experimenting, working with microscopes, dissecting, and classifying increased when participating in hands-on activities. However, the study indicated that participation in the various hands-on activities influenced students differently. In seven of the 28 hands-on activities, a positive effect on interest was reported, however, in one case the hands-on work influenced students' interest negatively. Moreover, for the majority of the activities, no effect of experience on interest was found. The quality of hands-on experiences showed positive correlations with interest in the respective hands-on activities. The researchers concluded that lessons allowing for experiences with hands-on activities, which also interest students, have a positive effect on the students' attitude and should, therefore, be incorporated in instruction in a differentiated manner (Holstermann, Grube, & Bogeholz, 2010).

Darby-White completed a study in 2016 in response to the widely held belief that within STEM disciplines the laboratory has long been the major component for understanding theoretical knowledge and the demand for online courses has challenged educators to focus virtual science laboratories to meet the goal of the 21st century student. Darby-White's research evaluated the effect of virtual chemistry laboratories on students' learning outcomes, attitudes, self-efficacy, and gender differences. Sixty undergraduate science majors enrolled in a chemistry laboratory course participated in the study. The students performed three experiments both virtually and in the hands-on laboratory. Quantitative and qualitative data were gathered using an attitude survey, self-efficacy questionnaire, and semi-structured interviews. The quantitative results indicated that virtual laboratories can positively affect learning outcomes and students' attitude toward chemistry. Similarly, the qualitative results from the student interviews indicated that students' attitudes toward chemistry and self-efficacy increased after the integration of the virtual laboratory (Darby-White, 2016).

**Test Scores**

The effectiveness of hands-on activity in increasing student achievement was evaluated for a unit involving sense organs. The study was conducted using two teachers and a total of 140 sixth-grade students. Each teacher had one class where students participated in hands-on activities and a second class was treated as a control and received traditional instruction. The Science Achievement Test was administered to both the experimental and control groups as a pre-test and then as a post-test to measure students' achievement. A multivariate analysis of covariance showed hands-on activity-enriched instruction to be more effective than traditional instruction (Sadi & Cakiroglu, 2011).

The study by Tatli and Ayas (2013) examined the effect of a virtual chemistry laboratory (VCL) on student achievement using 90 student participants from three different ninth-grade classrooms. The study included an experimental group and two control groups. Data was collected from a pre and post-chemical-changes unit achievement (CCUA) test, a laboratory equipment test (LET), and unstructured observations. The data were analyzed using SPSS (version 16.0) and comparisons within and between groups showed the developed virtual chemistry laboratory software to be as effective as the real laboratory, both in terms of student achievement in the unit and students' ability to recognize laboratory equipment (Tatli, & Ayas, 2013).

Contradictory to Tatli and Ayas (2013), Ural (2016) found a positive effect of hands-on inquiry instruction when he studied the effect of guided-inquiry laboratory experiments on science education students' chemistry laboratory achievement. Ural's study was completed with 37 third-year, undergraduate science education students, as a part of their Science Education Laboratory Applications I and II courses. The research used a pre-test at the beginning of the academic year, followed by a post-test method after completion of the guided inquiry experiments. The results revealed a significant increase in students' academic achievement as a result of the applications (Ural, 2016).

The President's Council of Advisors on Science and Technology (PCAST) report, *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics,* which was released in 2012, provides a strategy for improving STEM education. The report is a response to the economic need for the United States to produce approximately one million college graduates with STEM backgrounds in the next decade in order to keep its historical preeminence in science and technology. The report discusses teaching methods at the undergraduate level, stating that a substantial and increasing body of research reveals that STEM education can be significantly improved through diversification of teaching methods (PCAST, 2010). These data show that evidence-based teaching methods are more effective in increasing academic achievement even in the ‘underrepresented majority’ (women and members of minority groups). The report proposes three strategies to address issues of student intellectual engagement and achievement, motivation, and identification with a STEM field. These three key strategies are to adopt STEM teaching strategies that emphasize student engagement, provide all students with the tools to excel and to diversify the pathways to a STEM degree (Jones, 2012).

**Summary**

Laboratory work has long been an underlying support in science that helps students relate conceptual knowledge with experimental processes (Domínguez, Miranda, González, Oliet, & Alonso, 2018; Finstein, Darrah, & Humbert, 2013). Including laboratory activities in a course gives students opportunities to design investigations, engage in scientific reasoning, manipulate equipment, record data, analyze results, and discuss their findings (Domínguez et al., 2018, Finstein et al., 2013; NSTA, 2007). Not only does the manipulation of physical objects enhance the vital understanding of concepts, but it also aids in keeping students engaged in the learning process (Cruse, 2012; Satterthwait, 2010; Zacharia, 2015). When students are performing science experiments, the use of tangible equipment requires physical sensorimotor movements that create motor patterns that guide reasoning which will lead to an understanding of scientific processes being studied (Kontra et al., 2015; Zacharia, 2015). The complexity of science content requires partaking in different inquiries with tangible objects to solidify the abstract concepts (Zeluff, 2011).

However, some researchers and educators focus on the disadvantages and question the effectiveness of hands-on labs for all learners (Dhanapal & Shan, 2014; Hennessy, Deaney, & Ruthven, 2006; Hawkes, 2004; Hofstein & Lunneta, 2004; Sawyer, 2006). Hands-on labs are more expensive, less safe, consume more time, and sometimes lead to erroneous conclusions due to equipment error, data collection errors, and students' focus (Dhanapal & Shan, 2014; Hennessy et al., 2006; Sawyer, 2006; Schwichow, Zimmerman, Croker, & Härtig, 2016). Rapid technological advances along with the aforementioned negatives of hands on experimentation have led to an increase in the use of online classrooms and virtual laboratories in science education (Dhanapal, & Shan, 2014; Keengwe & Georgina, 2013; Kontra, Lyons, Fischer, & Beilock, 2015; Nzai, Feng & Reyna, 2014; NEA, 2008; Rivera, 2016; Thompson, 2013; Zhang, 2014). "Online education has demonstrated comparable learning gains when analyzed to those of the traditional classroom, but research is mixed when reviewing students' ability to manipulate tangible laboratory equipment after participating in online experimentation" (Rivera, 2016, p. 209). Virtual learning environments can make abstract theories more concrete by linking various depictions of models and permitting students to observe variables that are not openly visible (Olympiou & Zacharia, 2012; Son et al., 2016; Tatli & Ayas, 2012).

Laboratory settings are definite physical spaces, where students interact with tangible equipment and materials, each other and the instructor (Pyatt & Sims, 2012). These experiences encourage the application of genuine scientific processes and procedures while stimulating interest through kinesthetic learning (Achuthan, Francis, &

Diwakar, 2017; Pyatt & Sims, 2012; Sari, Ay, & Yilmaz, 2015). Some researchers suggest the use of both hands-on and virtual labs depending on the concept to be learned (Chini, Madsen, Gire, Rebello, & Puntambekar, 2012). Considering the evidence that the incorporation of hands-on laboratory activities improves students' understanding, critical thinking, ability to think in a scientific way, and problem-solving abilities, educators should be following the state mandated requirement that 40% of instructional time is spent on laboratory experiences (Rivera, 2016; Tatli & Ayas, 2010; TEA, 2019).

# CHAPTER III

## Methodology

### Introduction

This chapter describes the research methodology employed to conduct the study. The review of literature revealed numerous examples of the benefits of active teaching methods in science courses on student performance and attitude and interest in science (Ates & Eryilmaz, 2011; Myer & Berkowicz, 2015; Ural, 2016;). A similar number of studies demonstrated the effectiveness of the computer simulated laboratory experience (Tatli, & Ayas, 2013; Myer & Berkowicz, 2015; Dyrberg, Treusch, & Wiegand, 2017). The purpose of this study, therefore, was to investigate the extent to which students who participated in hands-on lab experiences saw academic performance benefits and improvement in attitude and interest as compared to participating in computer simulations.

The general purpose of quantitative research is to collect numerical data in order to explain, predict, and investigate relationships between one thing (an independent variable) and another (a dependent or outcome variable) within a population (Mertler, 2015). The researcher attempted to describe current conditions or examine possible impacts or influences on designated outcomes. One of the underlying beliefs inherent in quantitative research is that the world is relatively uniform and unchanging and can, therefore, be measured in order to make broad generalizations about it. Facts and feelings can be separated from each other, and the world exists as a single reality (Mertler, 2015).

Conclusions drawn from quantitative studies cannot be reliable unless they can be proven by direct observation and measurement. Therefore, in quantitative research, nothing should be left to chance. The researcher remained as objective as possible. Only a few, specific, precisely defined, measurable variables were considered. Data collection instruments, procedures, and sampling strategies remained constant throughout the study (Mertler, 2015).

Techniques for data analysis and interpretation were entirely statistical. The focus was on the application of existing indices such as calculating average mean, using formulas such as the formula for standard deviation, and performing statistical tests such as the independent samples t-test. These indices provided consistent data regardless of the topic being studied or the variables (Seltman, 2018). Because generalizability of the results was important in quantitative research, research focused on a random sampling of participants in order to mirror populations. Reporting the results always occurs in a fixed, standard format (Mertler, 2015).

The purpose of this research was to determine if there is a relationship between levels of achievement in learning outcomes, attitudes, and level of interest of students participating in hands-on labs versus online labs. Levels of achievement were assessed through test questions from the Data Management and Communications (DMAC) and released STAAR questions. The literature review revealed paucity in research of hands-on labs using objective measures such as exams. In addition, research was lacking using high school chemistry students as participants. Attitude and interest were measured through a focus group discussion. This study was a quantitative, experimental research study designed to add to the literature comparing traditional hands-on laboratory experiences to computer-simulated laboratory experiences.

The data was compiled from a random sample of Chemistry students at an East Texas high school who participated in five units that each contained both a hands-on lab and a computer simulated lab. Test questions from each of the five different unit exams was used to collect data. The researcher reviewed both STAAR and DMAC test question coding to ascertain which TEKS were covered. Then the researcher reviewed the designated TEKS covered by the HO and CS lab activities. Test questions were specified as being aligned with content covered in hands-on (HO) labs or being aligned with content in computer simulated (CS) labs. The questions were multiple-choice and bubble-in numerical answer questions selected from released STAAR Chemistry exams and from the Region 7 DMAC database.

A focus group of students was interviewed. Their responses were recorded and used to assess their interest in and attitude toward science. “Quantitative data can be collected in a focus group setting when the focus group research is examining the attitudes and opinions of members of low incidence groups which are too difficult or costly to study using traditional quantitative research designs” (Leiman, 1988, para. 3).

This chapter outlines the research questions and hypotheses, research design, validity and reliability, and reporting the data.

## Research Questions

Research questions are descriptive, relational, and causal. The questions describe the situation or scenario as it currently exists, address a relationship between two or more variables, and allow the researcher to draw a causal inference (Balakumar, Inamdar, & Jagadeesh, 2013). The essential questions this research sought to answer were:

1. How does students' performance on unit test assessments after participating in hands-on laboratory-based experiences compare to students' performance on unit test assessments after participating in computer-simulated laboratory experiences?
2. What impact does participation in hands-on laboratory experience have on students' attitude toward and interest in science?
3. What impact does participation in computer simulated laboratory experience have on students' attitude toward and interest in science?

## Hypothesis

The hypothesis is an operational definition of a predicted answer to the research question. The hypothesis matches the concept with a measurement method or tool. By operationalizing the concepts of the study, the researcher makes the hypothesis testable (Creswell, 2013). When conducting a relational or causal study, the development of a null hypothesis is required. The hypothesis and null hypothesis use parallel sentence structure (Mertler, 2015):

**Null hypotheses ($H_0$).**

There will be no significant difference between the means of the assessment scores earned by students after the execution of hands on laboratory activities and those scores earned by the same students after the execution of computer simulated laboratory experiences.

There will be no significant difference in attitude toward and interest in science as measured by a focus group, after students participate in hands-on laboratory experiences.

There will be no significant difference in attitude toward and interest in science as measured by a focus group, after students participate in computer simulated laboratory experiences.

**Hypotheses ($H_1$).**

There will be a significant difference between the means of the assessment scores earned by students after the execution of hands on laboratory activities and those scores earned by the same students after the execution of computer simulated laboratory experiences.

There will be a significant difference in attitude toward and interest in science as measured by a focus group, after students participate in hands-on laboratory experiences.

There will be a significant difference in attitude toward and interest in science as measured by a focus group, after students participate in computer simulated laboratory experiences.

**Main Characteristics of Quantitative Research**

When using quantitative research methods, the data is usually gathered using structured research instruments. For the purposes of this study, unit test questions were chosen from released STAAR Chemistry tests and the DMAC test question bank. The questions chosen assess knowledge of the TEKS covered in the HO and CS laboratory activities for each of the five units. Additionally, a focus group composed of seven participants randomly selected from a stratified list of classes discussed attitude toward and interest in science as related to the HO and the CS labs. The research study could be replicated or repeated, given its high reliability. All participants in the study received the same instruction, activities, and assignments.

The units of instruction used in this research were part of the coursework for receiving Chemistry credit at an East Texas high school. A total of five units met the requirement of having both hands-on and computer simulated laboratory activities. Each of the units also included classroom instruction and other appropriate learning activities. Learning for each unit was assessed using a performance indicator and a multiple-choice test. For the purposes of this study, test questions were evaluated by the researcher and designated as either pertaining to content covered in the hands-on lab, content covered in the computer simulated lab, or content covered in other learning experiences. A cumulative score of the test items designated as covered in the HO labs was determined by finding the percentage of the 25 questions the student answered correctly. Likewise, a cumulative score for all items covered in the CS labs was determined for each student.

Data is in the form of numbers and statistics, arranged in tables, charts, figures, or other non-textual forms. The research project could be used to generalize concepts more widely, predict future results, or investigate causal relationships. The researcher used tools, such as computer software, to collect numerical data (Labaree, 2019).

## Research Design

A research design is a plan that considers when and how often data will be collected. The design takes into account the types of data which will be gathered and the sources of the data. Historical data was collected from student responses to test questions on five different unit test exams that were administered at the conclusion of the units. A focus group was used to make comparisons and discuss interest in and attitude toward science.

### Independent Variable

The aim of this study was to discover whether hands-on laboratory experiences effect students' assessment scores, attitudes, and interest in science. The study used an independent t-test to compare students' cumulative test answers aligned with HO laboratory experiences to cumulative test answers aligned with CS laboratory experiences. Therefore, the independent variable (the one variable the researcher is changing) was the use of hands-on laboratory experiences.

### Dependent Variables

As stated above, the purpose of this study was to discover whether hands-on and computer simulated laboratory experiences have a significant effect on students' assessment scores, attitudes, and interest in science. Therefore, the dependent variables in the research were students' test scores, attitudes toward science, and interest in science. After students participated in laboratory experiences, the researcher collected data from test scores, attitude and interest ratings, and key words used in focus group discussions. This quantitative data was examined to see whether the independent variable did in fact affect the dependent variables.

**Selection of Laboratory Experiences**

Two criteria were used to select the laboratory experiences for this study. First, it was established in the literature that "typical" science labs should be integrated into the science curriculum (Singer, et al., 2006). Because of the integration requirement (Singer, et al., 2006), the labs chosen for this chemistry class, and ultimately used in this study, were integrated into the high school chemistry curriculum. Second, in the case of general high school chemistry instruction, the labs chosen reflected the central theme of the general high school chemistry curriculum.

The laboratory experiences in the first unit focused on comparing solids, liquids, and gases in terms of compressibility, structure, shape, and volume. The computer simulated lab that covers these concepts was accessed at https://phet.colorado.edu/sims/html/states-of-matter/latest/states-of-matter_en.html. The hands-on lab for unit one was a stations lab that addressed physical and chemical properties and also extensive and intensive properties of matter. Lab experiences used in the second unit included a HO lab where students built models to show periodic trends in radius and a CS lab available at https://ptable.com/ that allowed students to explore periodic trends of ionization energy, and electronegativity. Unit three covered molecular structure and VSEPR theory. The CS lab for this unit was taken from PHeT at https://phet.colorado.edu/sims/html/molecule-shapes/latest/molecule-shapes_en.html. The HO lab had students test conductivity of ionic and covalent solutions and draw Lewis dot structures. The topic of the fourth unit was precision, accuracy, and significant figures. The HO lab in this unit had students determining precision and accuracy and the CS lab had them choose the correct number of significant figures in various measurements at https://teachchemistry.org/classroom-resources/measuring-volume-simulation and is located on the American Association of Chemistry Teachers website. The fifth unit used in this study covered moles, molar mass, and conversions. The CS lab accessed at http://chemcollective.org/activities/vlab/2 , engaged students in creating stock solutions and then diluting solutions to obtain a given molarity. The HO lab involved applying the general rules regarding solubility through investigations with aqueous solutions and investigating factors that influence solubilities and rates of dissolution such as temperature, agitation, and surface area. Details of each HO lab are located in Appendix D.

Similar studies have investigated the learning implications associated with the chemistry lab environment (Arasasingham, Taagepera, Potter, and Lonjers, 2004; Robinson, 2003; and Jensen, 2003). The labs chosen for this study specifically dealt with concepts the Texas Education Agency has included in the Texas Essential Knowledge and Skills as part of the curriculum outline for high school chemistry. The laboratory experiences were easily integrated into the lab environment and the high school chemistry environment.

**Hands-on labs.**

Specifically, the hands-on laboratory experiences chosen for this study are from American Association of Chemistry Teachers. The American Association of Chemistry Teachers (AACT) is a professional community by and for K–12 teachers of chemistry which allows educators to take advantage of connections with peers and access to quality classroom resources. AACT is “the world’s largest scientific society and seeks to transform science education in the United States" (AACT, 2019, para. 1). Membership is open to educators and anyone in the United States and around the world with an interest in K–12 chemistry education.

**Computer simulated labs.**

The computer simulated labs are also linked from the AACT website. The CS labs in units one and three are part of the PhET interactive simulations from the University of Colorado Boulder. PhET was founded in 2002 by Nobel Laureate Carl Wieman, the PhET Interactive Simulations project at the University of Colorado Boulder gives students and educators access to interactive science simulations. PhET simulations are based on extensive education research and engage students through an intuitive, game-like environment where students learn through exploration and discovery (PhET, 2020).

The computer simulated lab for unit two comes from Ptable. Ptable is a dynamic and interactive web application that contains numerous data subsets. The application also allows instant searches and a flexible interface. Source data on Ptable is reliable since it is acquired from primary sources and curated libraries such as the excellent

WolframAlpha. “Layout and presentation were reviewed by the world's foremost periodic table academic Eric Scerri and match the official layout offered by International Union of Pure and Applied Chemistry” (Dayah, 1997).

The computer simulated lab used in the fifth unit in the study was developed as part of the National Science Digital Library (NSDL) and is located on the ChemCollective website. Their goal is to support chemistry education through interactive and engaging online activities. The site provides “simulation-based exercises that promote learning and motivation by allowing students to explore and reinforce concepts” (Yaron, Introduction, para, 1). The project began in 2000 and evolved to create scenario-based learning activities designed to provide interactive, engaging materials that link chemistry concepts to the real world. The project leader is Dr. David Yaron, Associate Professor of Chemistry at Carnegie Mellon. The Virtual Lab was recognized in 2003 with MERLOT's Classic Award in chemistry and Editor's Choice for exemplary software across all disciplines. “In 2010, the ChemCollective won the Science Prize for Online Resources in Education (SPORE) award” (Yaron, Introduction, para. 4).

**Focus Groups**

Students’ science attitudes make reference to the favorable or adverse feelings and tendencies to learn science. Educators can use attitude measures concurrently with learning measures, to discern conclusions regarding the ability to produce the desired result of their instructional intervention. The measurement of students’ attitudes poses similar but distinct challenges as compared with measurement of learning, including determining validity and reliability of instruments and selecting appropriate methods for conducting statistical analyses (Lovelace & Brickman, 2013).

Some controversy surrounds the collection of quantitative data through focus groups because focus groups do not employ rigorous sampling plans and do not interview large numbers of respondents. However, Dr. James M. Leiman, who has his Ph. D. in Cognitive Psychology and Measurement and served as vice president of a creative marketing research firm, reported his methodology for using focus groups to collect quantitative data. Dr. Leiman's areas of expertise include survey sample design, multivariate statistical analysis, and the measurement and modeling of consumer preference and choice (Leimann, 1988).

According to Leimann, quantitative data can be collected in a focus group setting in support of a number of different quantitative research objectives. This is especially true when the focus group research is examining the attitudes and opinions of members of low incidence groups which are too difficult or costly to study using traditional quantitative research designs (Leimann, 1988). Furthermore, complex stimulus materials can be easily presented in a focus group, and data collection tasks can be easily accomplished (Leinmann, 1988).

Using the researcher as the moderator, group discussions about interest in and attitude toward science and perceived learning, can be used to collect data. Paper and pencil scales on which students attribute importance rating to experiences will be used to generate quantitative data. Following this activity, the moderator can stimulate discussion by having participants share their ratings and participate in reflective discussions about their experiences.

The requirements and limitations for using focus groups to collect quantitative data must be addressed. The first is the lack of a random sampling plan used for the recruitment of participants. For the purposes of this research, each student was assigned a number based on an alphabetized list of each class. The numbers were entered in a random number generator from https://stattrek.com/statistics/random-number-generator.aspx. Using the random number generator, one participant was selected from each of the seven classes. for a total of seven participants.

The Random Number Generator Program was used for stratified random sampling. Strata (in this case, classes) were created and one participant was sampled from each strata (Graziano & Raulin, 2019). Selecting one participant from each class insured a proportionate representation of each class. Many research studies focus on a limited set of issues of consequence only to members of the subgroup (experimental or control). Such groups tend to exhibit a greater homogeneity of response compared to groups recruited to discuss more general types of issues. The greater homogeneity of response of the groups has direct implications for the second area of concern: sample size. As the homogeneity of response increases, sampling variance decreases, and the sample sizes required to establish acceptable levels of reliability get smaller (Leibmann, 1988). Much focus group research is conducted with members of relatively small subgroups (Leimann, 1988).

**Collection of Data**

After the focus group of chemistry students was assembled, the researcher had participants make importance ratings on a questionnaire for a set of attributes. Following the paper and pencil questionnaire ratings, the researcher used the rating as a vehicle for getting participants into a general discussion of the research questions. Next, some actual examples of hands-on and computer simulated labs were presented. Participants rated the products using the same set of attributes as before (Leimann, 1988).

After participants rated the lab experiences, the focus group discussion took place for the remainder of the 30-minute time designation. The discussion was recorded, and key words were used to assess attitude and interest. The next step was to have the participants choose just one of the products, either the hands-on or the computer simulated lab. The participants were asked to rate their choice and non-choice. The quantitative analyses yielded tabulations of importance and product ratings, as well as attitudes and interests. These ratings, along with the thematic coding of the discussion, were used to compare attitude, interest, and perceived learning in science using hands-on or computer simulated lab experiences. An important consideration was that the introduction of the quantitative tasks did not detract from the groups and, in fact, added an additional dimension to the analysis.

**Stratified Assignment of Participants**

Stratification is a procedure whereby the sampling frame for a population is divided into separate subpopulation frames, in order to draw a separate sample from each subpopulation. Stratification entailed dividing the relatively large group of student participants into smaller groups, so that samples could be gathered separately from each. There were several good reasons for dividing the overall frame into subpopulation frames. Unlike sample selection, however, this division was not based on some random process. Both theoretical and practical reasons underlie the technique of stratification. The practical considerations are usually the more decisive. The two most common reasons behind stratification are to facilitate making estimates for subgroups and to increase sample precision (that is, to reduce the size of standard errors and confidence intervals). Guidelines on choosing stratification variables that would possibly improve the sampling were provided in the FT Sampling Guidelines Manual (OECD, 2013).

Stratification was done according to class periods. Period one has 14 students; period two has 18 students; period three has 21 students; period four has 22 students, period five has 16 students, period six has 19 students; and period seven has 18 students. One student was randomly chosen from each class period.

**Sample and Population**

This study took place in a public, rural area, high school in East Texas, USA. The school is in a city with a population of 1,386 and is situated approximately 20 miles south of the closest city with a population over 50,000. The 2019 demographics of the school, according to schooldigger.com, were as follows: Number of students enrolled in grades 9-12: 482. Racial breakdown: White: 46.5% African American: 26.8% Hispanic: 24.3%. The number of students receiving free/discounted lunch is 49.6% and the gender balance is 47% female and 53% male.

## Sample Characteristics

Seven classes of chemistry students who have returned their assent and consent forms (See Appendix A) participated in this study. The sample size used in this study is comparable in size to similar studies such as White and Bodner (1999); Kennepohl (2001); Bourque and Carlson (1987); Miller (1987); Huppert, Lomask, and Lazorawitz (2002); and Mencer (2002) that employed sample sizes of 100, 169, 51, 300, 181, 150, respectively. Students in the classes in this study ranged from grade 10 to grade 12.

All students used a Chemistry curriculum which integrated hands-on laboratory experiences and computer simulated experiences for at least 40% of instructional time. Test questions from assessments given at the end of each of the five units used in the study were selected for their alignment with the participation in laboratory experience (hands-on or simulated). Composite scores for questions aligned to HO labs were compared to composite scores for questions aligned to CS labs. Having each student participate in both groups increased the validity of the research.

## Facilities

The school is the only high school in the rural community. Every student who is taking Chemistry this school year is enrolled in the classes in this study. The facilities where the study took place are in a chemistry classroom/laboratory combination. The classroom is spacious enough to accommodate 24 students with resources and adequate space for both seat work and laboratory activities. The middle of the classroom has individual student desks, movable tables that can be arranged in groups and will seat two students each, and two recliners for flexible student seating. The laboratory section is located along the perimeter of the classroom and has three laboratory tables on each side. Each lab table is equipped with a sink and four gas valves. A wide range of glassware, chemicals, safety equipment, and tools such as scales, hotplates, and probeware are available for student use. A vent hood is located at the front of the room and additional sinks are located at the front and back of the room. The classroom has a dedicated computer cart with 22 Chromebooks. Students used Google Chromebooks with wireless connectivity to the Internet to perform simulated labs.

**Unit Tests**

All students completed a total of five multiple choice tests composed of questions taken from the 2011 and 2013 STAAR Chemistry tests and the DMAC data base of test questions which specifically address the TEKS being covered in the units. Answers to the tests were entered in DMAC Solutions, which was developed and is maintained entirely in-house by a team of software engineers and education content specialists at the Region 7 Education Service Center. The web-based applications provided by DMAC exist to allow Texas educators state-of-the-art tools and services necessary to disaggregate data to assess learning of specific TEKS and process skills, generate, administer, and report on TEKS based assessments, monitor student achievement and progress, and create curriculum maps, to develop and improve the quality of education provided to students (https://www.dmac-solutions.net/). One feature of DMAC, the test generator (TAG), was used to locate test questions. Each question in TAG is either a released STAAR question or is a question that was written by a science teacher and evaluated by specialists at Region 7. TAG is a web-based program which allows educators to create assessments. Using this tool gives administrators and teachers the ability to monitor student progress and to make data-driven instructional decisions based on specific strengths and weaknesses. Questions are coded for depth and complexity and according to the TEKS they cover. Student performance data can be disaggregated according to performance on each TEKS, by demographics, gender, and socioeconomic status.

## Experimental Research Design

Experimental designs are often called true experimentation. These studies use the scientific method to establish cause-effect relationship among a group of variables in a research study (Mertler, 2019). The researcher made an effort to control for all variables except the one being manipulated (the independent variable). The effects of the independent variable on the dependent variable were collected and analyzed for a relationship. The ability to manipulate treatment conditions and controls for many extraneous conditions make experimental studies the most conclusive of all research designs (Creswell, 2013).

The type of lab experience was the only condition that was different in the study; other components of instruction were all the same. Appendix D contains detailed plans for hands-on laboratory experiences and links to computer simulated experiences used for instruction for all students in the study. Differences between groups' academic performance on content learned during HO labs and CS labs was assessed.

## Steps in the Research

Typically, dissertation research in educational leadership seeks to fill a gap in practice (Creswell, 2013; Mertler, 2015). Seminal works and current peer reviewed primary sources were reviewed to learn what others have done (see references). Literature on quantitative research previously conducted on the topic was reviewed to determine what methods were used. The strengths and weaknesses of the various data collection and analysis methods were considered. Every aspect of research has a body of literature associated with it. Researchers need to read broadly and deeply to gain expertise in quantitative research (Mertler, 2015). For the purposes of this study, prior research was used to create a hypothesis which predicts a relationship between the study's variables (Creswell, 2013; Lebaree, 2019).

## Data Collection and Analysis

Two sources of data were collected and analyzed in this research. First, data was derived from unit test assessments for the five units. Students responded to multiple choice questions that the researcher pulled from TAG. The questions were chosen based on their coding (done by TEA for STAAR questions and by DMAC specialists for other questions) as pertaining to the TEKS being covered for each unit. Students entered their responses and the assessment data was collected through DMAC. Students were given access to the test for one class period. Results were stored and used for data disaggregation.

The assessment data was analyzed to determine if there was normal distribution. Independent t-tests were conducted to determine difference of means between questions assessing content learned in simulated labs and content learned in hands-on labs. According to Laerd Statistics, the independent t-test, also called the two sample t-test, independent-samples t-test or student's t-test, is an inferential statistical test that determines whether there is a statistically significant difference between the means in two unrelated groups (Laerd Statistics, t-test, para. 3). The researcher attempted to show evidence to reject the null hypothesis and accept the alternative hypothesis, which is that the population means are not equal. To do this, a significance level (also called alpha) was set that allowed either rejection or acceptance the alternative hypothesis. The independent t-test assumes the variances of the two groups you are measuring are equal in the population (Laerd Statistics, 2019).

The focus of this study was to determine the significance of the effect of hands-on laboratory experience compared to computer simulated laboratory experience on students' performance on assessments. This study also determined whether a significant difference exists in learner attitudes toward and interest in science after participation in physical versions or simulated versions of chemistry labs. Data was collected from unit test assessments, questionnaires, and discussions. From these data, the research questions were addressed to determine whether hands-on experience affected learner performance on assessments and attitude toward and interest in science.

**Measuring Assessment Scores**

To measure the effect of participation in hands-on labs on learner performance, all questions that can be directly aligned to content learned in HO lab experiences were assessed for each student on each of the five, unit tests (Appendix E). Likewise, all questions that could be directly aligned to content learned in CS lab experiences were assessed for each student for each of the five, unit tests. A t-test was used to determine if the difference between means for the scores is significant. Once it was determined whether significant differences existed between learner performances on test questions aligned with HO labs and test questions aligned with CS labs, the learner performance component of research questions one was answered.

## Measuring Attitude and Interest

### Ratings questionnaires.

To measure learner attitude differences that exist between the physical and simulated lab environments, ratings questionnaire data was used to code discussion and inspire further conversation. Specifically, paired items from the ratings were used to determine differences in learner attitudes with respect to the physical and simulated lab experiences. This analysis was adapted from a similar study conducted by Foley and McPhee (2008). These differences were broken into categories, which included (a) students' like or dislike of chemistry; (b) students' perception of the difficulty of science (c) students' attitude of relevance of science to everyday life and (d) user preference (students preference for physical or simulated) (Foley and McPhee, 2008). The statements and phrases within the discussion that convey messages which can be assigned to these categories were coded by the researcher. The frequency of occurrence of each code was used to determine attitude, interest, and perceived learning of the focus group participants.

**Discussions and key word frequency.**

Second, data was derived from the focus group discussions. Discussions using the researcher as the moderator were recorded and used to collect data. Rabiee, (2004) and Schmidt (2015) assessed that text exported from interview transcripts and excerpts from focus group interviews can be analyzed and undergo statistical analyses to estimate the keywords and trend of the discussion. Rabiee (2004) pointed out that a number of approaches to the analysis of qualitative data treat them as quantifiable data.

Using quantitative analyses, the texts and words in the transcripts were statistically analyzed for frequency. Keyword trend analysis is a quantitative measure that was used to analyze the text using Chi-Square (T-lab) test to check if the frequency values obtained by a survey and recorded in some cross-table, are significantly different from the theoretical ones (the "expected" values) (Majumder, 2018). The words used most frequently in the focus group discussions were used to check the trends of attitude and interest of the participants in the focus group discussions (Majumder, 2018).

## Validity and Reliability

In educational studies it is extremely difficult to establish sufficient controls in the complex social settings being studied; however, variables must be controlled so that one can be certain of the relationships being tested. One way to improve control of variables is to report results using numerical data. For example, researchers may use a rating scale, choose a rating from a scale, select one or more items from a list, or select other responses that result in numerical data (Balakumar, Inamdar, & Jagadeesh, 2013; Mertler, 2019).

Studies which use surveys or tests must use several strategies to establish the validity of the tests or surveys used. Establishing reliability and validity in your study is one of the most critical elements of the research process. Validity is the strength of our conclusions, inferences or propositions. More formally, Creswell (2013) defines it as the "based on determining whether the findings are accurate from the standpoint of the researcher, the participant, or the readers of an account" (Creswell, 2013, p. 201).

Researchers can ensure validity by having experts review the test (Trochim, 2019). Individual test items were checked to be certain they deal only with the subject being addressed. Checking sampling validity confirms that the range of item topics is appropriate to the subject (Trochim, 2019). Assessing concurrent validity was another strategy to increase reliability by ascertaining that the new test correlates with older established tests which measure the same thing. STAAR tests are accepted as reliable and valid not only as a whole testing instrument, but by individual item (TEA, 2019).

Establishing validity is a critical part of any quantitative research study. There is a defined approach for establishing validity. This also allows for transferability of the findings since the results may be able to be applied in other research. For the study to be valid, the evidence must support the interpretations of the data. The data must be accurate and their use in drawing conclusions must be logical and appropriate (Creswell, 2013).

**Instrument Reliability**

Researchers using quantitative methods must also establish the reliability of the instruments they are using. The multiple-choice objectives tests used in this study consisted of questions from the state assessment used to measure academic achievement in chemistry and questions that have been through an extensive vetting process by science teachers and specialists. The focus group instrument used was an audio recording of the discussions and paper and pencil ratings. The reliability and validity of this process was shown in Leimann's research in 1988.

**DMAC Test Question Reliability**

According to Deanna Greene, the DMAC specialist for science TAG questions, each test question in the data bank is submitted by teachers, curriculum developers, or specialists. After submission, the specialists at Region 7 Educational Support Center filter assessment items by depth of knowledge, genre, readability level, reporting category, keyword, and more. Once the questions are vetted and placed in TAG, educators can choose items to create customized local assessments tied to the appropriate student expectations by supporting/readiness standards and process skills (DMAC, Tag Overview, para. 1).

**STAAR Test Reliability and Validity**

Reliability refers to the expectation that repeated administrations of the same test should generate consistent results. Reliability is a critical technical characteristic of any measurement instrument because unreliable scores cannot be interpreted as valid indicators of students' knowledge and skills (TEA, 2013). During the 2012–2013 school year, reliability for the STAAR test score was estimated using statistical measures such as internal consistency, classical standard error of measurement, conditional standard error of measurement, and classification accuracy (TEA, 2013).

Internal consistency is a measure of the consistency with which students respond to the items within a test. According to TEA, tests involving dichotomously scored (i.e., multiple-choice and gridded-response) items, the Kuder-Richardson 20 (KR20) statistic was used to estimate reliability. For tests involving a combination of dichotomous and polytomous constructed-response items, the stratified coefficient alpha was used to estimate reliability (TEA, 2013). TEA also states that as a general rule, reliability coefficients ranging from 0.70 to 0.79 are considered adequate, those from 0.80 to 0.89 are considered good, and those at 0.90 or above are considered excellent (TEA, 2013). However, what is considered appropriate can vary in accordance with how assessment results are used. For the primary STAAR English and STAAR Spanish assessments administered in spring 2013, the internal consistency estimates ranged from 0.75 to 0.94 (TEA, 2013).

Validity refers to the extent to which a test measures what it is intended to measure. When test scores like STAAR, are used to make inferences about student achievement, it is important that the assessment supports those inferences. In other words, the assessment should measure what it was intended to measure in order for any uses and interpretations about test results to be valid. The TEA maintains that Texas collects validity evidence annually to support the interpretations and uses of the STAAR test scores (TEA, 2013). Furthermore, Texas follows national standards of best practice to continue to build its body of validity evidence for the STAAR assessments. The Texas Technical Advisory Committee (TTAC), a panel of national testing experts created specifically for the Texas assessment program, provides ongoing input to TEA about STAAR validity evidence (TEA, 2013).

Validity evidence based on test content refers to evidence of the relationship between tested content and the construct that the assessment is intended to measure. The TEA purports that STAAR assessments have been designed to coordinate with content as defined by the TEKS and that content validity evidence is collected at all stages of the test-development process. Nationally established test-development processes for the Texas assessment program are followed while developing the STAAR assessments in order to support the use of the STAAR scores in making inferences about students' knowledge and understanding of the TEKS.

Teachers, curriculum specialists, test development specialists, college educators, and TEA staff worked together in advisory committees to identify appropriate assessment reporting categories for the STAAR assessments. The input of the advisory committees is reflected in the assessed curricula and test blueprints. In addition, prototype items were developed for the STAAR assessments early in the development process. The educator advisory committees reviewed these prototypes to identify how well these items would measure the student expectations to which the items were aligned. These early reviews provided valuable suggestions for item-development guidelines and item types. Item development guidelines continued to be refined through the test-development process.

As part of the annual process of item development, committees of Texas educators meet to review the STAAR items and confirm that each item appropriately measures the TEKS to which it is aligned. These committees also review items for content and bias. Two distinct types of educator committees are regularly convened to support the validity of test content: item-review committees and content validation committees. Item-review committees are made up of Texas K-12 educators, and these committees revise and edit items, as appropriate, prior to test administrations. Item-review committees are convened for all STAAR assessments. Content validation committees, by comparison, are made up of university faculty who are experts in the relevant subject matter. Content validation committees review items to ensure that relevant content is being represented and assessed fairly and appropriately by test items.

A comprehensive discussion of STAAR tests and individual questions is available on the TEA website (TEA, 2019). The technical digests contain historical information on test development, performance standards, reliability, and validity. The tests from 2011 through 2018 are currently listed.

**Focus Group Reliability and Validity**

Richard Krueger, a professor at the University of Minnesota, asserts that successful focus groups are composed of five to ten participants, that participants are similar types of people, and that the groups are repeated. This study met all of these criteria as previously outlined in this chapter. Additionally, Krueger recommends that the environment is comfortable and circle seating is used (Krueger, 2002). The focus groups met during school hours, in the library where there are comfortable chairs and a relaxed, quiet environment. Discussions were tape recorded to provide a record of the conversions. The moderator, who is the researcher in this case, can be considered skillful in group discussions based on her eighteen years of teaching experience and numerous other speaking engagements. Krueger recommends the use of pre-determined questions during the discussion, as well as a permissive environment (Krueger, 2002). The analysis and reporting was systematic and verifiable due to the recordings and the paper and pencil ratings. See Appendix F for Krueger's recommendations for a focus group.

**Internal validity.**

Other measures of validity to be monitored are internal validity, conclusion validity, and external validity. Internal validity means evidence shows that what was done in the study (the program) caused what was observed (the outcome) to happen. Internal validity refers to the validity of the findings within the research study (Lebaree, 2019). The primary concern was controlling the extraneous variables and outside influences which could influence outcomes of the study. Controls are especially important in experimental studies since they help ensure that the experimental treatment was, in fact, responsible for a change in the dependent variable (scores, attitudes, and interest). This was critical if the study was going to be able to determine a comparative relationship (Lebaree, 2019). Therefore, the researcher controlled or eliminated the influence of other variables whenever possible in order to increase confidence when making conclusions about the relationship between lab experiences and assessment scores, interest, and attitude (Lebaree, 2019).

History is a threat to interval validity that occurs when unplanned events alter the study results unintentionally. Participants in the study often have different experiences as the study progresses. Maturation, natural biological or physical changes occurring in the subjects over the course of the study are also threats to internal validity (Creswell, 2013). However, since this study used historical data gathered between September 2019 and March 2020, the time-period was short enough that variance in maturation, biological and physical changes should be minimal.

Non-random selection or inequivalence in groups cause bias (Creswell, 2013). Therefore, all students enrolled in Chemistry classes for the 2019-2020 school year will be asked to participate in the assessment comparison study. Furthermore, participants in the focus group were stratified according to classes so that each class had one randomly chosen participant in the groups.

**External validity.**

Threats to external validity include the interaction effects of testing. One threat to external validity was the reactive effect to testing. Subjects may react differently in a controlled laboratory setting than they would in a real-world setting where there is less control. However, since the students were not aware that their scores would be used in the research at the time they took the tests, the results of the study can be more strongly associated with the application of the different laboratory experiences. Yet another threat to external validity is multiple treatment interference. In tests where subjects receive more than one treatment, the previous treatment may influence responses due to cumulative effects (Creswell, 2013; Lebaree, 2019). Questions from five unit tests will be used in this study, so some effects of prior learning could influence the results.

In conclusion, the researcher considered numerous threats to validity. No experimental research project is perfect or free from potential threats to validity. Researchers must take the necessary steps to ensure that these threats are controlled as best as possible. Randomization and the appropriate use of research designs and statistical analysis were the most common methods to achieve internal and external validity. Planning and preparedness were important in controlling these threats when creating the experimental design.

### Time Data

The amount of time over which a study is conducted is a defining point. Cross sectional data was collected at one point in time, while longitudinal data was collected over a long period of time such as a semester, year, or even several years (Punch, 2013). The data in this research study came from tests administered over a six-month period. Data for the focus group interviews was gathered during a seven separate Zoom conferences, lasting approximately 30 minutes each, that were held in the late Spring of 2020.

## Reporting the Data

Reporting the results of a study using quantitative methods involved several steps. First, the researcher explained the data collected and statistical treatment as well as all relevant results in relation to the research problem investigated. The interpretation of results is not appropriate in this section but will be done in chapter five. Next, the researcher reported unanticipated events which occurred during the collection of data. In this section, the researcher explained how the actual analysis differed from the planned analysis and offered an explanation of how outliers, homogeneity of samples, skewness, and kurtosis were determined and handled (Creswell, 2013; Lebaree, 2019).

The researcher provided a rationale for the use of each statistical procedure and a reference for it and identified any computer programs used. The next step was to describe the assumptions that were made for each procedure and the steps that were taken to ensure that they were not violated (Creswell, 2013). The final step was to determine whether the data was able to refute the null hypothesis.

**Summary**

Quantitative research focuses on gathering numerical data and generalizing it across groups of people or explaining a particular phenomenon. The aim was to determine the relationship between two or more variables within a population. Quantitative research relies on the collection and analysis of numerical data to describe, explain, predict, or control variables of interest. Quantitative research focuses on objectivity to achieve generalizability. Experimental studies involve a treatment or intervention (independent variable). Quantitative research designs generally require a minimum of 30 participants to represent the general population. All types of quantitative research are subject to threats in validity (Creswell, 2013).

# CHAPTER IV

## Results

### Introduction

The purpose of this chapter is to provide a written description of the statistical findings comparing performance scores on exam questions aligned with participation in hands-on (HO) laboratory scores to scores aligned with computer simulated (CS) laboratory experiences. The descriptive statistical findings from focus group interviews where attitude and interest in science were discussed, will also be included in this chapter. The participants in the final group sample for the performance scores consisted of 82 participants in tenth and eleventh grade who were enrolled in an East Texas high school Chemistry course and who returned both consent and assent forms. This number was lower than the anticipated 120 students because schools were closed in March and did not reopen for the remainder of the 2019-2020 school year due to the Covid-19 pandemic. One participant from each of the seven classes in the study was selected using stratified random sampling. These seven students participated in the focus group interviews and discussion.

## Research Question One

Research question one states:

> How does students' performance on unit test assessments after participating in hands-on laboratory-based experiences compare to students' performance on unit test assessments after participating in computer simulated laboratory experiences?

Statistical Package for Social Science SPSS (Version 26) was used to analyze for differences in the means of the average test score (continuous, dependent variable) in the two different groups, HO test questions and CS test questions. Test questions aligned with concepts covered in hands-on labs formed the first group in the study. Test questions aligned with the CS activities formed the second group.

### Independent T-Test

Data were collected using reliable and valid instruments from participants' previous exams and were analyzed with the Statistical Package for Social Science SPSS (Version 26). An independent t-test was used to analyze for differences in the means of the average test score (continuous, dependent variable) in the two different groups, HO test questions and CS test questions. The hands-on labs chosen were aligned with specific TEKS (See Appendix B). Test questions that aligned with the concepts covered in these lab activities formed the first group in the study. Likewise, the computer simulated labs covered specific TEKS. Test questions that aligned with the CS activities formed the second group.

Statistical and visual tests for outliers and normality were conducted using (SPSS) analytics software to identify if assumptions for independent t-tests were met (e.g., skewness, kurtosis, histograms, box plot, and Normal Q-Q Plot). This analysis and evaluation provided findings from the results of the research performed which aligned, guided, and were central to RQ1: How does students' performance on unit test assessments after participating in hands-on laboratory-based experiences compare to students' performance on unit test assessments after participating in computer-simulated laboratory experiences? Assumptions using analytical and graphical statistics are presented.

**Results of the Independent T-Test**

Boxplots were generated from the data set to discern whether there were outliers in the data set. One outlier was assessed by visual inspection of the boxplots (See Fig. 2). After determining the single outlier to be a genuinely unusual data point and not a data entry mistake or a measurement error, the outlier was kept in the data set because there was no good reason to reject it as invalid. The data set is large enough that the single outlier will not grievously affect the results.

**Boxplot Comparison**

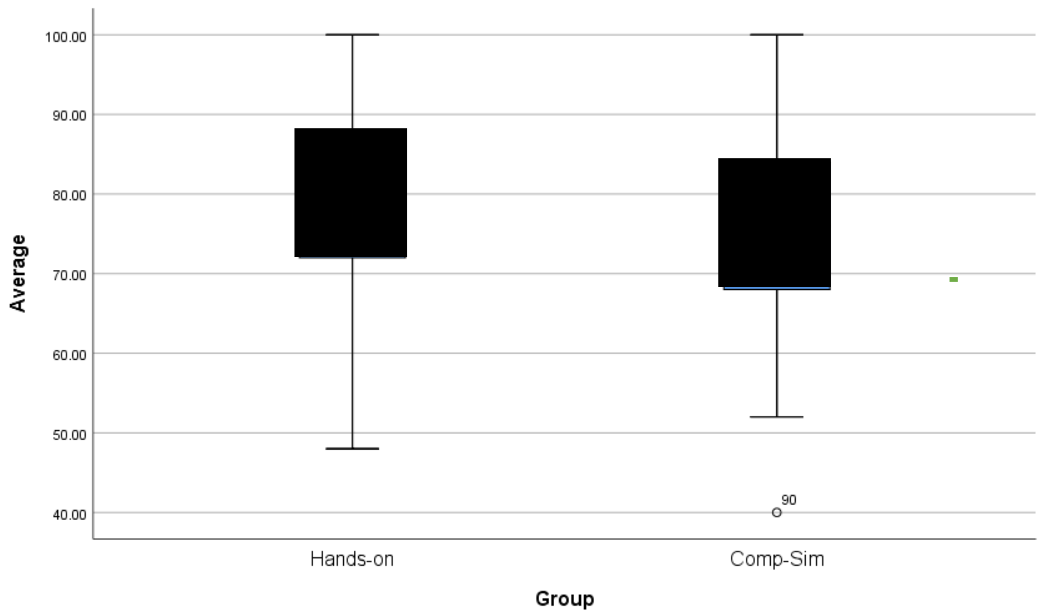


*Figure 2.* Boxplot comparison of HO & CS mean test averages (IBM SPSS, Version 26).

Since the sample size is greater than 50, a graphical method, the Normal Q-Q plot, was used to flag deviations from normality as statistically significant. Figure 3 represents the plot of the HO mean scores, while figure 4 shows the mean scores for CS questions. Normal distribution can be assumed because the data points fall nearly about a single straight line.

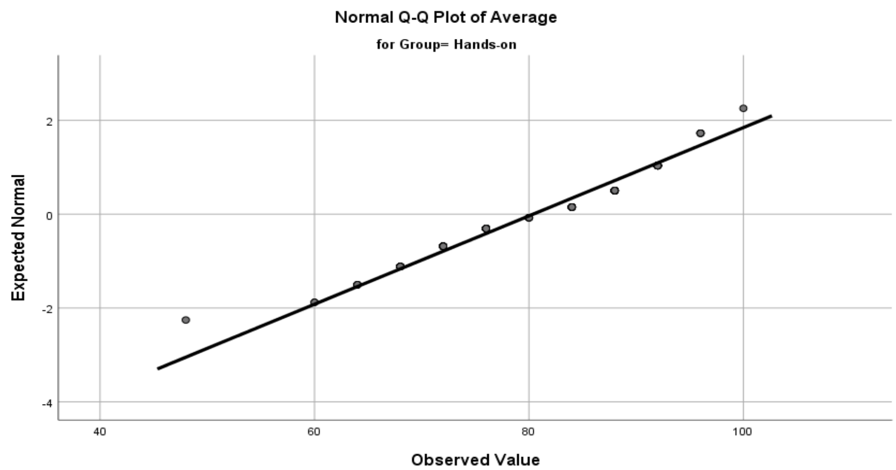


*Figure 3.* Normal Q-Q plot of the mean scores for HO questions (IBM SPSS, Version 26)

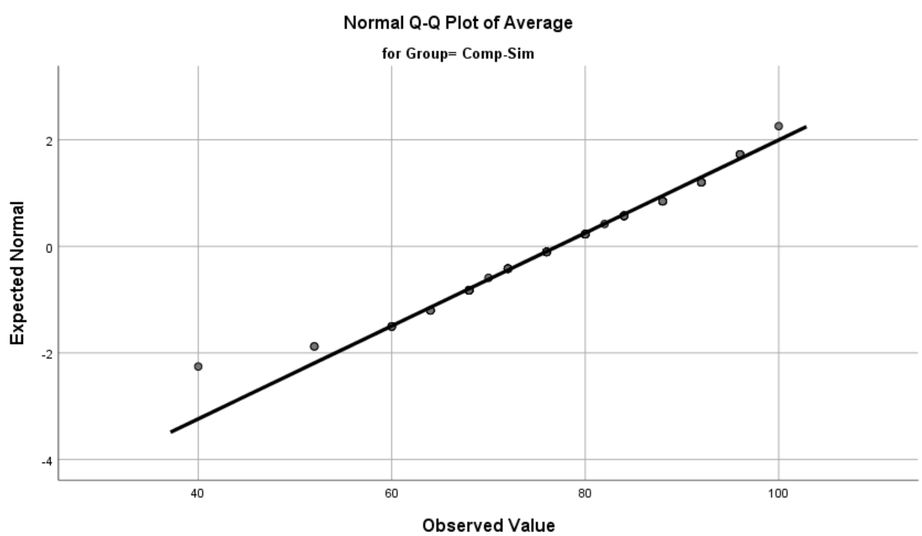


*Figure 4.* Normal Q-Q plot of the mean scores for CS questions (IBM SPSS, Version 26)

Skewness shows the extent to which a variable's distribution is symmetrical and not stretching toward the right or left tail of the distribution. Kurtosis is a measure of whether the distribution is too narrow or flat. Generally, if skewness and kurtosis are numbers between +1 and –1, then distribution is considered normal. The statistically derived values for skewness and kurtosis for the data set of HO and CS mean scores fall within the defined parameters and can be assumed normal (See Table 1).

Table 1

*Descriptive Analysis of Data Set for Mean Scores on HO & CS Test Questions (IBM SPSS, Version 26).*

| | Group | | | Statistic | Std.Err |
|---|---|---|---|---|---|
| Average | Hands-on | Mean | | 80.3902 | 1.17304 |
| | | 95% Confidence Interval for Mean | Lower Bound | 78.0563 | |
| | | | Upper Bound | 82.7242 | |
| | | 5% Trimmed Mean | | 80.7046 | |
| | | Median | | 82.0000 | |
| | | Variance | | 112.833 | |
| | | Std. Deviation | | 10.62231 | |
| | | Minimum | | 48.00 | |
| | | Maximum | | 100.00 | |
| | | Range | | 52.00 | |
| | | Interquartile Range | | 16.00 | |
| | | Skewness | | -.416 | .266 |
| | | Kurtosis | | -.352 | .526 |
| | Comp-Sim | Mean | | 77.1220 | 1.26572 |
| | | 95% Confidence Interval for Mean | Lower Bound | 74.6036 | |
| | | | Upper Bound | 79.6403 | |
| | | 5% Trimmed Mean | | 77.4580 | |
| | | Median | | 76.0000 | |
| | | Variance | | 131.368 | |
| | | Std. Deviation | | 11.46157 | |
| | | Minimum | | 40.00 | |
| | | Maximum | | 100.00 | |
| | | Range | | 60.00 | |
| | | Interquartile Range | | 16.00 | |
| | | Skewness | | -.386 | .266 |
| | | Kurtosis | | .368 | .526 |

Results depend on whether data meets or violates the assumption of homogeneity of variances. The population variances were equal to 0.955 as indicated in the "Sig." column located under the Levene's Test for Equality of Variances column in Table 2. The population variance of both groups is a *p*-value greater than 0.05 (i.e. p> .05); therefore, the data meets the assumption of homogeneity of variances.

The average of the scores for the HO test questions is 3.27 (95% CI, 0.14 to 6.68) higher than the average of the CS scores. There was no statistically significant difference in mean scores t (82) = 1.89, p=.060. Because there was no statistically significant difference in the means (p> .05) we cannot reject the null hypothesis nor accept the alternative hypothesis.

Table 2

*Independent T-Test Analysis of Data Set for Mean Score on HO and CS Test Questions (IBM SPSS, Version 26).*

Independent Samples T-Test

| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 95% Confidence Interval of the Difference | |
| | | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | Lower | Upper |
| Average | Equal variances assumed | .003 | .955 | 1.894 | 162 | .060 | 3.26829 | 1.72571 | -.13949 | 6.6760 |
| | Equal variances not assumed | | | 1.894 | 161.072 | .060 | 3.26829 | 1.72571 | -.13963 | 6.6762 |

**Paired T-Test**

To further analyze the data, the paired-samples t-test was used to determine whether the mean difference between paired observations is statistically significantly different from zero.  The participants are the same individuals tested under two different conditions on the same dependent variable.  The dependent variable, average test score, is measured at the continuous level.  The independent variable consists of two categorical, related groups (test questions related to HO or CS laboratory experiences).  The primary reason for having related groups is having the same participants in each group.  It is possible to have the same participants in each group when each participant has been measured on two occasions on the same dependent variable.  There are no significant outliers in the differences between the two related groups as indicated by visual inspection of the boxplot in Figure 5; and the distribution of the differences of the dependent variable between the two related groups is determined to be approximately normally distributed by the Normal Q-Q graph (See Figures 3 and 4 from the Independent t-test section above).

**Boxplot Difference in Mean Scores**

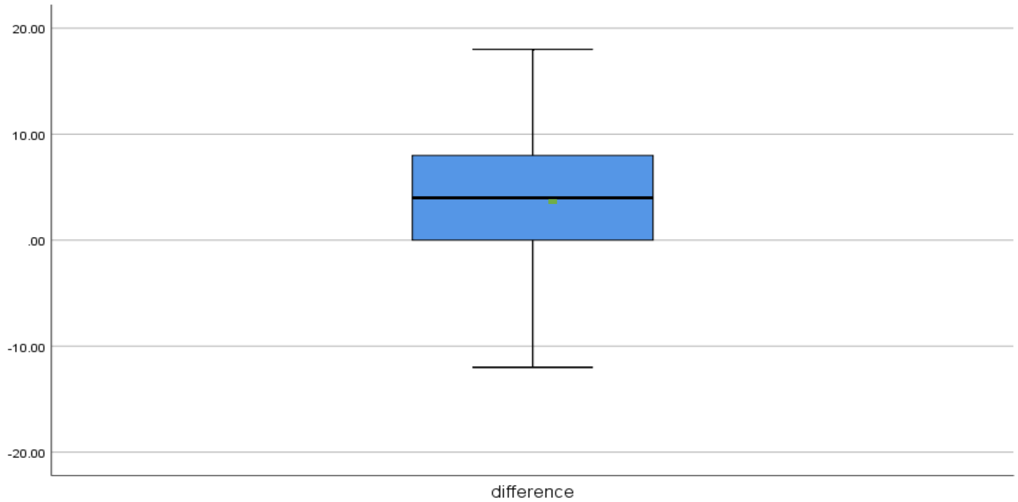


*Figure 5* Difference in mean scores of test questions (IBM SPSS, Version 26).

The mean + standard deviation remains the same as reported in the independent t-test with HO scores being higher (80.39 + 10.62) as opposed to CS scores (77.12 + 11.46) as shown in Table 3.

Table 3

*Mean Scores and Standard Deviation (IBM SPSS, Version 26)*

Paired Samples Statistics

| | | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Pair 1 | HO | 80.3902 | 82 | 10.62231 | 1.17304 |
| | CS | 77.1220 | 82 | 11.46157 | 1.26572 |

Table 3

The HO laboratory experiences elicited an increase of 3.27 (95% CI, 2.04 to 4.500) points in the mean test scores compared to the CS laboratory experiences.

Table 4

*Paired samples t-test results for mean differences (IBM SPSS, Version 26)*

Paired Samples Test

| | | Paired Differences | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 95% Confidence Interval of the Difference | | | | |
| | | Mean | Std. Deviation | Std. Error Mean | Lower | Upper | t | df | Sig. (2-tailed) |
| Pair 1 | HO - CS | 3.26829 | 5.59993 | .61841 | 2.03785 | 4.49873 | 5.285 | 81 | .000 |

If *p* < .05, this means that the mean difference between the two related groups is statistically significant. The "Sig. (2-tailed)" column of this paired-samples t-test is 0.00. Consequently, the analysis indicates that the HO laboratory experience elicited a statistically significant increase in mean test scores compared to the CS laboratory experience, t(81) = 5.285, p < .0005. Therefore, the null hypothesis can be rejected in favor of the alternative hypothesis.

**Attitude and Interest**

Data for research questions two and three were collected through focus interviews.

RQ 2: What impact does participation in hands-on laboratory experience have on students' attitude toward and interest in science?

RQ 3: What impact does participation in computer simulated laboratory experience have on students' attitude toward and interest in science?

Due to the age of the participants and concerns for confidentiality, each of these seven students shared his or her thoughts in an individual meeting with the researcher and a silent moderator, who is a teacher on staff at the high school where the research was conducted. Transcripts of the interviews were lightly edited to remove extraneous social conversation. Full transcriptions can be viewed in Appendix G.

**Key Word Analysis**

A key word analysis was conducted on the interview transcripts. The results are included in Appendix H. Science and chemistry were two of the most used words in the transcript due to the fact that the discussion topic was the student's attitude and interest in chemistry. The fourth most documented word was 'labs' since the conversations were designed to show how students' involvement in laboratory experiences may have impacted their attitudes and interest. The positive words: good, well, better, love, yeah or yes, favorite, great, and awesome were recorded 179 times. Likewise, the number five was used to indicate a strong positive feeling and was recorded 31 times in the transcripts. Alternatively, the only negative word (hate) was recorded nine times. Words that indicate involvement or action: think, hands-on, learn, work, doing, use, make, see or seeing, learning or learned, participating, interact or interacting, experiment or experiments, equipment, reaction, mixing, test, touch, dissect, apply, measurement, focused, and reactions were recorded 500 times. Another interesting finding was the occurrence of the words understand (39), help or helps (36), easy (13), confident (7), important (6), interesting (4), and intriguing (2) - all words which can be considered to indicate confidence and interest.

**Coding**

Transcripts were coded for further analysis.  Each code is a qualitative inquiry that is a word or short phrase used to symbolically represent a summative or salient attribute of some portion of the language used in the interview transcripts (Saldana, 2016).  The codes represent and capture the essence of the data.  The goal for assigning codes to transcripts is to find repetitive patterns or themes documented in the data and ideas that help explain why those patterns are there in the first place (Saldana, 2016).

According to Saldana (2016) a researcher can develop new codes customized to meet the unique needs of the study (p. 50).  The codes help give the researcher insight about and connections with the participants and the question under investigation (Saldana, 2016).  Elemental, descriptive, and initial codes were developed since they are best suited for transcript interviews.  This structural coding is designed to start organizing data around specific questions and helps find answers to questions asked.  A sufficient number of codes was developed as a ratio to the data (Saldana, 2016).  The transcripts contained approximately 10,000 words.  Therefore, the researcher developed 12 codes which directly aligned with the questions asked and the answers being sought to the research questions.

Due to the smaller sample size that was an inescapable consequence of the Covid-19 pandemic, the Chi-Square test was not a good fit for use on the limited focus group interview data.  However, a crosstabulation, which is a two-dimensional table that shows the frequencies of codes in each of the participant’s transcripts was done and is part of the analysis for the Chi-Square test.  The frequency of the data in the crosstabulation table can then be analyzed with the Chi-Square statistic to test for statistical significance of the frequencies. Coding for association was used to quantitatively determine whether the categorical variables of hands-on lab experiences and attitude and interest in science are associated. Codes were also used to determine whether computer simulated laboratory experiences impact attitude and interest in science.

Table 5

*Codes Used on Focus Group Transcripts*

| Code | Frequency |
|---|---|
| Confidence | 43 |
| Lack of confidence | 3 |
| Computer simulated labs- dislike and decrease in interest | 24 |
| Computer simulated labs- improve attitude and increase interest | 1 |
| Hands-on labs increase interest and improve attitude | 50 |
| Interest (science/chemistry in general) | 42 |
| Learn from computer simulated labs | 9 |
| Learn from hands-on labs | 19 |
| Neutral attitude (science/chemistry) | 1 |
| Neutral attitude toward computer simulated labs | 5 |
| Neutral attitude toward hands-on labs | 3 |

Table 6 shows a crosstabulation of coding of student responses during the focus group interviews. Each heading represents a code used by the researcher and each participant's total responses are included individually. The crosstabulation shows a somewhat equal distribution of themes expressed by the seven different participants.

Table 6

*Crosstabulation of Student Interviews and Qualitative Data Codes*

| | CS dislike & decreased interest | CS increases positive attitude & interest | HO increases positive attitude & interest | confidence | interest | lack of confidence | learn from CS | learn from HO | neutral attitude | neutral attitude toward CS | neutral attitude toward HO | positive attitude | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Student 3 TF | 4 | 0 | 8 | 5 | 9 | 1 | 1 | 3 | 0 | 0 | 0 | 7 | 38 |
| Student TE | 1 | 0 | 8 | 6 | 3 | 0 | 1 | 2 | 1 | 1 | 0 | 4 | 27 |
| Student Six | 4 | 0 | 6 | 6 | 4 | 0 | 2 | 5 | 0 | 1 | 0 | 5 | 33 |
| Student 7 RH | 3 | 0 | 5 | 5 | 5 | 1 | 1 | 1 | 0 | 0 | 0 | 6 | 27 |
| Student 2 LB | 5 | 0 | 9 | 8 | 7 | 0 | 2 | 4 | 0 | 0 | 0 | 11 | 46 |
| Student5 ER | 3 | 1 | 4 | 4 | 7 | 1 | 1 | 0 | 0 | 1 | 3 | 5 | 30 |
| Student 4 EZ | 4 | 0 | 10 | 9 | 7 | 0 | 1 | 4 | 0 | 2 | 0 | 4 | 41 |
| Totals | 24 | 1 | 50 | 43 | 42 | 3 | 9 | 19 | 1 | 5 | 3 | 42 | 0 |

**Confidence**

Student confidence was a recurring theme throughout the conversations. The student who spoke of confidence the lowest number of times had four statements or phrases in the conversation, while the student who indicated confidence the most had nine occurrences in the conversation. The total number of phrases coded for confidence from all seven students was 43. Students most often stated that they were sure of themselves when doing science and six of the seven stated they were confident of their ability to do advanced science. One student said science is his strongest subject and three students stated that they have always done well in science. In contrast, a total of three phrases were attributed to a student's lack of confidence and were coded as such.

**Interest**

Every student interviewed expressed some interest in science and chemistry in general. Students were asked whether they planned to pursue a career in science, whether they thought they would use science after high school, and how relevant science in school is to everyday life. Students statements of interest ranged from a low of three for one student to a high of nine for another who said, "I am going to be making medicine for people. Like, I want to develop new medicine to help people with chronic diseases or maybe even to keep people from getting sick in the first place. That's definitely science-maybe chemistry or biochemistry." Other student responses indicating interest in science included, "I might teach science", "I am always using science", and "I use a lot of the science we learn".

**Impact of Laboratory Experiences**

Focus group participants were asked what they liked and disliked about chemistry, how much they liked participating in hands-on (HO) or computer simulated (CS) laboratory experiences, and whether participating in HO and CS made them like chemistry more. Participants were also asked how much they learned from participating in HO and CS experiences. Fifty statements or phrases showed students' like (or love) HO labs, while only one statement could be coded as a student's attitude or interest improving due to CS labs. Interestingly, the numbers were much closer for students' perceptions of learning from each category of laboratory experience.

**Hands-on increases interest and increases positive attitude.**

The most coded theme in the transcripts was the students' increase in interest and positive attitude being attributed to participation in hands-on laboratory experiences. Most students rated participation in HO at the highest rating possible. One student had ten instances in the discussion where he related HO labs to a positive attitude or increase in interest. The student said, "I like the hands-on thing because there is more interaction." He also stated. "I like to make things, to see how things are made, and see the reaction." Another student said, "It's just more interesting and you know, engaging or intriguing when we are doing the hands-on things." Other students' comments included, "It's [HO] not boring", "I like touching it and seeing it and having it all in front of me", and "It's [HO] like a puzzle. You have some equipment, and chemicals, and a goal, and you have to figure it out. That's why I like it. You don't always know what's going to happen". Other students also commented that they are hands-on learners and learn more when they can hold or touch tangible objects. Students said, "I like actually doing it myself," and "I like doing the things." Student five said he liked the "fire and the big reactions."

Three neutral statements concerning attitude and interest toward HO labs were coded. All three of these statements were made by student six who said, "If I already understand something, I don't really need to do a lab," "Sometimes I just need to see it on paper and I get it, I don't need a lab," and "How much I like the [HO] lab depends on how much I like the topic." This student also expressed four positive statements regarding HO labs in addition to her neutral comments.

By contrast, only one student attributed participation in computer simulated laboratory experiences with an increase in positive attitude or interest in science. The student mentioned a specific CS lab where the students constructed molecules and the computer program displayed 3-D molecular structures for the molecules. She said, "…that one [computer lab] we did where we built the models-the shapes, that one was helpful." One student discussed his interest in becoming a computer programmer and improving the quality of the CS labs for "a better simulated environment- the improvement of the digital environment."

**Computer simulated decrease interest and increase negative attitude.**

Coding the interview transcripts for the impact of CS laboratory experiences on students' attitudes and interest shows that CS labs have an almost completely opposite effect of HO labs in this research. Students most often gave CS labs a rating of two on a scale of one to five, with one indicating a strong dislike and five indicating a strong like for the labs. The highest rating came from a student who rated the CS labs as a three after explaining that he loves computers, but the simulated chemistry labs need to be improved. He concluded, “I like them [CS labs] more than I dislike them.” In two cases, students expressed neutrality by saying, “They [CS labs] were okay.”

When asked about their experiences with CS labs, one student explained, “When we did the computer lab, everything ran together and it was confusing. I couldn’t tell what went with what.” This student described another CS experience saying. “It just doesn’t hold my attention. I find it hard to stay focused.” Finally, this student said, “I don’t like computer labs. I just don’t.” He was not alone. In fact, six of the seven focus group participants explicitly stated that they did not like the computer simulated chemistry labs. Other comments included, “It’s hard to know what to do”, “When we get the computer out a lot of us are not paying 100% attention. It’s easy to just click on over and look at other stuff”, and “Honestly it’s hard to stay interested.” Three different students also expressly stated that the CS labs were stressful.

More specific complaints were also recorded. Two students mentioned that there is no “thrill of actually doing something that might react” and one student noted that the CS labs are not exciting because there are “no consequences for making a mistake other than having to start over or give up”. In the third interview, the student said, “Computer labs take the mystery out of the lab.” The second participant said, “I got frustrated with having to read all the instructions to figure out how to make the computer work. It didn’t have anything to do with the experiment. It was mostly about how to work the computer.” Participant four said, “When we do the hands-on labs I get to see chemicals and equipment I've never seen before. I get to hold it and mix it and see what happens. It's not the same on the computer. I don't know what that stuff is and the computer is just a picture of it."

**Students learn from hands-on.**

When the interview participants were asked whether they learned from participating in HO experiments, their responses were not as definitive as their responses on attitude and interest. A total of 19 statements or phrases were coded as students' expressing that they learned from participating in HO laboratory experiences. Indeed, even though all students expressed their interest in and like for HO labs, one student never clearly stated that she learned from HO labs. The other six participants did articulate that they learned when participating in HO labs. Five of the participants stated that they "learn by doing" and one said he, "even learns from his mistakes" in the HO labs. Another student said, "I actually enjoy learning this way [HO labs]." Other students said HO labs, "Make it real," and "Help me understand." Several students conveyed the message that incorporating other senses helped them stay engaged in the learning and understand and remember the content. A particularly passionate student stated that, "You can't help but learn when it's in your face like that."

**Students learn from computer simulated.**

Interestingly, all the students interviewed claimed that they learned from participating in CS laboratory experiences. Participant one said, "It's my job to learn and so I know I have to work at it and get it," indicating that he does learn from CS labs. Two students remarked that they learned from the introductory information presented in the CS labs, while another student mentioned, "I learned something, but I'm not sure if it was what I was supposed to be learning." Similar excerpts from transcripts of the interviews include students' thoughts that they, "learned a little bit from some of them [CS labs]," "learned sometimes," "learned because I knew I had to," and "I did learn." A total of nine codes were assigned to words or phrases that expressed a message that the student learned from participating in CS labs.

**Attitude and Interest Conclusions**

The results of the key word analysis showed that the topics of science labs and chemistry were the overarching themes of the interviews. The discussions were determined to have a positive tone due to the occurrence of positive words at more than three times the occurrence of negative words. Over 500 words related to action or involvement and more than 100 words related to student confidence or interest. Coding of the data also revealed a high level of student confidence and interest in science. Based on the frequency of codes indicating students' positive attitude toward HO labs and interest in HO labs, the null hypothesis for research question two can be rejected and the alternative hypothesis can be accepted. Additionally, based on the frequency of codes indicating an increase in negative attitude , a decrease in interest, but a perception of learning nonetheless, after participating in a computer simulated experience, the null hypothesis for research question three can also be rejected and the alternative can be accepted.

## Summary

The statistical results of the research on achievement were mixed. The independent t-test failed to show a statistically significant difference between the mean scores on test questions aligned with HO activities and the mean scores on test questions aligned with CS activities. The paired t-test did show statistically significant differences in the scores. However, the results from coding the focus interview transcripts clearly showed a connection between participation in HO lab activities and an increase in positive attitude and interest in science. Conversely, coding transcripts showed that participation in CS labs decreased students' interest in science and increased negative attitudes.

These results add to research showing that activities that facilitated the use and application of knowledge that was learned in the context of a conceptual framework and structured in meaningful ways so that students could assimilate the learning and transfer new skills to new situations, resulted in a more positive attitude, an increased interest in science, and arguably higher achievement scores. The teaching strategies that allowed students to do this required careful integration of hands-on activities that kept students engaged in working with the material, built a level of increasingly complex problem solving, and assessed understanding to guide revisions.

# CHAPTER V

## Introduction

The goal of this study was to investigate the impact of hands-on and computer simulated laboratory experiences on student test performance, attitude towards, interest in, and perceived learning in science. The results could help educational leaders make more informed decisions concerning the enforcement of state mandates requiring that science students participate in laboratory and field investigations for at least 40% of instructional time. The results could also guide decisions for the allocation of resources. This final chapter includes a summary of the study and the conclusions, analysis, synthesis, and evaluation of the findings. Implications of the study will be discussed in this final chapter, and recommendations will be given for further research. Recommendations for policy, school administrators, and teachers are also included here, along with some concluding remarks.

## Problem Overview

The emphasis on standards across the United States has shifted the primary focus of traditional classrooms today toward instruction that centers on preparing students for passing standardized exams and state assessments (Mansell, 2007; Nichols and Berliner, 2007; Koretz, 2008). One consequence is that many schools are not holding teachers accountable and enforcing the state-mandated laws (Maerten-Rivera, Myers, & Penfield, 2010; Marx and Harris, 2006; Shaver, Cuevas, & Avalos, 2006). In Texas, the law states, "The student, for at least 40% of instructional time, conducts laboratory and field investigations…," (Texas Education Agency, 2019). As a result, science teachers may not be providing students with direct laboratory experiences for the mandated 40% of instructional time, and school leaders are not enforcing the state and national guidelines. This research sought to examine the relationship between hands-on laboratory experiences and computer simulated laboratory experiences effect on attitude, interest in science, and scores on end of unit assessments of students enrolled in a Chemistry course taught in a rural high school. The results of this research could add to the body of research done on the significance and importance of incorporating hands-on laboratory experiences into high school Chemistry classes and help school leaders make informed decisions concerning the allocation of resources for science and the enforcement of mandated laboratory and field experiences.

## Research Questions

The essential questions this research sought to answer were:

1. How does students' performance on unit test assessments after participating in hands-on laboratory-based experiences compare to students' performance on unit test assessments after participating in computer-simulated laboratory experiences?
2. What impact does participation in hands-on laboratory experience have on students' attitude toward and interest in science?

3. What impact does participation in computer simulated laboratory experience have on students' attitude toward and interest in science?

## Study Design

Assessment data were collected from a random sample of 82 students enrolled in a Chemistry course at an East Texas high school. The students participated in five units that each contained both a hands-on lab and a computer simulated lab. Five test questions designated as being aligned with content covered in hands-on (HO) labs and five test questions aligned with content in computer simulated (CS) labs from each of the five different unit exams were used. The overall mean score on the 25 HO questions was compared to the overall mean score on the 25 CS questions using an independent t-test. Next, the difference in each student's mean score for HO was compared to their mean score for CS using a paired t-test.

Attitude and interest data were gathered from one student from each of the seven classes in the research. The seven students were chosen by random stratification to participate in an individual interview that was approximately 30 minutes in length and was recorded using zoom.us. Questionnaires were used to guide the discussions. Each interview was then transcribed and an online website (textfixer.com) was used to find words that occurred most frequently. Transcripts were then coded to find themes and salient points within the students' responses.

## Data Analysis

### Hypothesis One

Hypothesis one states:

> There will be a significant difference between the means of the assessment scores earned by students after the execution of hands on laboratory activities and those scores earned by the same students after the execution of computer simulated laboratory experiences.

The results of the independent t-test showed no statistically significant difference, when tested at 95% confidence interval, between overall means of the HO test scores and the CS test scores. For the independent t-test, the HO and CS labs were considered to be two independent groups. This means that when comparing the two groups, a test question from the HO group could not also be a member of the CS group and vice versa. The average difference in mean scores was calculated to be 3.27 points. Considering that there are 25 questions per test, this difference equates to slightly less than one test question. These findings suggest that participation in HO labs and participation in CS labs result in the same mean scores on test questions that cover the content of the labs. Therefore, participation in either type of lab is equally valuable. The null hypothesis states:

> There will be no significant difference between the means of the assessment scores earned by students after the execution of hands on laboratory activities and those scores earned by the same students after the execution of computer simulated laboratory experiences.

The null hypothesis cannot be rejected from the statistical findings of this test.

However, when the paired t-test was conducted, a statistically significant difference was revealed. For this test, the independent variable consists of two categorical, related groups. Related groups indicate that the same subjects are present in both groups. It is possible to have the same subjects in each group because each subject has been measured on two occasions on the same dependent variable. The HO test questions and the CS test questions could be considered related because they both address chemistry TEKS covered in labs. Students were tested after participating in HO labs, and the same students were tested after participating in CS labs. A statistically significant difference was found, indicating that the null hypothesis can be rejected and the alternative hypothesis can be accepted.

**Hypotheses Two and Three**

When attitude and interest were assessed by key word, the overarching themes of science, chemistry and labs were noted. Not unexpectedly, the words science, chemistry, and labs were three of the most frequently used words in the discussions since the conversations were almost entirely concerned with students' interest, attitude, and learning in chemistry. The tone of the conversations was positive as noted by the use of more than three positive words for every negative word used. The threads of action and involvement were woven throughout the discussions, along with suggestions of learning and interest. The word think was recorded 93 times, while the word know was recorded 90 times. Work and learn were each recorded 54 times and understand was recorded 39 times, putting each of these words in the top 20 most frequently used words in the interviews. These key word occurrences suggest an overall tenor of positive attitude, engagement, and learning. However, a basic key word count analysis could not conclusively show a connection between hands-on labs and positive attitude or interest, nor could a connection be shown between computer simulated labs and attitude and interest. Thus, based on this key word analysis, neither hypotheses two, which states that there will be a significant difference in attitude toward science, and interest in science as measured by a focus group, after students participate in hands-on laboratory experiences, nor hypothesis three, which states that there will be a significant difference in attitude toward science and interest in science, as measured by a focus group, after students participate in computer simulated laboratory experiences can be confirmed.

Qualitative data, such as transcripts from interview, can be quantized to reveal the frequency of coding categories; therefore, coding was done to capture the essence of statements and phrases in the transcript. A list of codes is included in Table 5 on page 94. Student's statements consistently conveyed a positive attitude and strong interest in HO labs. Conversely, the sentiments students associated with CS labs were more negative or neutral and only one student said CS labs increased his interest in chemistry. Perhaps the best emic theme that occurred during the interviews was the following exchange:

> Researcher to student: Do you think participating in hands-on Chemistry labs makes you like Chemistry more?
>
> Student: Yes. Most definitely. I mean the online thing was okay, like the little labs, but like when I actually got to look at it and see, oh, that's what it does, I mean on the computer you can see it but it's just like uhhh, but when you get to mix stuff up and it's like OHHHH!!! You know that's a lot better. It helps me understand it.

This excerpt expresses the student's increased interest and positive attitude toward HO lab experiences. Even her tone and decibel level changed to indicate her interest and excitement when speaking about her experience. Meanwhile, she is also conveying her neutral to negative attitude toward CS labs stating that they are "okay" while keeping a level voice and expression.

Hypotheses two states:

> There will be a significant difference in attitude toward and interest in science as measured by a focus group, after students participate in hands-on laboratory experiences.

Hypothesis two can be accepted due to the positive change in attitude and the increase in student interest as evidenced by the occurrence of 50 codes for positive attitude and interest within the focus group discussion transcripts. In fact, increase in positive attitude and interest in science was the most frequently coded theme in the conversations. More support for the acceptance of this hypothesis can be gathered from the information that all students interviewed stated in some way that hands-on labs were the best part of chemistry. Student one said the way to make chemistry class better would be to "Have more hands-on labs and field trips." This student also specifically stated that her favorite part of chemistry class this year was a hands-on lab experience where students turned pennies to silver and then to gold. An interview with a different student contained the following interaction:

> Researcher to student: On a scale of one to five with one meaning I despise it and five meaning I love it, how much do you like hands-on labs?

Student: I love it! Definitely a five.

This student expressly and emphatically declares that HO labs are a positive and interesting component of chemistry class.

Hypothesis three states:

There will be a significant difference in attitude toward science and interest in science as measured by a focus group, after students participate in computer simulated laboratory experiences.

Hypothesis three can be accepted due to the negative change in attitude and the decrease in interest. Within the interview transcripts, 24 codes of negative attitude and decrease in interest were assigned. When asked how much they liked computer lab experiences, students said, “They are just okay,” and “I don’t like them,” or “I really don’t like them.” The following exchange is more evidence of the students’ dislike for CS labs.

Researcher to student: Okay, so on a scale of one to five with five being I love it and one being I hate it, how much do you like computer labs?

Student: Ummm…a two maybe. It’s definitely not my favorite.

The overwhelming sentiments expressed by students were that CS labs are not as engaging or interesting as HO labs and do not provide the same interactive experience. Curiously, students perceived that they learned from both types of labs.

## Findings

Hypothesis one was rejected when the independent t-test was conducted and accepted when the paired t-test was conducted. As noted earlier, the average difference in students’ mean score for HO questions was a mere 3.27 points higher than their mean score for CS questions. This number equates to less than one test question from a 25-question analysis for each category of lab. Because the results of the key word analysis were inconclusive in rejecting or accepting either hypothesis two or three, a coding system was used to further analyze the data. When the descriptive codes are counted for frequency, hypothesis two can be accepted on the basis of the numerous codes for positive interest and attitude being attributed to participation in HO labs. Meanwhile, hypotheses three can be accepted due to the frequency of codes suggesting an increase in negative attitude and decrease in interest that students attributed to participation in CS labs.

## Conclusions from Research Data

The empirical data presented in the study's findings indicate that students in a chemistry course achieved slightly higher scores on test questions aligned with their participation in HO laboratory experiences as compared to CS laboratory experiences. Findings also show that students' positive attitudes and interest increased with participation in HO labs. Conversely, negative attitudes increased and interest decreased with participation in CS labs. These findings led to several conclusions.

First, the relatively small difference of mean scores for students' HO and CS test questions is a partial picture of their learning experiences. Most students in chemistry classes are interested in careers that require advanced science and are motivated to succeed. Furthermore, course information is presented in multiple methods and modalities, so pinpointing the precise source of a student's knowledge is not entirely possible. This research assumes that the majority of the knowledge was derived from participating in laboratory experiences that directly addressed the content. Another point which should be included here is that there are questions and discussions related to both HO and CS labs which are notably similar.

Secondly, student success is not synonymous with proficiency on standardized test questions. York, Gibson, and Rankin (2015) assert that student success is not just academic achievement, but also “engagement in educationally purposeful activities, satisfaction, acquisition of desired knowledge, skills and competencies, persistence, attainment of educational outcomes, and post-college performance” (York, Gibson, & Rankin, 2015, p. 4). Tests measure a small portion of student learning. Many students mentioned specific laboratory experiences and related how they had been able to generalize that learning to other situations. Additionally, the test questions only measured TEKS content specific knowledge and not process skills which are also important to student learning in chemistry.

Key word analysis proved to be too simplistic to adequately provide a link between student laboratory experience and attitude or interest. However, coding for ideas and themes revealed students’ strong preference for hands-on learning in general and for physically interactive chemistry labs. Students enjoy the interaction with physical equipment and supplies. Nearly every student mentioned the gratification involved in mixing chemicals and the joy of the thrill or suspense involved in participating in hands-on labs. Even though they admitted that they did not perform any better on tests based on HO versus CS experiences, they much preferred the HO experiences. Students mentioned seeing, smelling, touching, and even hearing the effects of the HO lab.

Adding this additional layer of aesthetics certainly aids recall, transference, and a deeper understanding of knowledge.

It is noteworthy that many students voiced their concern over the digital environment and the lack of complexity involved in CS lab experiences. Four students mentioned that CS labs should be more "life-like" and two of these participants considered CS laboratory developers should work with gaming developers to produce a better experience for the students. The students realized they were learning from the background material presented, but believed the activities were largely a waste of time, boring, or too complicated.

## Implications

This research adds to the body of research about the effects of hands-on laboratory experiences on student test scores, attitude, and interest in science. Ruby (2001) said scientific knowledge is often complex and abstract, and noted that physically manipulating objects can help bridge the gap between the concrete and the abstract. Relatedly, other studies have shown an improvement in test scores after participating in HO labs (Darling-Hammond, et al, 2019: National Research Council, 2012). The paired t-test showed a statistically significant improvement in test scores when students participated in HO labs.

Perhaps more importantly, students clearly expressed their increase in interest and positive attitude toward chemistry because of the HO lab experiences. The jobs of the future are STEM jobs according to the 2013 report from the Committee on STEM Education. The committee stressed that "STEM competencies are increasingly required not only within but also outside of specific STEM occupations" (National Science and Technology Council, 2013, p. vi). Students who are interested in science and have a positive attitude toward science are more likely to pursue a career in a STEM field. Maltese and Tai completed an analysis to evaluate the school-based factors related to students choosing to complete a major in STEM. Their results indicate that the majority of students who choose STEM make that choice during high school, and the choice is related to a growing interest in mathematics and science rather than achievement (Maltese & Tai, 2011). Hands-on labs that convey the applications of science keep students interested in learning.

Interested, engaged students with positive attitudes toward science are needed to pursue careers and meet the demand for more science-related professionals, to address under-representation of girls and minorities in STEM careers, and to promote equity. The U.S. needs more students studying science-related subjects. Besides being in high demand, STEM careers usually offer good salaries. On a more personal level, understanding science aids in understanding of the world. From heartier tomatoes, to sending manned missions to explore the universe, to improving the safety of household cleaners and baking fluffier pastries, everything is the result of scientific research and experimentation.

Educational practice can be impacted by this research. Classroom teachers can add this study to the body of research confirming that student interest and attitude is important for future learning and one of the best ways to improve attitude and interest is to have students actively involved in relevant and engaging experiences. School administrators and district accountants should also cite this research as further proof that the investment in equipment and supplies for physically interactive laboratory experiences money well-spent.

## Recommendations for Future Research

Additional research is needed to provide further validation for time and money spent on hands-on labs. Student enjoyment and interest are worthwhile considerations, and have tangible benefits, but more proof of immediate learning would be beneficial in convincing teachers and administrators to invest the resources necessary for the successful implementation of a comprehensive program. Another consideration for further research would be to include retention of learning as a dependent variable, since this might show a more marked difference between the HO and CS lab methods. Future research could also be carried out using the original plan in this dissertation, which was designed to have different groups participate in hands-on and computer simulated labs and then compare results. Other research considerations include measuring science process skills and performance on non-standardized assessments. Applying a social justice lens to the research could reveal a relationship between participation in HO labs and attitude, interest, and academic achievement in under-served groups of students such as low-income students and students with learning disabilities. The social justice might also assess equity of impact according to gender or race. A larger sample size could also yield interesting results based on students' class rank or history of success in science.

## Recommendations Beyond Research

Educational standards and curriculum are routinely modified in seeking a higher quality of education and improvement of academic performance by all students (Darling-Hammond, et al. 2019). The mandates placed on the school systems have heightened the need for states to find valid research methodologies to provide concrete evidence in favor of implementing specific programs aimed at improving student achievement. Based on the results of this and other research studies, the implementation of interactive, hands-on science experiments improves student interest and attitude, and the participation in both HO and CS labs results in student learning. Therefore, educators should adhere to the state policy of requiring students to participate in laboratory and field investigations for at least 40% of instructional time. School leaders and district coordinators can allay teacher's insecurities concerning changing their normal routines to include more lab and field work by providing training and collaborative time or through partnerships with professionals and members of the community. Teachers' concerns of limited time for teaching and extra effort required to prepare for labs can also be alleviated through training by experienced mentors, availability of teacher aides (even students in higher grades could serve as aides), and strategically placed conference periods which allow for lab set-up and clean-up (Adb-Hamid, Campbell, Der, & Wolf, 2012; Guzman & Bartlett, 2012). Active research on time, resources, and student success, done by teachers, within their own classrooms and departments can also increase student engagement and lead to better allocation of resources which results in more student interest, better attitudes, and improved test scores.

## Study Summary as it Relates to Theory

Aristotle wrote of learning by doing nearly 2000 years ago (Aristotle, 2004) and John Dewey believed all principles by themselves are abstract and become concrete only in the consequences which result from their application (Dewey, 1938). The literature review revealed a link between hands-on activity and student attitude, interest, and achievement (Baseya and Francis, 2011; Darling-Hammond, Flook, Harvey, Barron, & Osher, 2019). The results of the statistical tests performed using the data from this research largely showed that participating in hands-on laboratory experiences increases positive attitude, interest, and achievement in science. Therefore, this research further supports that link.

Comprehension of how humans learn and develop has grown rapidly, but much of what we know from research on learning and instruction has yet to influence the design and enactment of everyday schooling in the form of curriculum, instruction, and assessment (Goldman & Pellegrino, 2015). Recommendations for improving educational practices have emerged from a general agreement about the science of learning and development, outlined in a recent synthesis of the research (Cantor, Osher, Berg, Steyer, & Rose, 2018). The theoretical rationale for the effect of hands-on experience on student achievement is grounded in developmental theory. This theory posits that there are successive stages of development through which humans progress. Thinking during the second stage of development depends on concrete matters and advancement to the third, abstract stage, is facilitated through interaction with the environment. Following this theory, hands-on activities must help students progress to the final level (Darling-

Hammond, Flook, Harvey, Barron, & Osher, 2019). This research adds support to this theory. A second theoretical rationale for the impact of hands-on experience is grounded in cognitive theory which states that "participating in tactile experiences adds a physical component to abstract knowledge, creating additional connections and improving retrieval" (Ruby, 2001, p. 28). Cognitive theory is also supported by the results of this research. Therefore, this study adds to the literature showing that people learn by doing, and also that being actively involved in and participating in learning leads to positive attitudes and increased interest.

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# APPENDIX A

## Letters of Consent and Assent

**Parental consent for child's participation in research**

*Dear parent,*

Your child is being asked to take part in a research study. This form has important information about the reason for doing this study, what I will ask your child to do, and the way I would like to use information about your child if you choose to allow your child to be in the study. Your child is being asked to participate in a research study about the relationship between hands-on laboratory experiences in science classes, versus computer simulated laboratory experiences in Chemistry. The purpose of the study is to gather information about chemistry students' performance on assessments, experiences, and interest in science. The study will use recorded data from Chemistry tests your student has already taken during the 2019-2020 school year.

One student will be randomly chosen from each class to participate in a focus discussion. If your student is chosen for the focus study, s/he will be asked to participate in a discussion session where we will have a conversation about his or her interest in and experiences with chemistry during the units. Participation in the focus group will take place during a Zoom meeting which will be held the week of May 25 or June 1 between 1 and 2 pm and will last about 30 minutes.

I would like to audio tape your child in the focus group as s/he answers questions and talks to make sure that I accurately remember all the information. Your child's responses will be seen only by the investigators involved in the project, but no identifying information will be collected. Your child's responses will be completely anonymous. We will only audio tape your child if you and your child give us permission. Audio recording is required for participation in the focus group portion of this study only. If you or your child do not wish to be recorded, it is not possible for your child to be in the focus group.

Your child's participation in this study may involve the following risks:

- All students will receive the same learning experiences regardless of whether they are involved in the research. The only difference will be that participants who agree to allow me to use their anonymous data will have their scores included in the research.
- If your child is uncomfortable with any of the questions and topics we discuss in the focus group, s/he is free to not answer or skip to the next question.

As with all research, there is a chance that confidentiality of the information we collect about your child could be breached – we will take steps to minimize this risk, as discussed in more detail below in this form. Taking part in this research study may not benefit your child personally, but we may learn new things that will help others. Results of this study may be used in publications and presentations. Your child's name and identity will not be used or shared. I will only say that high school chemistry students in a school in East Texas were tested and no other specifics will be given. Participation in this study will involve no cost to you or your child. Your child will not be paid for participating in this study.

Participation in this study is voluntary. Your child may withdraw from this study at any time -- you and your child will not be penalized in any way or lose any sort of benefits for deciding to stop participation. If you and your child decide not to be in this study, this will not affect the relationship you and your child have with your child's school in any way.

Participation or non-participation in this study will not affect your student's grade in the class in any way.

If your child decides to withdraw from this study, the researchers will ask if the information already collected from your child can be used.

Should you have any questions about this research, please feel free to contact Dr. Barbara Qualls, dissertation chair and professor of graduate studies in the department of educational leadership at Stephen F. Austin State University. Dr. Qualls may be contacted by phone at 936.468.1592

or by email at quallsba@sfasu.edu. Should you have any concerns about this research at any of its stages, please feel free to contact Stephen F. Austin State University's Office of Research and Sponsored Programs at 936.468.6606.

**Please keep one copy of the consent form for your records and return the other form with your child to school.**

*Many thanks.*

*Gretchenn Adkins*

*Educational Leadership Ed. D. Student*

*Department of Secondary Education and Educational Leadership*

*Perkins College of Education*

*Stephen F. Austin State University*

**Parental Permission for Child's Participation in Research**

I have read this form and the research study has been explained to me. I have been given the opportunity to ask questions and my questions have been answered. If I have additional questions, I have been told whom to contact. I give permission for my child to participate in the research study described above and will receive a copy of this Parental Permission form after I sign it.

I understand that some of my child's Chemistry test data from the 2019-2020 school year will be used. His or her test scores will be used to assess the effect of each type of laboratory experience on learning. His or her identity will be strictly anonymous.

Initial one of the following to indicate your choice:

__I agree to my child's test scores being used in the research

__I do not agree to my child's test scores being used in the research

I understand my child will be audio taped if s/he is selected for the focus group. His or her identity will be strictly anonymous.

Initial one of the following to indicate your choice:

_____ (initial) I agree to my child being audio taped…

_____ (initial) I do not agree to my child being audio taped…

I may wish to quote from the interview with your child either in the presentations or articles resulting from this work. A pseudonym (fake name) will be used in order to protect your child's identity.]

Initial one of the following to indicate your choice:

_____ (initial) I agree to allow the use of my child's quotes as long as a pseudonym is used…

_____ (initial) I do not agree to allow the use of my child's quotes as long as a pseudonym is used …

_______________________________________________________________________

Parent/Legal Guardian's Name (printed) and Signature Date

_____________________________________________________________________________

Name of Person Obtaining Parental Permission Date

**Student Assent for child's participation in research**

I am from Stephen F. Austin State University and I am asking you to be in a research study. I do research studies to learn more about how the world works and why people act the way they do. In this study, I want to learn about how hands-on laboratory experiences compare to computer simulated laboratory experiences in interest in Science, test scores, and retention of knowledge.

I would like to use some of your test score information from the unit tests you took in Chemistry for the 2019-2020 school year. I will not reveal your name or class, or even the school you attend.

I will randomly choose 1 student from each class to participate in a focus group. We will have a conversation about your experiences and interest in Science. I would like to meet with you for about 30 minutes one day during the week of May 25 or June 1 between 1 and 2 pm.

You do not have to participate in this study. It is up to you. You can say no now or you can even change your mind later. Your grades will not be affected by your choice to participate or not participate in the study. Your relationship with your school, teachers and classmates will not be affected if you choose to not participate in the study or if you choose to stop participating at any point. Being in this study will bring you no harm. There are no direct benefits to you for participating in this study. It will hopefully help us learn more about how hands-on lab experiences affect learning and interest in science.

I will be very careful to keep your test scores and comments in the focus group discussions private. Before and after the study we will keep all information we collect about you locked up and password protected.

If you want to stop doing the study at any time, please talk to your parent. There is no penalty for stopping. If you decide that you don't want your materials in the study but you already turned them in, just let your parents know.

*Many thanks.*

*Gretchenn Adkins*

*Educational Leadership Ed. D. Student*

*Department of Secondary Education and Educational Leadership*

*Perkins College of Education*

*Stephen F. Austin State University*

By signing this form, I agree to be in the research study described above.

**Name: ___________________________________________________**

**Signature: _______________________________________________ Date: ______________**

**You may print a copy of this form.**

# APPENDIX B

## Chemistry TEKS

**112.35. Chemistry (One Credit, Adopted 2017)**

(a) General requirements: Students shall be awarded one credit for the successful completion of this course. Required prerequisites: one unit of high school science and Algebra I, Suggested prerequisite: completion of or concurrent enrollment in a second year of mathematics. This course is recommended for students in Grade 10, 11, or 12.

(b) Introduction:

(1) Chemistry. In Chemistry, students conduct laboratory and field investigations, use scientific practices during investigations, and make informed decisions using critical thinking and scientific problem solving. Students study a variety of topics that include characteristics of matter, use of the Periodic Table, Development of the atomic theory and chemical bonding, chemical stoichiometry, gas laws, solution chemistry, thermochemistry, and nuclear chemistry. Students will investigate how chemistry is an integral part of our daily lives.

(2) Nature of science. Science, as defined by the National Academy of Sciences, is the "use of evidence to construct testable explanations and predictions of natural phenomena, as well as the knowledge generated through this process." This vast body of changing and increasing knowledge is described by physical, mathematical, and conceptual models. Students should know that some questions are outside the realm of science because they deal with phenomena that are not currently scientifically testable.

(3) Scientific inquiry. Scientific inquiry is the planned and deliberate investigation of the natural world. Scientific practices of investigation can be experimental, descriptive, or comparative. The method chosen should be appropriate to the question being asked.

(4) Science and social ethics. Scientific decision making is a way of answering questions about the natural world. Students should be able to distinguish between scientific decision-making methods and ethical and social decisions that involve the application of scientific information.

(5) Scientific systems. A system is a collection of cycles, structures, and processes that interact. All systems have basic properties that can be

described in terms of space, time, energy, and matter. Change and constancy occur in systems as patterns and can be observed, measured, and modeled. These patterns help to make predictions that can be scientifically tested. Students should analyze a system in terms of its components and how these components relate to each other, to the whole, and to the external environment.

(6) Statements containing the word "including" reference content that must be mastered, while those containing the phrase "such as" are intended as possible illustrative examples.

(c) Knowledge and skills.

(1) Scientific processes. The student, for at least 40% of instructional time, conducts laboratory and field investigations using safe, environmentally appropriate, and ethical practices. The student is expected to:

(A) demonstrate safe practices during laboratory and field investigations, including the appropriate use of safety showers, eyewash fountains, safety goggles, and fire extinguishers;

(B) know specific hazards of chemical substances such as flammability, corrosiveness, and radioactivity as summarized on the Material Safety Data Sheets (MSDS); and

(C) demonstrate an understanding of the use and conservation of resources and the proper disposal or recycling of materials.

(2) Scientific processes. The student uses scientific methods to solve investigative questions. The student is expected to:

(A) know the definition of science and understand that it has limitations, as specified in subsection (b)(2) of this section;

(B) know that scientific hypotheses are tentative and testable statements that must be capable of being supported or not supported by observational evidence. Hypotheses of durable explanatory power which have been tested over a wide variety of conditions are incorporated into theories;

(C) know that scientific theories are based on natural and physical phenomena and are capable of being tested by multiple independent researchers. Unlike hypotheses, scientific theories are well-established and highly-reliable explanations, but may be subject to change as new areas of science and new technologies are developed;

(D) distinguish between scientific hypotheses and scientific theories;

(E) plan and implement investigative procedures, including asking questions, formulating testable hypotheses, and selecting equipment and technology, including graphing calculators, computers and probes, sufficient scientific glassware such as beakers, Erlenmeyer flasks, pipettes, graduated cylinders, volumetric flasks, safety goggles, and burettes, electronic balances, and an adequate supply of consumable chemicals;

(F) collect data and make measurements with accuracy and precision;

(G) express and manipulate chemical quantities using scientific conventions and mathematical procedures, including dimensional analysis, scientific notation, and significant figures;

(H) organize, analyze, evaluate, make inferences, and predict trends from data; and

(I) communicate valid conclusions supported by the data through methods such as lab reports, labeled drawings, graphs, journals, summaries, oral reports, and technology-based reports.

(3) Scientific processes. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to:

(A) in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student;

(B) communicate and apply scientific information extracted from various sources such as current events, news reports, published journal articles, and marketing materials;

(C) draw inferences based on data related to promotional materials for products and services;

(D) evaluate the impact of research on scientific thought, society, and the environment;

(E) describe the connection between chemistry and future careers; and

(F) research and describe the history of chemistry and contributions of scientists.

(4) Science concepts. The student knows the characteristics of matter and can analyze the relationships between chemical and physical changes and properties. The student is expected to:

(A) differentiate between physical and chemical changes and properties;

(B) identify extensive and intensive properties;

(C) compare solids, liquids, and gases in terms of compressibility, structure, shape, and volume; and

(D) classify matter as pure substances or mixtures through investigation of their properties.

(5) Science concepts. The student understands the historical development of the Periodic Table and can apply its predictive power. The student is expected to:

(A) explain the use of chemical and physical properties in the historical development of the Periodic Table;

(B) use the Periodic Table to identify and explain the properties of chemical families, including alkali metals, alkaline earth metals, halogens, noble gases, and transition metals; and

(C) use the Periodic Table to identify and explain periodic trends, including atomic and ionic radii, electronegativity, and ionization energy.

(6) Science concepts. The student knows and understands the historical development of atomic theory. The student is expected to:

(A) understand the experimental design and conclusions used in the development of modern atomic theory, including Dalton's Postulates, Thomson's discovery of electron properties, Rutherford's nuclear atom, and Bohr's nuclear atom;

(B) understand the electromagnetic spectrum and the mathematical relationships between energy, frequency, and wavelength of light;

(C) calculate the wavelength, frequency, and energy of light using Planck's constant and the speed of light;

(D) use isotopic composition to calculate average atomic mass of an element; and

(E) express the arrangement of electrons in atoms through electron configurations and Lewis valence electron dot structures.

(7) Science concepts. The student knows how atoms form ionic, metallic, and covalent bonds. The student is expected to:

(A) name ionic compounds containing main group or transition metals, covalent compounds, acids, and bases, using International Union of Pure and Applied Chemistry (IUPAC) nomenclature rules;

(B) write the chemical formulas of common polyatomic ions, ionic compounds containing main group or transition metals, covalent compounds, acids, and bases;

(C) construct electron dot formulas to illustrate ionic and covalent bonds;

(D) describe the nature of metallic bonding and apply the theory to explain metallic properties such as thermal and electrical conductivity, malleability, and ductility; and

(E) predict molecular structure for molecules with linear, trigonal planar, or tetrahedral electron pair geometries using Valence Shell Electron Pair Repulsion (VSEPR) theory.

(8) Science concepts. The student can quantify the changes that occur during chemical reactions. The student is expected to:

(A) define and use the concept of a mole;

(B) use the mole concept to calculate the number of atoms, ions, or molecules in a sample of material;

(C) calculate percent composition and empirical and molecular formulas;

(D) use the law of conservation of mass to write and balance chemical equations; and

(E) perform stoichiometric calculations, including determination of mass relationships between reactants and products, calculation of limiting reagents, and percent yield.

(9) Science concepts. The student understands the principles of ideal gas behavior, kinetic molecular theory, and the conditions that influence the behavior of gases. The student is expected to:

(A) describe and calculate the relations between volume, pressure, number of moles, and temperature for an ideal gas as described by Boyle's law, Charles' law, Avogadro's law, Dalton's law of partial pressure, and the ideal gas law;

(B) perform stoichiometric calculations, including determination of mass and volume relationships between reactants and products for reactions involving gases; and

(C) describe the postulates of kinetic molecular theory.

(10) Science concepts. The student understands and can apply the factors that influence the behavior of solutions. The student is expected to:

(A) describe the unique role of water in chemical and biological systems;

(B) develop and use general rules regarding solubility through investigations with aqueous solutions;

(C) calculate the concentration of solutions in units of molarity;

(D) use molarity to calculate the dilutions of solutions;

(E) distinguish between types of solutions such as electrolytes and nonelectrolytes and unsaturated, saturated, and supersaturated solutions;

(F) investigate factors that influence solubilities and rates of dissolution such as temperature, agitation, and surface area;

(G) define acids and bases and distinguish between Arrhenius and Bronsted-Lowry definitions and predict products in acid base reactions that form water;

(H) understand and differentiate among acid-base reactions, precipitation reactions, and oxidation-reduction reactions;

(I) define pH and use the hydrogen or hydroxide ion concentrations to calculate the pH of a solution; and

(J) distinguish between degrees of dissociation for strong and weak acids and bases.

(11) Science concepts. The student understands the energy changes that occur in chemical reactions. The student is expected to:

(A) understand energy and its forms, including kinetic, potential, chemical, and thermal energies;

(B) understand the law of conservation of energy and the processes of heat transfer;

(C) use thermochemical equations to calculate energy changes that occur in chemical reactions and classify reactions as exothermic or endothermic;

(D) perform calculations involving heat, mass, temperature change, and specific heat; and

(E) use calorimetry to calculate the heat of a chemical process.

(12) Science concepts. The student understands the basic processes of nuclear chemistry. The student is expected to:

(A) describe the characteristics of alpha, beta, and gamma radiation;

(B) describe radioactive decay process in terms of balanced nuclear equations; and

(C) compare fission and fusion reactions.

# APPENDIX C

## Lab and Field: Frequently Asked Questions

## Laboratory and Field Investigations
**Frequently Asked Questions**

**August 2010**

**1. What is a laboratory investigation?**

A school laboratory investigation (also referred to as a lab) is defined as an experience in the laboratory, the classroom, or the field that provides students with opportunities to interact directly with natural phenomena or with data collected by others using tools, materials, data collection techniques, and models (National Research Council, *National Science Education Standards*, 2006, p. 3).

**2. Are there any new laboratory and field requirements in the 2010 science TEKS?**

Yes. In the new Texas Essential Knowledge and Skills (TEKS) for science, laboratory and field investigations will take on increased importance. First, the 40% time requirement has been expanded from the high school level to the middle school level. Second, science equipment and supplies are now specified at the high school level, expanding on the K-8 requirements. Third, the elementary-level science TEKS now have recommendations for time percentages.

- How much laboratory and field time is suggested for elementary school science programs?

  *In grades K-1, districts are encouraged to facilitate classroom and outdoor investigations for at least 80% of instructional time.*

  *In grades 2-3, districts are encouraged to facilitate classroom and outdoor investigations for at least 60% of instructional time.*

  *In grades 4-5, districts are encouraged to facilitate classroom and outdoor investigations for at least 50% of instructional time.*

- How much laboratory and field time is required for middle school science programs?

  *In grades 6-8, students for at least 40% of instructional time, conduct laboratory and field investigations.*

- How much laboratory and field time is required for high school science programs?

  *For all courses that receive science credit in grades 9-12, students for at least 40% of instructional time, conduct laboratory and field investigations.*

All of the science TEKS are found in 19 Texas Administrative Code (TAC), Chapter 112, and are available at http://ritter.tea.state.tx.us/rules/tac/chapter112/index.html.

**3. What types of investigations are cited in the 2010 science TEKS?**

The 2010 science TEKS reference three types of investigations—descriptive, comparative, and experimental.

- **Descriptive investigations** involve collecting qualitative and/or quantitative data to draw conclusions about a natural or man-made system (e.g., rock formation, animal behavior, cloud, bicycle, electrical circuit). A descriptive investigation includes a question, but no hypothesis. Observations are recorded, but no comparisons are made and no variables are manipulated.
- **Comparative investigations** involve collecting data on different organisms/objects/ features/events, or collecting data under different conditions (e.g., time of year, air temperature, location) to make a comparison. The hypothesis identifies one independent (manipulated) variable and one dependent (responding) variable. A "fair test"* can be designed to measure variables so that the relationship between them is determined.

- **Experimental investigations** involve designing a "fair test"* similar to a comparative investigation, but a control is identified. The variables are measured in an effort to gather evidence to support or not support a causal relationship. This is often called a "controlled experiment."

* A fair test is conducted by making sure that only one factor (variable) is changed at a time, while keeping all other conditions the same.

**4. How can classroom teachers design scientific descriptive and comparative investigations?**

Science often emphasizes experimental investigation in which students actively manipulate variables and control conditions. In studying the natural world, it is difficult to actively manipulate variables and maintain "control" and "experimental" groups, so field investigation scientists look for descriptive or comparative trends in naturally occurring events. Many field investigations begin with counts (gathering baseline data). Later, measurements are intentionally taken in different locations (e.g., urban and rural, or where some natural phenomenon has created different plot conditions) because scientists suspect they will find a difference. In contrast, in controlled experiments, scientists begin with a hypothesis about links between variables in a system.

**5. What types of variables are there in an experiment?**

- **Manipulated (changed) variable, also called the independent variable** – the factor of a system being investigated that is deliberately changed to determine that factor's relationship to the responding variable
- **Responding variable, also called the dependent variable** – the factor of a system being investigated that changes in response to the manipulated variable and is measured
- **Controlled variables** – the conditions that are kept the same in a scientific investigation

**6. What are the guidelines for field investigations?**

- **Guidelines for Instructional Field Experiences** – This brochure is designed to provide administrators with information to support field investigations on the campus. This brochure is available on the TEA science website.
- **Field Investigations: Using Outdoor Environments to Foster Student Learning of Scientific Processes** – This document contains examples of descriptive and comparative investigations. This document is available at http://www.fishwildlife.org/pdfs/Field%20Investigation%20Guide.pdf.

**7. What are the rules and laws regarding safety in science investigations?**

Safety information, including classroom, laboratory, and field investigations is available in the Safety Standards. The new science TEKS have expanded the required safety equipment for grades K-12.

**8. How many students can be placed in a science class?**

Schools should carefully consider the actual size of the classroom and laboratory space and how that relates to safety. See question 9 below for further information.

**9. What are the size requirements for school laboratories?**

The following requirements for school facility standards shall apply to projects for new construction or major space renovations for which the construction documents have been approved by a school district board of trustees, or a board's authorized representative, on or after January 1, 2004.

Specialized Classrooms – The following provisions shall apply to combination science laboratories/classrooms, where each student has a lab station and where typically there is a clearly defined laboratory area and a clearly defined lecture area.

- Combination science laboratories/classrooms shall have a minimum of 900 square feet per room at the **elementary** school level. The minimum room size is adequate for 22 students; 41 square feet per student shall be added to the minimum square footage for each student in excess of 22.

- Combination science laboratories/classrooms shall have a minimum of 1,200 square feet per room at the **middle** school level. The minimum room size is adequate for 24 students; 50 square feet per student shall be added to the minimum square footage for each student in excess of 24.
- Combination science laboratories/classrooms shall have a minimum of 1,400 square feet per room at the **high** school level. The minimum room size is adequate for 24 students; 58 square feet per student shall be added to the minimum square footage for each student in excess of 24.

For districts that choose to use separate science classrooms and science laboratories, the following provisions shall apply:

- A science classroom shall be a minimum of 700 square feet regardless of grade level served.
- A science laboratory shall have a minimum of 800 square feet at the elementary school level. The minimum laboratory size is adequate for 22 students; 36 square feet per student shall be added to the minimum square footage for each student in excess of 22.
- A science laboratory shall have a minimum of 900 square feet at the middle school level. The minimum laboratory size is adequate for 24 students; 38 square feet per student shall be added to the minimum square footage for each student in excess of 24.
- A science laboratory shall have a minimum of 1,000 square feet at the high school level. The minimum laboratory size is adequate for 24 students; 42 square feet per student shall be added to the minimum square footage for each student in excess of 24.
- Science classrooms shall be provided at a ratio not to exceed 2:1 of science classrooms to science laboratories at the middle school and high school levels. The science laboratories shall be located convenient to the science classrooms they serve.

The complete Commissioner's Rules Concerning School Facilities is located at http://ritter.tea.state.tx.us/rules/tac/chapter061/ch61cc.html.

**10. Where is information available for building science laboratories?**

Detailed information on building new science laboratories, or renovating old science laboratories, is provided in the *Texas Facilities Standards*. In addition, information on constructing outdoor science learning facilities for your school may be found in this document. This document will be posted soon on the science curriculum website.

**11. Can a school charge students "lab fees" to cover the cost of materials used in the science classroom or place items such as safety goggles on the student supply list?**

No. A district must have statutory authorization to charge a fee. Texas Education Code (TEC) §11.158 is where most allowed fees are delineated. Specifically TEC §11.158(b)(1) prohibits fees for "textbooks, workbooks, laboratory supplies, or other supplies necessary for participation in any instructional course . . . ." There are some exceptions (band instrument rentals, for example), but they do not apply in this instance.

**12. Do demonstrations, simulations and web explorations count as labs in regard to the 40% lab time requirement?**

Scientists across the state and nation have noted the growing use of computer generated data collection and investigation. Computer software, hardware, and online instructional resources are now an integral part of most science classes. Students enjoy and can gain knowledge from the use of computers in science. It is appropriate to include some level of simulations and computer generated laboratory experiences as science laboratory time. It is important, however, that these simulations, demonstrations, and two dimensional laboratory experiences do not dominate the student experience in science. The very nature of science warrants student manipulation of equipment, earth materials and organisms that engage all of the student's senses in a way that no computer program can simulate. Demonstrations, simulations, and web explorations can be considered part of the 40% lab requirements if they incorporate active learning and engagement. Schools should carefully consider the portion of the 40% lab requirement that is made up of such activities.

# APPENDIX D

## Hands-On Laboratory Experiences

**Unit One Lab**

**Station 1: Elasticity.**

Materials:
• safety goggles • black balls

Procedures:
1. Record all observations, thoughts, and responses to questions in your science notebook. 2. Drop both balls from the same height onto the floor.
3. What happened?
4. Why do you think this happened?
5. Make a sketch illustrating what you observed at this station.

**Station 2: Density.**

Materials: • safety goggles • spheres (same mass) (2) • plastic bowl with water • paper towels • STAAR Chemistry Reference Materials

Procedures:
1. Record all observations, thoughts, and responses to questions in your science notebook. 2. Write a prediction related to what will happen when you place the two spheres in a bowl of water.
3. Do so and then describe what happens.
4. Refer to the STAAR Chemistry Reference Materials. What is the formula provided to calculate density?
5. Both balls have the same mass. Explain your observations using the terms mass, volume, and density.
6. Make a sketch illustrating what you observed at this station.
7. Remove the spheres from the water and wipe them dry with a paper towel.

**Station 3: Viscosity.**

Materials: • safety goggles • viscosity apparatus (with 4 labeled liquids) • stopwatch • steel balls, 4 • magnet • paper towels
Procedures:

1. Record all observations, thoughts, and responses to questions in your science notebook. 2. Create a data table to document data.
3. Compare the time it takes for a steel ball to fall through each liquid and settle on the bottom of the tube.
4. Retrieve each steel ball using the magnet. Wipe them off with a paper towel.
5. Define viscosity.
6. Which liquid is the most viscous?
7. Which liquid is the least viscous?
8. Make a sketch illustrating what you observed at this station.

**Station 4: Compressibility.**

Materials: • safety goggles • capped syringe half full with liquid (water) • capped syringe half full with gas (air)
Don't push too hard on the pistons!

Procedures:
1. Record all observations, thoughts, and responses to questions in your science notebook. 2. Push in the piston of the syringe filled with air.
3. Push in the piston of the syringe filled with water.
4. How would you compare the compressibility of a liquid and a gas?
5. Make a sketch illustrating what you observed at this station.

**Station 5: Hot Pack vs. Cold Pack.**

Materials: • safety goggles • hot pack/cold pack bag • pipet, plastic (25 mL) • water in container, room temperature • MSDS for calcium chloride and sodium bicarbonate

Safety: • Wear safety goggles. • Review the MSDS for calcium chloride and sodium bicarbonate.
Procedures:
1. Record all observations, thoughts, and responses to questions in your science notebook. 2. Open the side of the bag labeled H.
3. Carefully squeeze one pipet-full of water into the baggie, and seal it completely.
4. Massage the bag until most or all of the substance dissolves, and record your observations.
5. Remove the clothespin, and carefully mix the contents from side H with side C. Be sure bag is sealed completely.
6. Record your observations.
7. Make a sketch and describe what you observed at this station.

8. Dispose of your materials as directed.

**Station 6: Sublimation.**

Materials: • dry ice (solid carbon dioxide) in cooler • dry ice MSDS • tongs • beaker (250 mL) • water • safety goggles

Safety: • Wear safety goggles. • Review the MSDS for dry ice. • Do not touch the dry ice.

Procedures:
1. Record all observations, thoughts, and responses to questions in your science notebook. 2. Place about 150 mL of water in the beaker.
3. Use the tongs to pick up a small piece of dry ice and place the dry ice in the water.
4. Write an explanation of what you think is happening.
5. Make a sketch illustrating what you observed at this station.
6. Dispose of the water and leftover dry ice as directed.

**Station 7: Condensation.**

Materials: • safety goggles • beaker with hot water on hot plate • watch glass • ice in small cooler • paper towels

Safety: • Wear safety goggles. • Use caution when working with hot liquid.

Procedures:
1. Record all observations, thoughts, and responses to questions in your science notebook. 2. Place the watch glass on top of the beaker of hot water.
3. Place two ice cubes on the watch glass and observe.
4. Write an explanation of what you think is happening.
5. Make a sketch illustrating what you observed at this station.
6. Dispose of the ice and wipe off the watch glass with a paper towel.

**Station 8: Water phase change.**

Materials: • hot plate with stirrer • magnetic stir bar • ice (4–5 cubes or crushed) in water in 250 mL beaker • thermometer or temperature probe with data collection software • ring stand

Safety: • Wear goggles.
Procedures:

1. Record all observations, thoughts, and responses to questions in your science notebook. 2. Place the beaker with the ice, water, thermometer or temperature probe, and magnetic stirrer on the hot plate. (Make sure the thermometer or probe is not touching the sides or bottom of beaker.)
3. Turn the heat on high and start collecting data.
4. Collect data until water boils for 10 or more seconds.
5. Sketch the resulting graph in your notebook; be sure to label the x- and y-axis.
6. Label the distinct sections of the graph as melting (solid and liquid), liquid, and boiling (liquid and gas).
7. Make a sketch illustrating what you observed at this station.

**Unit Two Lab: Periodic Trends**

1. Introduce students to 2D models of atomic radius of elements and isotopes.
2. Assign students in groups of 3–4 students to complete this activity.
3. Allow students to choose how they will model atomic radius and which families and periods they want to include. They may choose to look at a trend in one family or across the entire Periodic Table. Make sure all the listed trends are covered by a group.
4. Distribute copies of periodic trends to each student
5. You may want to provide a sample 3D model. You can use a Styrofoam block and toothpicks or bamboo skewers cut to size using a predetermined scale. For example, if the model is designed to relate atomic radius with position on the Periodic Table, a scale of 1 mm = 0.01 nm works well. Thus, a sodium atom with a radius of 0.192 nm would be represented with a skewer 19 mm long. All other elements would be represented and scaled in a similar fashion.
6. Organize a “Model Gallery Walk” so student groups can share their trend models. Have students walk through the gallery with their copies of the trends and make notes on patterns that they find.
7. Facilitate a summary discussion on trends in which students focus on the value of three dimensions, as an aid to seeing patterns.

**Unit Three Lab: Molecular Structure**

1. Divide the class into groups based on how many conductivity testers or probes you have available. Inform students that they will be conducting an investigation to test different solutions for conductivity.

2. Conduct a safety prelab discussion. Review the following with students before they begin: • location of safety equipment • reminder about wearing safety goggles • hazards of chemicals to be used and location of msds

Materials: • balances (triple beam or electronic, 1 per group) • beakers (250 mL, 5 per group) • weighing paper (several sheets per group) • Erlenmeyer flasks (250 mL, 2 per group) • graduated cylinders or pipettes (100 mL, 1 per group) • containers (labeled, 1 each per group) • deionized water, 1 L • tap water, 500 mL • sucrose solid, ~100 g • NaCl solid, ~100 g • empty for rinse water collection • conductivity probes or testers (1 per group) • rinse bottle containing deionized water (1 per group)

3. Remind students you will be expecting them to demonstrate safe practices, conservation of resources, and proper disposal.
4. Demonstrate proper use of the 100 mL graduated cylinder (meniscus) and/or pipette with bulb.
5. Inform students their first task is to make 100 mL of 10% sugar solution and 100 mL of 10% NaCl solution using deionized water in the Erlenmeyer flasks at their stations. Provide calculation and other assistance as needed to the groups.
6. Next, demonstrate the proper technique for using a conductivity probe tester. Emphasize the importance of rinsing with deionized water thoroughly between solutions.
7. Instruct students to use the conductivity tester to test the deionized water, tap water, sucrose solution, and NaCl solution (in that order to minimize contamination) for conductivity and record the data in their science notebooks.
8. Ask students to create a data table in their notebooks to record the data that will be taken. In addition, instruct students to draw and label the glassware/equipment they will use in completing the investigation.
9. Additionally, instruct students to write the Lewis dot structures for C, H, O, Na, and Cl in their science notebooks.
10. Monitor and assist students as they complete the investigation.
11. Test metal and nonmetal samples for conductivity. Record results.

Discussion Questions:

1. Why are some compounds good conductors in solution while others are not?

2. Write the Lewis dot structures showing what happens when NaCl is dissolved in water. Explain what is happening.

3. Why are metals good conductors? (Hint**:** $\mathbf{e}^-$)

4. Explain why ionic bonds form. Are the electrons given or shared? What kinds of elements form ionic bonds? Where are these elements located on the PTOE?

**Unit Four: Precision and Accuracy**

**Measure with Meaning Station Cards Station I – Length**

Materials:
• variety of metric rulers
• meter stick
• strips of paper or cardstock cut to the same length

Procedure:
1. Read the procedure.
2. Independently and silently measure the length of one strip, estimating to the nearest millimeter, using the meter stick and metric rulers.
3. Record your data on your lab **sheet.**
4. Compare your measurements of strip length with the others in your group, and record the additional measurements on your lab sheet.
5. Contribute group data to the class data table.

**Station II – Mass**

Materials:
• object of known mass
• variety of balances

Procedure:
1. Read the procedure.
2. Independently and silently measure the mass of the object, using the various balances. Record the results to the nearest hundredth.
3. Compare your measurements of mass with the others in your group, and record the additional measurements on your lab sheet.
4. Contribute group data to the class data table.

**Station III – Volume**

Materials:
• various types of containers, such as graduated cylinders, beakers, and Erlenmeyer flasks containing water

Procedure:
1. Read the procedure

2. Independently and silently measure the volume of water in each "measurer". Record the results in the data table on your lab sheet.
3. Compare your measurements of volume with the others, and record the additional measurements in your science notebooks.
4. Contribute group data to the class data table.

**Station 1—Measuring Length": Measure the strip of paper using 2 different rulers and the meter stick. Record your measurements in the table below and then write them in the class data table on the board. You will record the class data in this data table once it is posted.**

| Ruler #1 | Ruler #2 | Meter Stick |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

**Station 2—Measuring mass: Measure the weight using 3 different scales. Record your measurements in the table below and then write them in the class data table on the board. You will record the class data in this data table once it is posted.**

| Triple Beam | Digital Gram Scale | Digital |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

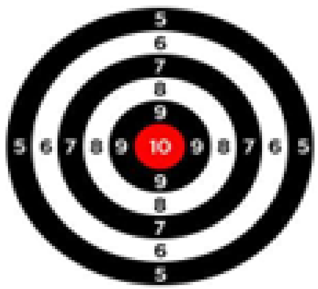
**Station 3—Measuring volume: Measure the volume in each container. (Do not add or remove any water.) Record your measurements in the table below and then write them in the class data table on the board. You will record the class data in this data table once it is posted.**

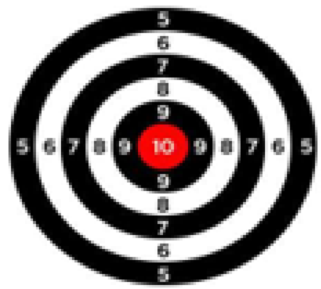
| Graduated cylinder | Beaker | Erlenmeyer flask |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

**Station IV**

Stand on the side of the table. Toss 4 pennies so that they land on the large target on the table. Record your results on the first bullseye on this sheet. Toss the pennies from the side of the table again and record your results on the second bullseye. Now toss the pennies from the end of the table. Record your results on bullseye #3. Toss the pennies from the end of the table again and record the results on bullseye #4.

Decide whether your results were accurate, precise, both, or neither for each bullseye. Record your answers and explain your answers. Discuss your conclusions with your lab partner.

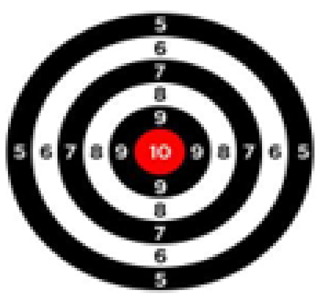


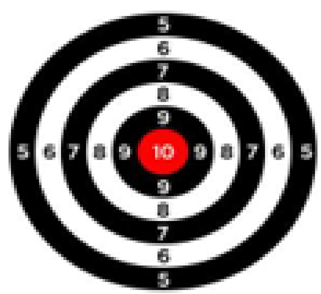




#1 ______________________ #2 ______________________

______________________ ______________________

______________________ ______________________




#3 ______________________ #4 ______________________

______________________ ______________________

______________________ ______________________

**Unit Five: Investigating Temperature and Solubility**

Introduction: There are a number of factors that affect the solubility of salts in water. In this activity, you will investigate the effects of temperature on the solubility of ammonium chloride.

Materials:
• balance
• 250 mL beakers (3)
• thermometer or temperature probe and interface
• graduated cylinder
• hot plate
• ice water
• hot water (about 90oC)
• stirring rod
• ammonium chloride (NH4Cl)
• plastic spoons or scoops
• massing papers
• beaker tongs
• tap water

Safety Notes: • Wear safety goggles and a lab apron. • Exercise caution in handling hot objects and glassware. • Read the MSDS sheet for handling of ammonium chloride. • Follow appropriate procedures for disposing of chemicals.

Procedures:
Part 1: Tap Water
1. Mass about 75 g of ammonium chloride on a massing paper. Accurately record the mass to at least the nearest 0.1 g. (Remember that you want only the mass of the salt.)
2. Measure 100 mL of tap water using the graduated cylinder. Pour the water into a 250 mL beaker.
3. Add a small amount (about 5 g) of the ammonium chloride to the water and stir to dissolve. Continue to add small increments of the salt, until no more will dissolve after you have stirred for about two minutes.
4. Record the final temperature of the solution.
5. Determine and record the mass of the remaining ammonium chloride.
6. Dispose of your solution and excess ammonium chloride as instructed by your teacher.

Part 2: Ice Water
1. Mass about 75 g of ammonium chloride on a massing paper. Accurately record the mass to at least the nearest 0.1 g. (Remember that you want only the mass of the salt.)

2. Obtain 100 mL of ice water (which includes a few small pieces of ice) using the graduated cylinder. Pour the ice water into a 250 mL beaker.
3. Add a small amount (about 5 g) of the ammonium chloride to the water and stir to dissolve. Continue to add small increments of the salt, until no more will dissolve after you have stirred for about two minutes.
4. Record the final temperature of the solution.
5. Determine and record the mass of the remaining ammonium chloride.
6. Carefully dispose of your solution and excess ammonium chloride as instructed by your teacher.

Part 3: Hot Water
1. Mass about 75 g of ammonium chloride on a massing paper. Accurately record the mass to at least the nearest 0.1 g. (Remember that you want only the mass of the salt.)
2. Obtain 100 mL of hot water using the graduated cylinder. Pour the water into a 250 mL beaker. Place the beaker containing the 100 mL of water on a hot plate and heat it until it reaches about 90oC.
3. Add a small amount (about 5 g) of the ammonium chloride to the water and stir to dissolve. Continue to add small increments of the salt, until no more will dissolve after you have stirred for about two minutes.
4. Record the final temperature of the solution.
5. Determine and record the mass of the remaining ammonium chloride.
6. Carefully dispose of your hot solution and excess ammonium chloride as instructed by your teacher.

Analysis:
1. Prepare a table showing your temperature versus mass of solute dissolved.
2. Prepare a second table showing the class data for temperature versus mass of solute dissolved.
3. Write a summary of the lab experience which includes your observations regarding rules for solubility, temperature, agitation, and surface area.
4. Give at least two example of ways you could get more ammonium chloride to dissolve in the water?

# APPENDIX E

## Unit Tests

**Test One**

Chemistry Test 2020 Name________________________________

Date___________________________

1. Which phase of matter shows the greatest changes in volume with changes in temperature and/or pressure?

   A. Gases
   B. Liquids
   C. Solids
   D. It depends on the mass.

2. A student is using a syringe, water, and blocks to investigate the compressibility of gases and liquids. They put 20.0 mL of air in the syringe and push on the plunger and are able to compress it to 10.0 mL. Next, they put 20.0 mL of water into the syringe and are not able to compress it at all. Which of the following statements would be a valid conclusion for this investigation?

   A. Air is compressible while water is not compressible.
   B. Adding pressure to the syringe allowed the gas to be compressed from 20mL to 10mL.
   C. Gases have more space between their molecules than liquids do, thus making them more compressible.
   D. Water would have compressed if more pressure had been used.

3. Which of the following observations is usually not evidence of a chemical change?

   A. Change of shape
   B. Formation of a precipitate
   C. Giving off of a gas
   D. Giving off of heat and/or light

4. Which process is not a chemical reaction?

   F. Condensation

G. Combustion
H. Oxidation
J. Tarnish

5. Which process is an example of a physical change?

A. Boiling of water
B. Combustion of wood
C. Digestion of food
D. Rusting of steel

6. Which of the following includes an example of a chemical property of an element?

F. Aluminum is a solid at room temperature and is a poor thermal insulator.
G. Sulfur is not shiny and is not malleable.
H. Sodium is a solid at room temperature and reacts with other elements.
J. Silicon is shiny and is a poor conductor of electricity.

7. In which phase does matter have a definite volume and shape?

A. Gas
B. Liquid
C. Solid
D. Plasma

8. In which of the following phases does matter have a definite volume, but no definite shape?

F. Gas
G. Liquid
H. Plasma
J. Solid

9. In which of the following phases does matter have no definite shape or volume?

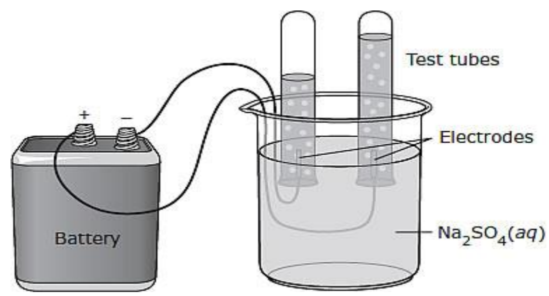
A. Gas
B. Liquid

C. Solid
D. Metal

10. A 5.0mL sample of ammonia is placed in a 100.0mL container which is then sealed. The ammonia sample completely fills the 100.0mL container and takes its shape. Which of the following best represents this sample of ammonia?

F. $NH_3(aq)$
G. $NH_3(g)$
H. $NH_3(l)$
J. $NH_3(s)$

11. The diagram below shows a battery giving off a current, producing bubbles in two test tubes.




Which of the following best shows that the investigation results in a chemical change?

A. Liquid condenses on a cold glass rod when gas from the test tube on the left is released.
B. A gas probe indicates that the water in the beaker contains dissolved nitrogen And oxygen.
C. A burning wood splint placed above the mouth of the test tube on the right glows brighter when some gas is released from the test tube.
D. The temperature of the wire connected to the battery increases.

12. Which of the following describes a chemical property of matter?

F. Helium does not form compounds.
G. Mercury will not soak into a paper towel.
H. Table salt will dissolve in water.
J. Water expands when it freezes.

13. A chemistry student's investigation is described below.

1. The student obtains 15 g of an unknown substance.
2. The student notes that at room temperature the substance is a solid and is colored white.
3. The student determines that the density of the substance is 2.17 $g/cm^3$.
4. The student then determines that the substance is soluble in water.

The student determines that the unknown substance is sodium chloride. Which of the following is an extensive property of sodium chloride?

A. Mass of 15 g
B. White color
C. Density of 2.17 $g/cm^3$
D. Solubility in water

14. The table below lists some properties of a sample of lauric acid.

| Property | Value |
|---|---|
| Volume | 79.6 mL |
| Mass | 70.022 g |
| Boiling point | 222°C |
| Number of moles | 0.350 |

Which of these is an intensive property of this sample?

F. Volume
G. Mass
H. Boiling point
J. Number of moles

15. Which process is not a chemical reaction?

A. Condensation
B. Combustion
C. Oxidation
D. Tarnish

16. Which of the following best explains why $CO_2$ gas is easily compressible but solid $CO_2$ (dry ice) is incompressible?

    A. The molecules of $CO_2$ gas are much closer together than the molecules in dry ice.
    B. The molecules of solid $CO_2$ are much closer together than the molecules of $CO_2$ gas.
    C. The molecules of $CO_2$ gas are much smaller than the molecules of solid $CO_2$.
    D. The molecules of $CO_2$ gas attract one another, while the molecules of the solid $CO_2$ repel one another.

17. Which of the following describes a phase change in which a solid becomes a gas without melting?

    A. Boiling
    B. Condensation
    C. Fusion
    D. Sublimation

18. Which type of substance cannot be broken down into simpler substances by a chemical change?

    A. Solutions
    B. Compounds
    C. Mixtures
    D. Elements

19. A student lab group is given four objects made of different materials. The objects are all of different sizes and masses. How can the students tell which object is made of the material with the highest density?

    A. The object with the greatest mass is the most dense material.
    B. The object with the greatest surface area is the most dense material.
    C. The object with the highest mass/volume ratio is the most dense

material.

D. The object with the lowest mass/volume ratio is the most dense material

20.

| Substance | Density | Conductive |
|---|---|---|
| Copper | 8.96 g/cm$^3$ | yes/high |
| Aluminum | 2.7 g/cm$^3$ | yes/high |
| Unknown metal | 7.87 g/cm$^3$ | yes/low |

A student completes an investigation and has gathered the information shown in the table above. The purpose of the investigation is to gather information about the different metals and compare it to known information on common metals. This information will help them identify the unknown metal. When the student has completed the activity, they are allowed to compare their results to a known information chart. Which of the following statements is correct regarding the information gathered in this investigation?

F. The information helps the student to find the identity of the unknown metal because they are all intensive properties.

G. Extensive properties, like density and conductivity, will identify the unknown material.

H. Measuring the density of a substance will help find the amount of the substance, thus identifying the type of substance.

J. None of these are correct.

21. Some students used a variety of procedures to investigate four liquid samples. The students recorded the following information.

- When Sample W was cooled, solid particles settled out of the liquid.
- The mass and volume of Sample X were measured, and the density of Sample X was calculated to be 1.6 g/mL.
- Sample Y was heated, and the temperature was recorded. All the liquid boiled away at the same temperature and left no residue in the container.
- When a dilute acid was added to Sample Z, gas bubbles formed and rapidly rose

to the surface of the liquid.

Based on these observations, which sample was clearly identifiable as a pure substance?

F. Sample W
G. Sample X
H. Sample Y
J. Sample Z

22. Which substance can be broken down into simpler substances?

F. Ammonia
G. Boron
H. Lithium
J. Magnesium

---

**Go to the lab stations located on your side of the classroom to answer the next 3 questions.**

23. Shake the jar of muddy water vigorously and then let it sit for 90 seconds. What is happening to the dirt when you let the jar sit still after shaking it? ___________

Shine the flashlight into the jar of muddy water so that you can see the beam of light reflecting off the small particles of soil suspended in the water.

How is this muddy water classified?

A. A compound
B. A homogeneous mixture
C. A heterogeneous mixture
D. An element

24. A scientist (you are the scientist) filters a sample of river water. Record your data from this process in the table below. Use the hair dryer to speed the drying process.

| Trial | 1 | 2 | 3 |
|---|---|---|---|
| Initial mass of dry filter paper (g) | 2.05 | 2.06 | 2.04 |
| Mass of filter paper after filtering river water and drying sample (g) | 2.64 | 2.53 | 2.61 |

These data support which of the following descriptions of the sample?

A. It is a pure substance because solid particles cannot pass through the filter paper.

B. It is a pure substance because the river water is composed only of free elements.

C. It is a mixture because dissolved ions in the water pass through the filter paper.

D. It is a mixture because solid particles are separated from the river water.

25.Perform this activity in the pan provided at the station. When you are finished, you must wash the labware and clean the area.

- Use the scoop to measure 15 grams of sodium bicarbonate ($NaHCO_3$) into the weighing pan on the digital scale.
- Next, measure 20 ml of dilute acetic acid ($CH_3COOH$) into the graduated cylinder.
- Pour the sodium bicarbonate into the baggie
- Add the acetic acid to the baggie, being sure to seal the baggie quickly.
- Shake the baggie.
- Feel the sides and note the temperature.

Draw a sketch of the bag after you added the sodium bicarbonate and the acetic acid.

Was the change you observed physical or chemical? **Give at least 2 specific reasons** that support your conclusion?

_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________

**Test Two**

Chemistry 2020 Name____________________________

Date____________________

1. Atomic radius increases down a group because

   A. The number of energy levels increases.
   B. The atomic number increases.
   C. The electronegativity decreases.
   D. The atomic mass increases

2. Which of these statements is an accurate description of the ionization energies of elements on the periodic table?

   F. The ionization energy of lithium is greater than that of potassium.
   G. The ionization energy of iodine is greater than that of fluorine.
   H. The ionization energy of magnesium is greater than that of sulfur.
   J. The ionization energy of krypton is greater than that of neon.

3. X-ray crystallography is a technique that allows scientists to determine the ionic and atomic radii of elements. Which of these statements correctly describes a trend in ionic or atomic radii in the periodic table?

   A. The ionic radius decreases from top to bottom in a group.
   B. The atomic radius increases from left to right across a period.
   C. The ionic radius remains constant from right to left across a period.
   D. The atomic radius increases from top to bottom in a group.

4. Which of the following correctly list the species in order of increasing radius size from smallest to largest?

   F. $K^+ < Ar < Cl^-$
   G. $K^+ < Cl^- < Ar$
   H. $Ar < Cl^- < K^+$
   J. $Cl^- < Ar < K^+$

5. Which of the following has the lowest ionization energy?

   A. Beryllium
   B. Carbon

C. Lithium
D. Nitrogen

6. Which of the following elements has the smallest atomic radius?

F. Sulfur
G. Chlorine
H. Aluminum
J. Sodium

7. Which of the following is the most reactive nonmetal?

A. Carbon
B. Fluorine
C. Nitrogen
D. Oxygen

8. When examining periodic trends, the elements with the largest atomic radii are most likely found in the

F. Lower left hand section of the table.
G. Lower right hand corner of the table.
H. Upper left hand section of the table.
J. Upper right hand section of the table.

9. Which term best describes the strength of an atom's attraction for electrons in a chemical bond?

F. Electronegativity
G. Heat of formation

H. Heat of reaction
J. Ionization energy

10. As atomic radius increases in a group or period, electronegativity

A. Generally decreases.
B. Generally increases.
C. May increase or decrease depending on the number of valence electrons.
D. May or may not change depending on the period and group.

11. Using the table of Electronegativity below, determine which of the following trends, in a period of the periodic table, is best supported by the data?

| Element | Electronegativity (Paulings) |
|---|---|
| Beryllium | 1.6 |
| Boron | 2.0 |
| Carbon | 2.6 |
| Fluorine | 4.0 |
| Lithium | 1.0 |
| Oxygen | 3.4 |

F. Metals have a higher electronegativity.
G. Higher atomic numbers have a higher electronegativity.
H. Nonmetals have a higher electronegativity.
J. Higher atomic masses have a lower electronegativity.

12. On the Periodic Table, what are the group and period trends in ionization energy?

A. IE increases down a group and increases from left to right across a period.
B. IE increases down a group and decreases from left to right across

a period.

C. IE decreases down a group and decreases from left to right across a period.

D. IE decreases down a group and increases from left to right across a period.

13. What is the result of adding electrons to a neutral atom?

A. A cation
B. A different element
C. An acid
D. An anion

14. On the Periodic Table, the period and group trends for atomic radius, ionization energy, and electronegativity are related. Which of the following statements true?

A. Larger atoms have low electronegativity and low ionization energy.
B. Larger atoms have low electronegativity and high ionization energy.
C. Smaller atoms have low electronegativity and low ionization energy.
D. Smaller atoms have high electronegativity and low ionization energy.

15. A student is researching element property trends that explain the shape and structure of the Periodic Table. When examining a graph of the first ionization energies of the elements, which movement correlates with a decrease in the value on the graph?

A. Among the groups, from left to right
B. Among the groups, from right to left
C. Among the periods, from top to bottom
D. Among the periods, from bottom to top

16. Which of the following elements has the greatest tendency to attract electrons?

F. Barium
G. Beryllium

H. Boron
J. Bromine

17. Which of the following statements best describes the changes in the elements in Period 3 of the Periodic Table from left to right?

A. The atomic mass decreases.
B. The electronegativity decreases.
C. The number of protons increases.
D. The metallic character increases.

**Go to the lab tables on your side of the room to answer the last 3 questions. You will find the questions, instructions, and materials at the tables.**

| | |
|---|---|
| **18** | |
| **19** | |
| **20** | |

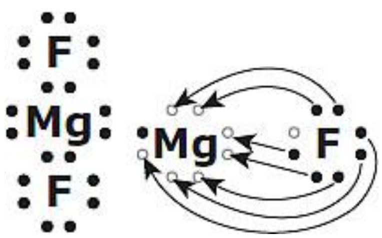
**Test Three**
Chemistry 2020 Name_______________________________________

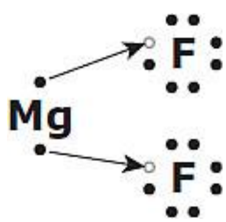
Date_______________________________________

1. What type of compound is formed when atoms of lithium and carbon react?

F. Ionic Compound
G. Binary Compound
H. Molecular Compound
J. Covalent Compound

2. Which of the following diagrams correctly represents the formation of a compound consisting of magnesium and fluorine?

A.



C.



D.



3. Which type of bond holds the positively charged ion $Na^+$ to the negatively charged ion $Cl^-$ in sodium chloride?

F. Amino bond
G. Hydrogen bond
H. Ionic bond
J. Peptide bond

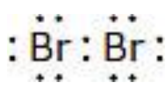
4. What type of bonds are formed when atoms of sulfur and phosphorus react?

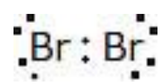
A. Binary
B. Covalent
C. Ionic
D. Molecular

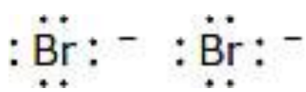
5. When a metal reacts with a nonmetal, the metal will most likely

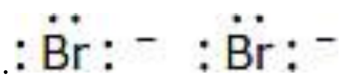
F. Gain electrons and form a negative ion.
G. Gain protons and form a negative ion.
H. Lose electrons and form a positive ion.
J. Lose protons and form a positive ion.

6. Which of these is the electron-dot diagram for $Br_2(l)$?

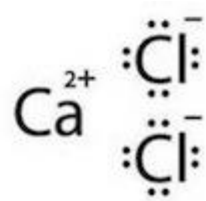
A. 

B. 

C. 

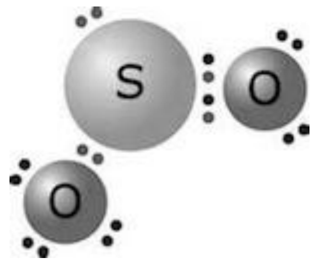
D. 

7. What kind of bonding is illustrated by the electron dot diagram below?



F. Ionic bonding
G. Covalent bonding
H. Metallic bonding
J. Network bonding

8. What type of bonding is illustrated in the diagram below?




A. Ionic bonding
B. Covalent bonding
C. Metallic bonding
D. Network bonding

9. Which of these elements is most likely to donate one electron?

F. He
G. Be
H. K
J. Xe

10. Using the VSEPR theory, predict the molecular structure of carbon dioxide.

A. Angular/bent
B. Linear
C. Tetrahedral
D. Trigonal planar

11. A student is studying the basic geometric shapes of molecules. After creating and analyzing the Lewis Structure for $F_2$, which would best describe its molecular geometry?

F. Linear
G. Tetrahedral
H. Trigonal planar
J. Trigonal pyramidal

12. What is the shape of a carbon tetrachloride molecule?

A. Angular/bent

B. Linear
C. Tetrahedral
D. Trigonal pyramidal

13. According to VSEPR, what is the shape of the molecule shown below?

F. Bent/angular
G. Linear
H. Tetrahedral
J. Trigonal planar

14. Based on electron dot structures and the Valence Shell Electron Pair Repulsion (VSEPR) theory, what is the shape of the polyatomic ion, ammonium, $[NH_4]^{+1}$ ?

A. linear
B. tetrahedral
C. bent
D. trigonal planar

15. Metals are good conductors of electricity. Which of the following properties of metals allow electricity to flow?

A. Metallic bonds are strong and a lot of energy is needed to break them.
B. Metals are ductile.
C. Metals contain electrons that are free to move in the metal structure, carrying charge from place to place and allowing metals to conduct electricity well.
D. The particles in metals are held together by metallic bonds

**Questions 15-20 are lab practical questions. Visit each lab table on your side of the room. Thoroughly and completely answer each question and follow all instructions carefully.**

| |
|---|
| 16. Use the materials provided to construct a compound of your choice.<br>Take a picture and send it to your google classroom account.<br>Is the compound ionic, covalent, or metallic?<br>What shape is the molecule?<br>Write the formula for your compound. |
| 17. Create a solution from the materials provided.<br>Test the conductivity of your solution.<br>Based on your previous experience, is this solution ionic or covalent?<br>Justify your answer. |
| 18. Test the conductivity of each sample. Tell whether each sample is a metal or a nonmetal based on your results.<br>Sample A:<br>Sample B:<br>Sample C:<br>Sample D:<br>Sample E:<br>How can you tell whether the samples are metals or nonmetals? |
| 19. Look at the 3-D model on the table. What is the shape of the molecule? |
| 20. Build a water molecule.<br>Take a picture and send it to your google classroom account.<br>Draw the molecule.<br>Is water covalent, ionic, or metallic? |

| |
|---|
| What is the shape of a water molecule?<br><br><br>**Bonus**: What are the bond angles in the water molecule? Label them in your diagram. |

**Test Four**

Chemistry 2020 Name________________________________________

Date_______________________

1. Which mass measurement is expressed to exactly five significant figures?

   A. 0.1007 g
   B. 0.4560 g
   C. 4008.00 g
   D. 5692.0 g

2. Which volume is expressed to exactly three significant figures?

   F. 400 mL
   G. 20.0 mL
   H. 0.90 mL
   J. 0.03 mL

3. Which quantity is expressed correctly to exactly five significant figures?

   A. 0.0031 mol
   B. 00.506 mol
   C. 2890.0 mol
   D. 10500 mol

4. Rain falls at a density of 2341 drops/$ft^2$. If a tile patio has exactly 12 tiles/$ft^2$, which value best describes how many drops will fall on each tile?

F. 1234 drops/tile
G. 378.3 drops/tile
H. 195.1 drops/tile
J. 16.25 drops/tile

5. Given 1 inch=2.54 cm, which value best represents the number of square centimeters in 5.660 $ft^2$?

A. 5258 $cm^2$
B. 102.4 $cm^2$
C. 0.5533 $cm^2$
D. 0.003617$cm^2$

6. Which density is expressed correctly to three significant figures?

F. 0.13 g/L
G. 304 g/L
H. 506.0 g/L
J. 720 g/L

7. Which molarity is expressed to exactly two significant figures?

A. 0.01 M
B. 0.99 M
C. 10 M
D. 30.0 M

8. Which density is expressed correctly to exactly two significant figures?

F. 90 g/mL
G. 20.0 g/mL
H. 0.90 g/mL
J. 0.03 g/mL

9. Which mass measurement is expressed to exactly four significant figures?

A. 0.053 g
B. 0.521 g

C. 4002 g
D. 8860 g

10. Groups of students in a chemistry class experimentally determined the mass of a piece of copper. Each group shared their results with the class. A total of 5 groups recorded their data. Which of the following class data sets has the best accuracy if the actual density of copper is 8.9 g/cm$^3$?

A. 8.8 g/cm$^3$, 8.8 g/cm$^3$, 8.7 g/cm$^3$, 9.0 g/cm$^3$
B. 7.9 g/cm$^3$, 7.9 g/cm$^3$, 7.8 g/cm$^3$, 7.9 g/cm$^3$
C. 8.9 g/cm$^3$, 8.9 g/cm$^3$, 7.8 g/cm$^3$, 8.4 g/cm$^3$
D. 8.7 g/cm$^3$, 8.0 g/cm$^3$, 8.5 g/cm$^3$, 9.8 g/cm$^3$

11. Groups of students in a chemistry class experimentally determined the mass of a piece of copper. Each group shared their results with the class. A total of 5 groups recorded their data. Which of the following class data sets has precision but not accuracy if the actual density of copper is 8.9 g/cm$^3$?

A. 8.8 g/cm$^3$, 8.8 g/cm$^3$, 8.7 g/cm$^3$, 9.0 g/cm$^3$
B. 7.9 g/cm$^3$, 7.9 g/cm$^3$, 7.8 g/cm$^3$, 7.9 g/cm$^3$
C. 8.9 g/cm$^3$, 8.9 g/cm$^3$, 7.8 g/cm$^3$, 8.4 g/cm$^3$
D. 8.7 g/cm$^3$, 8.0 g/cm$^3$, 8.5 g/cm$^3$, 9.8 g/cm$^3$

12. Which of the following best describes precision?

A. A measure of how close a set of measurements are to the accepted value.
B. A measure of how close a series of measurements are to one another
C. A measure of how much a series of measurements deviates from the accepted value.
D. A measure of how much a set of measurements vary from each other and the accepted value.

13. The closeness of a measurement to its true value is a measure of its

A. Precision
B. Reproducibility
C. Accuracy
D. Estimate

14. Which tool for measuring volume provides the most accurate measurement?

A. Beaker
B. Graduated cylinder
C. Erlenmeyer flask

D. Electronic balance

15. In a famous experiment conducted by Ernest Rutherford, positively charged alpha particles were scattered by a thin gold foil. Which of the following is a conclusion that resulted from this experiment?

A) The nucleus is negatively charged.
B) The atom is a dense solid and is indivisible.
C) The mass is conserved when atoms react chemically.
D) The nucleus is very small and the atom is mostly empty space.

16. Based on his observations, the English chemist John Dalton formulated an atomic theory.

| Dalton's Atomic Theory |
|---|
| 1. All elements are made up of tiny indivisible particles called atoms. |
| 2. Atoms of the same element are identical. The atoms of one element are different from the atoms of another element. |
| 3. Atoms of different elements chemically combine to form chemical compounds. |
| 4. During chemical reactions, atoms are rearranged. Atoms of one element cannot be changed into atoms of a different element as a result of a chemical change. |

In 1897, J. J. Thomson showed that negative charges could be made to move from one end of a cathode ray tube to another, causing the tube to glow. Because of this, Thomson is credited with the discovery of the electron. Based on this information, which part of Dalton's atomic theory conflicted with Thomson's new data?

A. 1
B. 2
C. 3
D. 4

**Visit each lab table on your side of the room to answer questions 17-20. Read the instructions carefully and answer each question thoroughly.**

.

| | |
|---|---|
| 17 | Look at each bullseye and decide whether the darts are accurate, precise, both or neither. |

| | |
|---|---|
| | 1.<br>2.<br>3. |
| 18 | Use the Play-doh to construct a model of John Dalton's idea of an atom. Take a pic and send the pic to Gclass. |
| 19 | Record the most accurate measurement you can possibly determine of the mass of the brass sample using the triple beam balance. |
| 20. | You recorded one measurement for #19. Can you determine whether the measurement is accurate with just one measurement?<br><br>Is it possible to determine precision with a single measurement? Yes or No<br><br>How could you determine precision? |

**Test Five**

Chemistry 2020 Name___________________________________

Date__________________________________

1. A solution is made using 32.0 g NaCl and 350. mL of water. What is the concentration of this solution?

   A. 1.56 M
   B. 5.34 M
   C. 192 M
   D. 655 M

2. A student made a 2.00 L solution using 86.3 g of sodium chloride. What is the molarity of the solution that the student made?

   A. 0.200 M
   B. 0.738 M

C. 1.47 M
D. 4.82 M

3. Hydrogen chloride dissolved in water yields hydrochloric acid. What is the molar concentration of HCl if 3.65 g of hydrogen chloride is dissolved in 500 mL of water?

F. 0.07 M
G. 0.1 M
H. 0.2 M
J. 0.7 M

4. A student has a 25.0mL solution of 2.0M hydrochloric acid. What volume of water would the student need to dilute the solution to 0.50M?

F. 0.010mL
G. 6.3mL
H. 100mL
J. 1.0L

5. A lab technician is called on to prepare 2.0L of a .9M saline solution. The lab has 2L beakers in stock. What steps must she follow to fill the order?

F. Add 116.9g of NaCl to 2.0L of water, stir until dissolved, then pour out any solution in excess of 2.0L.
G. Measure 105.2g of NaCl, pit it into the beaker, add enough distilled water to make 2.0L, and stir until dissolved.
H. Measure 58.4g of NaCl, add it to 2.0L of H2O already in the beaker, stir until dissolved.
J. Pour tap water into the beaker until full, add 9.0g of table salt, then stir until dissolved.

6. During a lab activity, student mix aqueous solutions of silver nitrate and sodium chromate. A reddish-brown precipitate forms and settles to the bottom of the solution. Which product of this reaction remains dissolved after the reaction?

F. sodium oxide
G. sodium nitrate

H. silver chromate
J. silver oxide

7. Which compound in this reaction is the precipitate?
$NaCl + AgNO_3 \rightarrow NaNO_3 + AgCl$

A. AgCl
B. $AgNO_3$
C. NaCl
D. NaNO3

8. Which mixture can be separated through filtration because one of the substances is insoluble in water?

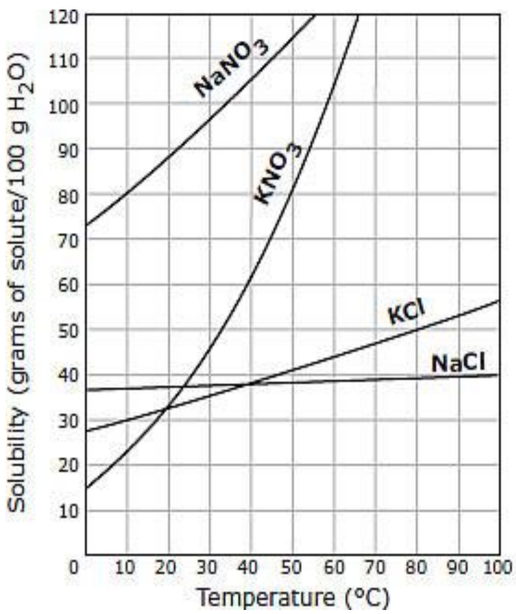
F. $NaClO_3$ and $Pb(ClO_3)_2$
G. $Na_2SO_4$ and $SrSO_4$
H. $NaNO_3$ and $Pb(NO_3)_2$
J. $NaC_2H_3O_2$ and $Pb(C_2H_3O_2)_2$

9. Upon completion of a lab exercise, students examine the above data table. Which of the following conclusions is supported by this data?

| **Substance *(started with 25 grams of each)*** | **Amount dissolved after 5 minutes** |
|---|---|
| $CaCl_2$ | 17 g |
| NaCl | 23 g |
| $Mg_2CO_3$ | < 1 g |
| KF | 12 g |

F. $CaCl_2$ is insoluble
G. NaCl is insoluble
H. $Mg_2CO_3$ is soluble
J. NaCl is more soluble than $CaCl_2$

10. The solubility of an unknown substance was tested during an experiment.




Mass of Unknown Solute That Dissolves in 100 g Water

| Trial | 30°C | 40°C | 50°C |
|---|---|---|---|
| 1 | 46.0 g | 63.2 g | 80.2 g |
| 2 | 45.9 g | 61.4 g | 81.3 g |
| 3 | 44.3 g | 62.9 g | 79.8 g |
| Average | 45.4 g | 62.5 g | 80.4 g |

Based on the solubility curve information and the results of the experiment, what is most likely the identity of this unknown solute?

F. NaCl
G. KCl
H. $KNO_3$
J. $NaNO_3$

11. Students are preparing a sodium nitrate solution. Which of the following will not increase the rate of solution?

A. Use a hot plate to increase the temperature of the water.
B. Use a large beaker instead of a small one
C. Use a mortar and pestle to crush the $NaNO_3$ crystals.
D. Use a stirring rod to agitate the solution.

12. What combination of factors would allow for maximum solubility of a gas in water?

F. Cold water, high pressure, no agitation
G. Cold water, low pressure, no agitation
H. Warm water, high pressure, stir vigorously
J. Warm water, low pressure, stir vigorously

13. A restaurant manager wants to find out why some customers are complaining about the iced tea. One urn of tea was available with ice cubes, lemon wedges, and various sweeteners available for customers to add as they wished. Those who preferred traditional iced tea sweetened with sugar said that sugar sank to the bottom of the glass and the tea was not sweet. After surveying customers and employees on how to make the "perfect" glass of sweet iced tea the following procedures have been suggested. Based on what the consultant remembers from high school chemistry what order should be followed to please the customers?

I. Bring water to a boil.
II. Pour over ice cubes in a glass.
III. Add granulated sugar and stir until dissolved.
IV. Add tea bags and steep to desired strength.
V. Allow to cool to room temperature.

A. I, II, III, IV, V
B. I, IV, V, II, III
C. I, III, II, IV, V
D. I, IV, III, V, II

14. For which of the following is pressure a factor in solubility?

F. Gases
G. Solids
H. Solids and gases
J. Neither solids nor gases

15. Students are producing a sodium bicarbonate solution. How can students increase the rate of solution?

A. Decrease the pressure.
B. Decrease the temperature.
C. Increase the temperature.
D. Increase the pressure.

16. This picture is illustrating all of the following except


A. A chemical change.
B. A physical change.
C. Effervescence.
D. The release of a dissolved gas.

**For questions 17-20, you will need to visit each lab table on your side of the room. Read each question carefully, follow directions, and answer the questions.**

| | |
|---|---|
| **17.** | Follow the instructions for making the 2 solutions.<br><br>Calculate the molarity of the solution you made.<br><br>How could you experimentally determine whether the solution is saturated?<br><br>How could you get more of the solute to dissolve in the solvent? (List 2 ways) |
| **18.** | Follow the instructions at the station. |

| | |
|---|---|
| | Calculate the molarity of the solution you made.<br><br>Add 100 ml more water.<br><br>Calculate molarity of the diluted solution. |
| **19.** | Use your knowledge of solubility to determine which set-up would completely dissolve the given amount of solute in the given amount of solvent under the given circumstances. (Check your solubility chart for precipitates.)<br><br>A.<br><br>B.<br><br>C. |
| **20.** | Use your solubility chart to determine the identity of the precipitate which forms when you follow the instructions for combining the 2 solutions.<br><br>Make a sketch of your experiment. Label the reactants and the products.<br><br>Write the balanced chemical equation for this double replacement reaction. |

# APPENDIX F

## Focus Group Interview Format

Bulleted Outline

- Welcome
- Introduce moderator and assistant
- Our topic is ...
- The results will be used for research- to help educators understand student interest and...
- You were selected because ...

Guidelines: No right or wrong answers, only differing points of view

- We're tape recording, one person speaking at a time
- You don't need to agree with others- feel free to share your views

Rules for cellular phones and pagers

- We ask that your turn off your phones or pagers.
- My role as moderator will be to guide the discussion

Opening activity:

The first few moments in focus group discussion are critical. In a brief time the moderator must create a thoughtful, permissive atmosphere, provide ground rules, and set the tone of the discussion. Much of the success of group interviewing can be attributed to the development of this open environment. The recommended pattern for introducing the group discussion includes: (1) Welcome, (2) Overview of the topic (3) Ground rules and (4) First question.

Script for focus group for this research:

Good afternoon and welcome to our session. Thanks for taking the time to join us to talk about your interest and attitude in laboratory experiences. You all know I am Gretchenn Adkins and I am conducting research for the completion of my doctoral dissertation. I am interested in your input about Chemistry labs. I want to know what you like, what you don't like, how you rate simulated labs versus hands-on labs, and the relationship between your participation in labs and your interest in science. We will meet for about 30 minutes today. You were invited because you are in a chemistry class and you indicated that you would be willing to participate in a focus group on your consent and assent forms. You are familiar with Chemistry labs since you have been in the class since August. There are no wrong answers but rather differing points of view. Please feel free to share your point of view even if it is not what you think I want to hear. Keep in mind that we're just as interested in negative comments as positive comments, and at times the negative comments are the most helpful. You've probably noticed the microphone. We're tape recording the session because we don't want to miss any of your comments. People often say very helpful things in these discussions and I can't write fast enough to get them all down. You may be assured of complete confidentiality.

Information from our discussions will be used in my research to help me determine whether there is a relationship between labs and attitude and interest in science.

(I will take notes throughout the discussion and operate the recording equipment.)

The following is an interest survey taken from file:///C:/Users/dwhit/Downloads/GLFSTEM-ASEE13-ERM-Final.pdf used as part of an interest in STEM survey.

**Science**

| | Strongly Disagree | Disagree | Neither Agree nor Disagree | Agree | Strongly Agree |
|---|---|---|---|---|---|
| 9. I am sure of myself when I do science. | O | O | O | O | O |
| 10. I would consider a career in science. | O | O | O | O | O |
| 11. I expect to use science when I get out of school. | O | O | O | O | O |
| 12. Knowing science will help me earn a living. | O | O | O | O | O |
| 13. I will need science for my future work. | O | O | O | O | O |
| 14. I know I can do well in science. | O | O | O | O | O |
| 15. Science will be important to me in my life's work. | O | O | O | O | O |
| 16. I can handle most subjects well, but I cannot do a good job with science. | O | O | O | O | O |
| 17. I am sure I could do advanced work in science. | O | O | O | O | O |

**Attitude toward chemistry**

Each of the statements below expresses a feeling toward chemistry. Please rate each statement on the extent to which you agree. For each, you may (A) strongly disagree, (B) disagree, (C) be undecided, (D) agree, or (E) strongly agree. Place an 'x' in the appropriate column after you have made your choice.

| | **A** | **B** | **C** | **D** | **E** |
|---|---|---|---|---|---|
| | **Strongly Disagree** | **Disagree** | **Undecided** | **Agree** | **Strongly Agree** |
| I like chemistry | | | | | |
| I like chemistry class | | | | | |
| Participating in hands-on chemistry labs make me like chemistry more | | | | | |
| I learn from participating in hands-on chemistry labs | | | | | |
| Participating in computer labs make me like chemistry more | | | | | |
| I learn from participating in computer labs | | | | | |
| | | | | | |

What do you like about Chemistry?

What is your least favorite part of Chemistry?

What would make Chemistry class better?

On a scale of 1-5, with 5 being I love it and 1 being I despise it, how much do you like hands-on labs?

**Circle a number from 1-5 for the following questions:**

1. How much do you like computer labs?

   I don't like them at all 5 4 3 2 1 I like them a lot
2. How hard is science for you?

   Very hard 5 4 3 2 1 easy

3. The science in school is not related to my everyday life

Agree 5 4 3 2 1 Disagree

4. Being able to physically interact with lab equipment helps me learn better than interacting with a computer lab experiment

   Agree 5 4 3 2 1 Disagree

5. Science is too complicated for most students to understand.

   Agree 5 4 3 2 1 Disagree

# APPENDIX G

## Transcriptions from Focus Group Interviews

**Transcription One: June 1, 2020**

**Third period Student: African American Female: 10th grade**

Me: I will be recording our conversation today. I won't use your face or your name. I will only say that you are a student in an East Texas High School Chemistry class. I just need to record us so that I can get all of the words we say, because I cannot write as fast as we can talk. I that okay?

Student: Yes ma'am.

Me: I am going to ask you some questions. I am just as interested in the negative things you have to say as I am in the positive things. I want to share this research with other teachers to help improve student interest in and attitude toward science – and performance on tests.

Student: Okay.

Me: So, my first question is: Are you sure of yourself when you do science?

Student: I am sure of myself when I do science. I mostly agree. When I learn science I write it down. I gotta use colors to understand so when I get ready to go back and I am studying for a test, I go back to my notes and if that question is on the test I'm able to answer that question correctly. I know that I can do well in science.

Me: Would you consider a career in science?

Student: I'm going into the medical field, I'm gonna be an RN so I am gonna be around the medication side of science.

Me: Do you expect to use science when you get out of school? Do you think science will help you earn a living?

Student: Yes, of course I do. I strongly agree that knowing science will help me earn a living.

Me: How do feel about this statement: I can handle most subjects well, but I cannot do a good job with science

Student: I disagree with that one. Because Like I am kinda all around scholar.

Me: Are you sure you could do advanced work in science?

Student: Yes ma'am.

Me: Do you like Chemistry?

Student: Yes ma'am I do I honestly do. I agree.

Me: Do you like Chemistry class?

Student: Ummm…it's like iffy. I'm undecided. Sometimes I like it and sometimes I want to be able to move at my own pace. I don't love it every day, but I do love it some days. I guess I like it most of the time.

Me: How do you feel about this statement? Participating in hands-on Chemistry labs makes me like Chemistry more.

Student: Strongly agree. Like touching it and seeing it and being able to move things around with my hands and working with my group t try to figure it out. You know, that's the best part.

Me: Do you learn from participating in hands-on Chemistry labs?

Student: Undecided. I mean like some of the hands-on stuff I don't really understand the concept of it until you go back and do the lesson on it and then I understand the lesson of it. The hands-on part helps me understand the lesson, so I guess I do learn from it. It just might not be while I'm doing it.

Me: What about the computer labs?

Student: I really didn't like the computer lab. Honestly, it's hard to stay interested. The videos you posted in Google classroom helped me more than the computer labs. I watch those.

Me: Did you learn from participating in the computer simulated labs.

Student: Yes. I did learn.

Me: What do you like about Chemistry?

Student: You never know what you are going to get. Like something don't come out the way you expect them do. You can mess it up the first time I mean like have the wrong measurements and get something completely different.

Me: What is your least favorite part of Chemistry?

Student: I don't always like the lesson part when you have to break everything down and it goes slow.

Me: Do you have any ideas about how we could make Chemistry class better?

Student: I would say have more hands-on activities that follow the lesson. I liked the field trips where we got to see how Chemistry is used in the real world.

Me: On a scale of one to five with five being I love it and one being I despise it, how much do you like hands-on labs?

Student: Five. I really love the hands-on labs.

Me: On a scale of one to five with five being I love it and one being I despise it, how much do you like computer simulated labs?

Student: Three-

Me: How hard is science for you?

Student: Science is pretty easy for me. I don't have to work very hard to make good grades. I understand most of it.

Me: How do you feel about this statement? The science in school is not related to my everyday life.

Student: It's kind of related, but you have to understand the science to even know it's going on around you.

Me: Does being able to physically interact with lab equipment help you learn better or do you learn better interacting with a computer experiment?

Student: I learn better with the hands-on for sure. The touching and seeing helps me learn better and not knowing how the chemicals are going to react like bubbles or heat or even fire – that's more interesting so I learn more.

Me: Do you think science is too complicated for most students to understand?

Student: No. You just have to listen and try and participate.

Me: What was your favorite part?

Student: My favorite lab this year was turning the pennies to gold.

Me: Was there anything we could improve?

Student: You could do more color in our notes- that would help me. I enjoyed being in your class.

## Transcription Two: June 2, 2020

**Fourth Period Student: African American Female: Tenth Grade**

Me: I will be recording our conversation so I can get all the words we say, because I cannot write as fast as we talk. I won't use your face or your name in my paper. I will just say that you are a student in an East Texas High School. Is that okay?

Student: Okay

Me: Everything you say is confidential and I want to know the bad stuff as much as I want to know the good stuff. So, don't feel bad about saying that you didn't like something, because I want to help teachers understand what students like, what motivates them, and how to help them. I am just going to ask you some questions.

Me: If somebody asked you if you are sure of yourself when you are doing science, what would you say?

Student: I would probably agree with that. Some parts of science it takes me longer to grasp what we are doing, but other than that science comes easy.

Me: Would you consider a career in science?

Student: I always had my heart set on being like an English teacher. I guess if it came down to it, I might choose science.

Me: What grade do you want to teach?

Student: I either want to teach second or go all the way up to high school.

Me: That's good. You know, sometimes elementary teachers teach more than one subject. Would you feel confident teaching science to second graders?

Student: Yes, I would. I would feel confident. I understood it pretty good.

Me: Do you expect to use science when you get out of school?

Student: Kind of. Not in the way that it would help me every single day, but in the way that like if I mix these two chemicals it's not going to be okay or if I smell this smell then I need to get out of the room. That's just the way that I would use it. Or like if I'm explaining something to somebody and I need to know some science.

Me: Awesome. Do you think that knowing science could help you earn a living?

Student: Yea. I do. I just feel like in school today it's hard to get kids to understand that because if you're not being a doctor or a actual scientist it's hard to see how science will actually come into play. I think we just need to be shown more examples of how we will use it to better actually want to do it.

Me: Do you think you can do well in science?

Student: I strongly agree. I do well in science.
Me: Can you handle most subjects well? How do your other subjects compare to science?

Student: I make all A's. I understand it pretty easy.

Me: Are you sure you can do advanced work in science?

Student: I agree with that, because like if it's a college chemistry class I know it's going to get harder. I know I can do it, but I just don't know if I can keep up the A average.

Me: So, these next questions are about your attitude toward chemistry. Like how much you like it. Again, please don't hesitate to tell me how you really feel. It's okay to say you don't like things.

Me: Do you like Chemistry?

Student: Yes. I really like chemistry.

Me: Do you like chemistry class?

Student: Yes. Umm…Some parts of it get confusing- like when we learned how to …the PSP and all of that it was confusing at the beginning, and it took me like a whole week to understand, and it was kind of stressful, and then I'm really good at math and you know how we use math a lot in chemistry, but like I hate math and so it was kinda like I had to push myself more to work when we use math in there than when it was like doing ummm labs and things like that, but other than that I love chemistry because I like doing experiments and things.

Me: Okay, Well good. So, tell me what you think about this: Participating in hands-on chemistry labs makes me like chemistry more.

Student: I strongly agree. It helps me understand better and faster.

Me: Okay. So, it helps you understand better and faster. Would you like to say more?

Student: When we do things that are just on paper or on a computer, it's kinda harder to get cause I know some of the elements and chemicals we used to experiment with I had never seen in my life and would never see if you didn't bring them in there. It was kind of cool to get to actually use them to see like if we were working on reactions and I would see the reaction and I would think okay this does that when it is mixed with that and if we didn't have that I would just look at the paper and it would tell me okay when you mix this with that what happens and it wouldn't even cross my mind what actually happens, so it just helps me understand what we are learning more.

Me: That was a great explanation. Thank you. The next question is about computer labs. As far as participating in computer labs, do those make you like chemistry more.

Student: Nope. No. Ummm…I say that, well first, I'm like an old-fashioned person.
I like

the labs and things, but if we are gonna do work in school I believe in doing it on paper or whatever because not all people have internet at home and outside of class if you have to finish the work not all people are able to do it on the computer because they may not have the resources. Besides that, doing it on the computer, I was more focused on getting the work done than actually learning what I was working on, so it was just a lot. It was stressful. I did learn sometimes, but it was more of stressing trying to get this turned in than actually learning what I was looking at.

Me: Thank you. So, you did learn, but you didn't like it. So, if you had to choose between doing lessons, hands-on, or computer labs, or some combination, what would we choose?

Student: I would choose hands-on because it can get out of hand and it can be more about having fun but we did all actually learn something. Me and all of my classmates, even those who did some playing around, we did all learn something because you can't help but learn something when it's in your face like that.

Me: Can you tell me something else that you like about chemistry?

Student: I've always liked doing like seeing things react to each other and that was even before I knew about chemicals and stuff when I was younger. So that's what made me initially start liking Chemistry because I would just go in the kitchen and mix things up and just watch how it would react and so getting to do it in school made me like it even more cause it was cool to see. The periodic table of elements is cool when you don't have to learn all of them and I don't know, I think I like chemistry because it's not what you think it is, like most people think chemistry is literally just the periodic table of elements and mixing things up to watch them blow up and there's just so much more you have to learn and actually go through and so it's kind of cool to find out that you've been just kind of doing it your whole life.

Me: So, you like the unexpected and it was more than you thought it would be. So, what is your least favorite part of chemistry?

Student: The unit just before we left- stoichiometry. That was not fun. I didn't like the math and it was kind of hard to get.

Me: Right? It would have gotten better if we could have gone back to school and finished. I'm so sad we didn't get to go back. Okay, so what could be done to make chemistry better.

Student: Focus on making sure the students actually grasp the concept more than making sure the concept is there. A lot of my science classes over the years, the teachers have been focused on okay, this is my lesson plan, we are gonna do this unit this week and this unit next week. It was never maybe I need to extend this a little bit because a lot of my students aren't getting it. A lot of my students are stressed. Let me just elaborate on it. I think that would make it better because a lot of kids stress over it and there's no need to stress. They just need a little bit more time.

Me: Did I do that to y'all? Did I push you too hard?

Student: No. I'm just talking about other teachers I've had in the past.

Me: Are you sure? I need to know if I pushed too hard.

Student: You didn't push too hard. I was really talking about other teachers. You are a good teacher.

Me: On a scale of one to five with one meaning I despise it and five meaning I love it, how much do you like hands-on labs?

Student: I love it! Definitely a five.

Me: Okay. Awesome. So, on a scale of one to five with one meaning I despise them and five meaning I love them, how much do you like computer labs?

Student: A two.

Me: Alright. How hard is science for you?

Student: Not extremely hard.

Me: Okay. So how do you feel about this statement? What if somebody says the science in school is not related to everyday life.

Student: I kind of agree with it and I kinda don't. The science that we learn in school, like not even just chemistry, but ummm…like stuff about cells and stuff, that's good to know like if you want to educate somebody or like if something like the Corona virus is going on and you want to speak up about it, but if was just normal like going to the store or something like I said with the chemicals and stuff that's how I feel science would help me outside of school-like we look at how we bake a cake differently- like the chemical reactions going on and the ratios and limiting factors and stuff. Like that lab we did. That's how I feel like I use science outside of school-like the actual science they teach us. Other than that, I really don't – I really don't use it that much.

I do think about the stars and stuff. Like the stars and the clouds and the planets and stuff. My mom likes to hear me talk about that stuff. I think we all use science more than we realize, we just don't think about it. It's just life.

Me: How do you feel about this statement? Being able to physically interact with lab equipment helps me learn better than interacting with computer lab experiments.

Student: Hands-on I definitely learn more because it's there in front of me and with the computer lab I was stressing more about getting the work done. Also, when we are doing computer labs, it's easier for kids to just look up the answers and go on about their day. Then with the hands-on, you can look up the answers for the hands-on too, but it was just easier to just go ahead and do the experiment at hand. There's less chance of cheating with the hands-on lab.

Me: Do you think that science is too complicated for most kids to understand?

Student: No. It's the way that some teachers present it. You are very passionate about science. I really like teachers who are passionate about their subject and really want to do their job. Sometimes you are so passionate that sometimes you forget that we are just learning and that some students actually hate science. I know that hurts your heart. Because they hate it- they just shut down - they don't want to learn it. They just want to pass the class and get out of there. I think that's its not a hard subject, but you have to have a strong will for this subject because it does take a lot. If you don't want to do it there's no way you are going to succeed in this subject.

Me: Is there anything else you want to say about Chemistry or science?

Student: It should flow from year to year. We didn't have a good teacher in sixth grade or in seventh grade. Then we got to you and you had to teach everything we missed. That might not be an individual teacher thing, but I feel it would be easier if you we just go from year to year- okay, learn this this year and then add to it next year and by the time you get to high school it would easier to learn everything.

**Transcription Three: June 2, 2020**

**Sixth Period: African American Male: Tenth Grade**

Me: Alright, let's get started. The first statement I'd like for you to respond to is: I am sure of myself when I do science. What do you think?

Student: Yes ma'am. I am pretty sure of myself. I mean, sometimes I have to work harder, but I can always get it. I'd say I am sure of myself.

Me: Great. Okay, now think about this statement. I would consider a career in science.

Student: Well I am thinking I am going to be making medicine for people. Like, I want to develop new medicine to help people with chronic diseases or maybe even to keep people from getting sick in the first place. That's definitely science- maybe chemistry or biochemistry?

Me: Yes. That sounds exciting. I am sure you will be great if that's the career path you choose. Okay, so the next statement kind of springs off of that last one. Do you expect to use science when you get out of school?

Student: Well yes, of course. I will be using science in my career, and you know, we all use science every day, right?

Me: Yes. I would agree with that. Alright, so the next statement says, I will need science for my future work.

Student: Yes- yes!

Me: Ok. I guess we have established that you will be using science (laugh). So do you know that you can do well in science?

Student: Yes ma'am. I've done well in all of my science classes so far. It's easy for me to understand. Like, I get it. I like it. It makes sense. (Pause) I have to say I'm a little worried about physics, though. Is it hard?

Me: You will be fine. You will love the teacher. She is kind and helpful and oh so smart! I'm not worried about you at all. Okay, so the next one says science will be important to my life's work. What do you think?

Student: Yes. This is kind of like the other questions, but I know I'll be using science and no matter what field I go into I will need science. So, yes. Science is going to be important for my life's work. You know, I want to make a difference. I think science will help me make a difference in people's lives.

Me: Okay, I know that you will do great things. Okay, the next one says, I can handle most subjects well, but I cannot do a good job in science.

Student: Hmmmmm…are you asking me if I'm good at other subjects?

Me: Here, I'll repeat it. I can handle most subjects well, but I cannot do a good job in science.

Student: Well I disagree with that. I really do good in all my subjects, but science is my favorite subject. It's my strongest subject. Science keeps me intrigued and I like it the most.

Me: Awesome. Alright so are you sure you can do advanced Chemistry?

Student: Ummm…yes ma'am. We did some more advanced stuff this year, like we covered some stuff that was extra and we did that genius hour thing. You know, we are already doing some advanced Chemistry and I can do it. I guess maybe I'm just a little apprehensive, but maybe that's about college in general and not really about science. So yes. I think I can do well in advanced science.

Me: Good. Alright, so do you like Chemistry?

Student: Yes. I like some topics more than others. Some topics I really love and enjoy learning about and others I just kind of love.

Me: Okay, so do you like Chemistry class?

Student: Yes ma'am. Like it's always something different and I like my friends in there and the hands-on stuff and it's just not boring. Chemistry class is probably my favorite class this year.

Me: Nice. Alright, so do you think that participating in hands-on Chemistry labs makes you like Chemistry more?

Student: Well, I learn by doing, so I learn by putting my hands-on things. I guess I'm a hands-on learner. So, yes, hands-on makes me like Chemistry more. Definitely.

Me: Alright. So, do you learn more from participating in hands-on chemistry labs?

Student: Well, I know how important it is to learn from whatever you are doing, like it's my job to learn from the lesson, so I am going to learn. It's just more interesting and you know, engaging or intriguing when we are doing the hands-on things. But, you know, if I have to wait like if something is taking a while to happen, then I sometimes lose interest. It's hard for me to stay interested.

Me: I got you. So, you don't like to wait on results?

Student: Well, I guess I just like to see what's happening.
Me: Alright. Okay. Let's shift to computer labs. So, does participating in computer labs make you like Chemistry more?

Student: No ma'am. No. I don't like computer labs. I don't know. I just don't.

Me: Do you enjoy computer labs or computer learning in other classes?

Student: Ummmm….I honestly don't. Not really. In history we watch some movies, clips sort of, and there are quizzes to go with them. Those are okay sometimes. We didn't do any in math.

Me: Okay, So do you learn from participating in computer labs?

Student: It's not my preferred method of learning. Like I said earlier though, it's my job to learn and so I know I have to work at it and get it.

Me: Thinking specifically about Chemistry, what is it that you like about Chemistry?

Student: It's like so many new things, like in one, and you can like make things and you can see how things are made. I like the reaction part.

Me: Is there anything else?

Student: We use science everyday so it's like you - I wanna make a difference and science can help me make a difference.

Me: Awesome! What is your least favorite part of Chemistry?

Student: I've always struggled with the conclusion part, because like I can think of like I can say what I want to say but it's like writing it down on a piece of paper so like the conclusion part where you have to go into details of how you got your results and like that it's hard for me to get it on paper. That's the only part I really don't like.

Me: What can you think of that would make Chemistry class better?

Student: I really feel like the hands-on thing because I really wanted to do more hands-on labs I guess like more interaction- like I know we did a lot of group work but some students should have switched groups so they would learn more. So, like maybe you could switch the groups after each unit or something.

Me: So you don't like being able to choose your own group?

Student: I like being able to choose my group because I have friends in the class and we all work together, but like Student X, she did not have friends in the class and she just got stuck and she could have learned more and maybe made more friends if we had switched groups.

Me: That's a good idea. I like that. Okay. So, on a scale of one to five with five being I love it and one being I hate it, how much do you like hands-on labs?

Student: A five.

Me: How about computer labs?

Student: I'd say a two or a one. Well I'll say a one, because I really don't like computer labs.

Me: How hard is science for you?

Student: It's pretty hard sometimes. I mean, like, some of the things we studied I had to study and work on it to get it. Then other things were really pretty easy though.

Me: How do you feel about this statement: The science in school is not related to my everyday life.

Student: I don't know- I mean everybody uses science- I mean they use science everyday- I use science- so I mean I don't know what to say. I use it when I'm cooking, and when I'm working out- you know staying hydrated, and metabolism and macros and the way digestion works. Science helps me with everyday stuff. I don't know everything, but I use science- especially with me getting hurt and how my body functions…yeah.

Me: The next statement says: Being able to physically interact with lab equipment helps me learn better than interacting with computer simulate lab experiences. How do you feel about that statement?

Student: Me, I mean, I just don't learn- I just don't pay attention when I'm on the computer. I guess also like you can ask anything on the computer, but with hands-on, it's like in front of you and you've got some instructions, and you have to figure out what to do. Basically, and like they don't give you all the instructions -like this is what you do here and this is what you do here – so you skim through and figure it out. It holds my attention better.

Me: So, thinking about other students and not about yourself, do you think science is too complicated for most students to understand?

Student: I agree because I mean if you don't have, I mean you have to reason sorta kinda and really use reasoning and you really have to just think. Some people have a hard time with real in-depth thinking and so I feel like it would be too in-depth for some people.

Me: Is there anything else you want to add about science or the labs?

Student: I'm thinking about what we did…I think it was periodic table- going on the periodic table and looking for increasing and decreasing trends- that computer lab- everything ran together and it was confusing. I couldn't tell what went with what. The notes we wrote on the periodic table helped me more.

Me: Anything else?

Student: I don't like the journals. I don't know what else we could do, but I was unorganized. I did the reviews in Google classroom that you posted though. Notes don't really help me. I only write down the baseline- like the minimum- and then I don't know what it means when I look back at it. The notes help other people though.

**Transcription Four: June 3, 2020**

**Second Period: Hispanic Male: Tenth Grade**

Me: The first question I would like for you to respond to is: Are you sure of yourself when you are doing science?

Student: I feel very self-confident in my ability to do science. I will say I am sure of myself.

Me: Would you consider a career in science?

Student: Sure- well if computer science counts, then I am definitely going to pursue a career in science.

Me: Yes. Computer science is probably science and technology, but definitely STEM.

Do you know what you want to do with computer science?

Student: I'm probably going to study computer science when I go off to college. I will

probably become an applications developer after I graduate. Ummm…just learning about JAVA in computer science UIL was intriguing and I'm having fun when I'm doing it, so I think I will be doing something like that. That sounds like a good career path.

Me: Do you expect to use science when you get out of school?

Student: Yes.

Me: Do you think that knowing science will help you make a living?

Student: Uhh…Yes. I strongly believe that I will need science to be able to make a living and I will need science for my future work. I also think I can do well in science. I'm pretty confident in my abilities.

Me: Do you make good grades in your other classes? Do you make good grades in science?

Student: I pretty much do well in all of my classes including science. I like making good grades and I think it's important to do my best I school.

Me: Do you like your other classes? How much do you like them compared to science?

Student: I like my classes. My favorite classes, I'd have to say, are band and Algebra II though. The other classes are okay. I mean, I like them but they are not amazing as far as me just loving them.

Me: Are you concerned about doing well in advanced science?

Student: I'm not concerned. I think I'll do fine. There might be a few bumps in the road here and there, but I'll get it done. It will be smooth sailing.

Me: This next section is about attitude. So, how do you like Chemistry?

Student: I like chemistry but I don't love it

Me: Do you like Chemistry class?

Student: I like Chemistry class, but again, I don't love it- and I don't hate it either.

Me: Does participating in hands-on chemistry labs make you like Chemistry more?

Student: Yes. I really like doing hands-on Chemistry labs. We get to work with the ingredients – we get to work with the reactants and actually like – it's not like we are doing it in theory- like you know with the- what was the stuff we were doing the polyatomic ions- uh yeah you know like the chemistry in theory- I prefer like the chemistry that we can actually touch.

Me: Okay, good. Do you think you learn from participating in hands-on labs?

Student: Yes.

Me: Alright. What about the computer labs? Thinking about the computer labs we did this year, did they make you like chemistry more?

Student: Well that were alright, but they were just okay.

Me: You like computers.

Student: Yes. The labs are not real-life. They need to be improved.

Me: Do you think you learned from the computer labs?

Student: Yes. I did learn, but it wasn't as engaging as the hands-on activities.

Me: Any ideas about what could be done to make the computer labs better?

Student: I guess they need to create, you know simulate, a better virtual environment. You know like some of them it doesn't come with like the danger. Okay, because like in the computer lab, there isn't a danger of like messing up. It's like you can't just drop this here and then create a spill have everyone in your group trying to figure out what to do next. It takes all the thrill out of it. It takes all the mystery out of the experience.

Me: The element of surprise?

Student: Well really the life-like feel. You know in life you are always being thrown curveballs and on the computer it's just straight-forward. There is nothing to watch out for.

Me: You did a good job of articulating the difference in the experiences. Thank you. So, thinking about what you do like about Chemistry- can you tell me what you like?

Student: I like the seating arrangement and my friends. I like the hands-on labs the best- especially the ones involving fire and electricity. I liked the pickle lab. That was great. I also like the demonstration you did for us. You did some pretty cool demos. I wish we could have done some of the demos ourselves. They were too dangerous for us, weren't they? Oh! Why didn't we get to dissect anything in science?

Me: It's really up to the teacher. You should have dissected something in seventh grade and then something in Biology.

Student: We have not gotten to dissect anything.

Me: Maybe you will get to dissect something in A&P. It's really up to the teacher most of the time.

Student: Yeah, well none of my science teachers – except you- has ever done labs with us. Why don't you teach A&P so we can have you again?

Me: Well…I don't know about that. Maybe you could ask your teacher to do a dissection with you.

Student: Or you could just be our teacher.

Me: What was your least favorite part about Chemistry?

Student: Hmmm…I think it was kind of how if you got stuck behind or you missed out on a few days then it was hard to catch up or more difficult because then the work would just start- I mean it would take a while to catch up. I mean from UIL, that did set back a little bit. I mean it caused me to have a bit more work than I would have had been there.

Me: What did you do to catch yourself up?

Student: I watched the videos you posted on Google Classroom and I did the activities. I think I kind of just brute forced the work that we got. I just worked harder to get what I missed done.

Me: Okay. So, what would make chemistry class better?

Student: Hmmm…I think a better simulated environment or hands-on labs- wait, hands-on labs for everything except for things that would be too dangerous to do in real life and those things could be computer simulated. Then we would need a better simulated environment- the improvement of the digital environment.

Me: Do you think we should introduce the lesson with a lab?

Student: Okay, I think it would be better for the teacher to do a demonstration to introduce the lab- start the lesson. Then she could explain what's occurring in the lab and why it works the way it does. Then the students could do the lab. Then they learn by doing.

Me: That's a different perspective. Thank you for sharing. Okay, so on a scale of one to five with five being I love it and one being I hate it, how much do you like hands-on labs?

Student: I think four. Hands-on labs are pretty cool and we get to do chemistry with our hands and its not something that's being done in theory. It's stuff that we are learning and we are putting it into practice. It's not like a test where you learn stuff, memorize it, and then spit it back out. It's like, okay, you learn it you understand it and then you apply it. Isn't that critical thinking?

Me: Yes. That is critical thinking. You have to apply what you learned to a new situation.

Student: I did not give it a five because I like band better.

Me: How much do you like computer labs?

Student: I'll give it a pretty solid three. I like them more than I dislike them, but I still like the hands-on labs more. The simulated environment is just not that great.

Me: Okay. So how hard is science for you? Like how hard do you have to work?

Student: I think it's pretty easy but if I encounter like a road bump, then I have to work a bit harder than usual to understand the concept. It's easy.

Me: Do you think the science we learn in school is related to everyday life?

Student: Well thinking about the things in everyday life, somebody had to have learned that in order for it to be applied. That way we could have that thing that exists in our daily life- but if it's about the students learning something themselves and then applying it to their daily lives, then it's pretty relevant.

Me: Okay, so you think it's relevant. Can you think of any specific examples of how you use science in everyday life?

Student: Maybe like the combustion reaction- like when I'm burning the trash I know what's safe to burn and what's combustible. Also, when I'm cooking pancakes I know those bubbles are carbon dioxide being produced from the reaction of the water and the yeast. We did a lab on that.

Me: I know how much you love fire. How about this one? Do you think being able to physically interact with the lab equipment helps you learn better than interacting with a computer lab experiment?

Student: Absolutely. I strongly agree. Being able to actually touch the lab equipment and do stuff with it rather than being limited by the virtual simulation helps me to learn better and also teachers me to be more aware of my environment rather than taking out the fear and element of surprise.

Me: I think that's interesting. Okay, so now let me ask you about other people…Do you think science is too complicated for most students to understand?

Student: No. Science is just a matter of laying a foundation and then building off of that foundation bit by bit. If you have a block that's missing in the foundation or you haven't laid a strong foundation then that's where you have problems. That's where your foundation is unstable. What you build off that foundation won't necessarily be stable itself either and then that leads to confusion and that's where people will begin to like not understand because their foundation wasn't proper.

Me: Do you feel like you have a fairly solid, basic foundation for science?

Student: Yes ma'am. I feel like I do and I can always make repairs.

Me: Is there anything we haven't discussed about Chemistry, hands-on or computer labs, your attitude or interest- anything you would like to add?

Student: Well now that I've had time to ponder the point, I think in the future I might develop a better format for simulating virtual labs. It shouldn't be too difficult. You just have to program things to where they now have the possibility of doing this or add a randomizer in to say oh this could happen- like one out of every few beakers could be broken or have a chip or a crack in it, you know? Make it more life-life.

Me: I would love to see you do that.

## Transcription Five: June 3, 2020

**Fifth Period: White Female: 10th grade**

Me: I am going to ask you some questions or ask you to respond to some statements to get the conversation started. The conversation will be about your attitude and interest in science. Okay, so the firs statement I'd like for you to respond to this: I am sure about myself when I am doing science.

Student: No, I am not sure of myself unless it's pretty obvious. I'm always so nervous and anxious like what if I did it wrong what if we put a little bit too much and it made something different. That's why I let Student X do all of my mixing and stuff because if she wants to do it and like if it messes up it's her fault. I am too nervous. I have a little performance anxiety.

Me: Okay. That is interesting. I did not know that. Alright. So, the next statement says: I would consider a career in science. What do you think?

Student: Yes, I would consider a career in science. I agree with that statement. I am into astronomy. I like astronomy a lot. I would consider something in that area.. You know we have NASA not too far from here. NASA is a good place to work.

Me: You know you can take astronomy in high school?

Student: I'll have to look into that.

Me: Maybe you could even take it online for credit. Okay, the next statement says: I expect to use science when I get out of school.

Student: Yeah, well I am sure I will use it. I guess it depends on what career path I choose and like conversations. Sometimes I use what I've learned in basic conversations.

Me: The next statement I'd like for you to respond to is: Knowing science will help me earn a living.

Student: Yeah. I agree with that. I am sure it will.

Me: So, do you think you will need science for your future work.

Student: I will need it, but I will need it even more if I go into a career that requires it. So overall I am sure I will need it. Yeah.

Me: What do you think about this statement? I know I can do well in science.

Student: Yes. I know I can do good. I strongly agree with that since I think I have had a hundred average all year long.

Me: Yes. I am sure you can do well. You have in fact had a hundred average all year long. Okay, moving along then…how do you feel about this statement? I know I can do well in other subjects, but I cannot do a good job in science.

Student: Ummm…I think I would disagree with that statement. I handle science pretty well, and I also handle the other subjects well.

Me: Okay. Anything else you want to add? The last statement in this part says: I am sure I could do advanced work in science. How do you feel about that?

Student: Yeah, I feel like I could handle that pretty well. I think it's just part of my personality that I handle whatever is thrown at me. I have a strong work ethic.

Me: I would tend to agree with that. So how do you feel about this statement? I like chemistry.

Student: I do, I like Chemistry- depending on how hard or how quickly I can like understand the subject. Because the week that I was out, you know I still liked it, but I like it more when I can understand what's going on. I don't like missing the class because it's hard to catch up. I did go back and look at the notes and videos you posted in Google classroom, but it's not the same as being in class. In class, you are teaching it and saying it and making us use it. That makes it click in my mind.

Me: Alright, so the next question is: Do you like Chemistry class?

Student: Class, yeah, I like chemistry class a lot. I strongly agree with that statement. Some days I liked it more than other days- some parts better than others- some lab partners other than lab partners- you know.

Me: Yes. I do know. Okay, so would you say that participating in hands-on chemistry labs makes you like Chemistry more?

Student: It depends on the subject. Like okay, so you remember the hamburger building thing?

Me: Yes. That was not a lab though. That was an activity.

Student: Whenever we were in other science classes, that would have been considered a lab. So, we have not really done like lab labs, real labs, until like you came and were with u teaching. If I already like kind of understand it then the lab does not really help me all that much, but if I need like a real-world situation, then the labs help.

Me: Okay. We will talk about that a little more in a minute, but let me ask you this, do you learn from participating in hands-on labs?

Student: Sometimes. I think it depends on the person. I am a visual person. If I can just see you do it, like see you do the math and whatever, then I can basically get it. But like other people, like, I don't know, Student X, well he might learn more from a hands-on lab because he might not learn good from just sitting there watching somebody. Personally, if it's an easy topic, I can just learn it on paper because it isn't that hard for me to grasp. But for other people it might be better if they can touch it. I think it just depends on the person.

Me: I got it. Okay. So, thinking about the computer labs, do the computer labs make you like Chemistry more?

Student: Not really. We had a rough time with that one 'cause it was like 100 questions and people were always losing their work. I like to just have it all in front of me and see what needs to be done so I can see what I can answer first. I like to see what I already know and then what I maybe need to answer later after I ask you for help. With that computer activity, it was hard to see everything at once.

Me: Maybe not 100 questions, but there were quite a few questions. I understand.

Student: You know that one (computer lab) we did where we built the models- ummm the shapes, that one was helpful.

Me: That's good to know. Do you think you learn from participating in computer simulated labs?

Student: I learned a little bit from some of them- not as much as when you are explaining it to me and I can see it done- but what I need to fill the blanks.

Me: Alright. So let me ask you specifically- what do you like about Chemistry?

Student: I like the knowledge, like everything that goes into Chemistry. I don't really know how to answer that. I like Chemistry in general- well I like the parts I can understand. Because if you don't understand it, it's not that enjoyable to try and figure out, but once I understand it I enjoy having the knowledge because you never know when you are going to need something like that. If that makes any sense.

Me: That makes total sense to me. Okay, let's see…What is your least favorite part about Chemistry?

Student: Hmmm…I don't know. Actually, sometimes it does not make me happy when you make us partner up and do group work because I don't like group work. I don't do group work very much. I was really glad when I found a lab partner that I could work with and you let s work as a pair. I would rather you just show me how to do it and teach me and then be done with it. Also, sometimes when people don't get it, we will drag the stuff on for like a week I'm so over it and we are still trying to help people catch up.

Me: What would make Chemistry class better?

Student: I don't know. I know that sometimes people might want it to slow down if the teacher goes too fast and then others might want it to go faster is the teacher goes too slow. It really like depends on the students and what their learning style is. I don't know how to really give you a good answer for that. Chemistry kind of has something for everybody though. You know, we do math, write, hands-on, computer, videos, yeah, we really did a lot of different stuff in Chemistry. I think everybody except the people who just didn't want to work probably learned something.

Me: Did we have any of those? (Both laughing) Okay, on a scale of one to five with five being I love it and one being I hate it, how much do you like hands-on labs?

Student: About a four…it wasn't my favorite thing in the world, but I did enjoy them.

Me: Okay, so on a scale of one to five with five being I love it and one being I hate it, how muh do you like computer labs?

Student: Ummm…a two maybe. It's definitely not my favorite.

Me: I got you. Okay, so I know we touched on this before, but how hard is science for you?

Student: I know I don't have to put very much effort into it. It depends on the subject.

Me: Please respond to this statement: Science in school is related to everyday life.

Student: Yeah. Ummmm… it depends on what you are doing but like if I'm writing an essay, then I probably won't use science very much, but if I'm watching a science show on tv, then I'm using science. I guess Chemistry is good for teaching you to follow instructions and pay attention to measurements and like thinking about the elements and compounds around. You know, like the laundry detergent or the tear gas on tv, or like the stuff in the foods we eat- and like what you can mix together – and even how to get it to dissolve. Yeah. I guess it's relative.

Me: I got you. Alright, next. Do you think being able to physically interact with lab equipment helps you learn better than interacting with a computer lab?

Student: Ummm..probably the hands-on lab. Whenever it's a computer lab I think I tend to get distracted because it' just a black screen and with hands-on labs you can think about okay I have to measure this and I have to do this right or we are gonna blow up the whole classroom and that's not good. So, you have to be more engaged and more focused. I think that might have happened if Student X had worked by herself this year.

Me: Thank you for being engaged and not blowing up the classroom (Both laughing). So, this is the last question: Do you think science is too difficult for must students
to understand?

Student: I disagree. I think if you pay attention and you focus on what they are talking about and not like dazing off every five seconds, you will understand some of it. You might not understand like all of it, but science is not supposed to be easy. It's not like majorly easy, that's why like people who have to work at Walmart work at Walmart. If they could do science, they would have a better job (nervous laughter). I'm trying to think of examples. It takes effort to understand science and if you would just apply yourself and try to understand it then it would be a lot easier for students.

Me: Do you want to add anything else?

Student: I like science. I think I would not understand a lot of stuff in my daily life if I didn't know science and what was going on. There's some stuff from Biology that I use a lot. There's stuff from Chemistry I use a lot.

**Transcription Six: June 4, 2020**

**First Period: White Female: Eleventh Grade**

Me: How do you feel about this statement? I'm sure of myself when I do science.

Student: Well at the beginning like the class I was afraid and I was like this is gonna be hard, oh my goodness- and like I had known you but not really known you and I was like I hope Mrs. Adkins can help me and I wasn't very confident. But once we started doing the assignments I was like oh this is pretty- you know- if you really just listen you know with my friends and we were like helping each other and you were helping us and toward the end I got really confident about whatever lesson you would give us.

Me: Well good. So as the year progressed you gained self-confidence. That's good. I am glad to hear that.

Student: Yeah, umm hmmm.

Me: Okay. So, would you consider a career in science? Have you thought about what you want to do when you finish high school?

Student: Well, I wanna teach. It would probably be English and not science. I want to go to SFA and cheer or whatever but I either want to major in like education or pharmaceutical rep. Is that science?

Me: I guess that would be science - and also business. So, what grade would you want to teach?

Student: The littles, like my mom- like pre-K through third. Sometimes they teach more than one subject and I know I might teach science and English.

Me: Alright. I think you are right. In elementary, the teachers sometimes teach three or four different subjects, right?

Student: Yes ma'am.
Me: Okay, so do you think you will use science when you get out of school?

Student: Oh yeah! Most definitely. Yes. I'm always using science.

Me: Good. Okay, so the next question is: Do you think knowing science will help you earn a living?

Student: I think that with the whole pharmaceutical rep thing I sure would. You know that's a butt ton of money. It's a lot. Mr. M he did it almost ten years, but then he said there were a lot of hot girls with like rockin' bodies that came in and all the people wanted to talk to the hot girls and he wasn't making as much money so I just went to the bank. Yeah, so I guess I might want to be one of the hot girls with a rockin' body and a brain and I could make lots of money.

Me: (Laughing) Alrighty. That sounds like a plan. So the next question is, do you think you can do well in science?

Student: Like I said at the beginning, I was like oh gosh, like Biology I did okay, but like not how I wanted to do. So, Chemistry I thought it's so hard, it's so hard and when I got in there I was like mmmm but then when I started doing it I was like, okay, this is easy and so I feel confident about doing it now.

Me: Awesome. So, how do you feel about this statement? I can handle most subjects well, but I cannot do good in science.

Student: I disagree with that. The one that I do struggle with is math and when we did like the moles and all that stuff I struggled a little bit but then, again, all you have to do is listen and yeah it wasn't that bad but I don't think I struggle with it. I can do good, I mean I did good in Chemistry this year.

Me: Yes, you did. Okay, the next question is, are you sure you could do advanced work in science?

Student: Yeah! I think of course, I wouldn't have a great teacher like you, but I think I could do it.

Me: I have confidence in you. Ummm so the next part is about attitude- you know, how you feel…The first question is, do you like Chemistry?

Student: Yes. I actually do. I didn't think I would, but I really do.
Me: Okay. What about Chemistry class? Do you like Chemistry class?
Student: Personally, I like our little class. I like my table group and my class. We help each other and we work good together. I wanted to be in your advanced class, but I couldn't because of cheer.

Me: How about this one? Do you think participating in hands-on Chemistry labs makes you like Chemistry more?

Student: Yes. Most definitely. I mean the online thing was okay, like the little labs, but like when I actually got to look at it and see, oh, that's what it does, I mean on the computer you can see it but it's just like uhhh, but when you get to mix stuff up and it's like OHHHH!!! You know that's a lot better. It helps me understand it.

Me: Mixing stuff up, actually doing it…So do you feel like you learned from participating in hands-on labs?

Student: Yes!

Me: Okay. So, what about the computer labs? Does participating in computer simulated labs make you like Chemistry more?

Student: No. (Laughs) I can understand it, but I am a hands-on learner. I need to have it in my hands, and it was kind of hard to get on the computer and just type it in. I just need to see it and hold it.

Me: Alright. So, do you learn from participating in the computer labs?

Student: Yes. I think there was a lot more information, not just directions wise, but the like when they give you the little intro into the lab and whatever. I learned a lot more from that than from doing the lab. But…

Me: I got it. Okay, so tell me what you liked the most about Chemistry.

Student: I would say the hands-on labs. It made it- not only was I learning something that I enjoy learning, but that I could actually do it myself. Like with math or reading, you know you -of course you get to do it yourself, but you don't get to light stuff on fire or blow stuff up, you know. Also, you kind of realize that there's more to measurements like moles and you know you have to be careful when you measure stuff out.

Me: Okay, so what is your least favorite part about Chemistry?

Student: I hated like when we first started doing like the periodic table- like the conversions. I did not like the stoichiometry when we first started. It was a lot of math.

Me: Ok, can you think of anything that would make Chemistry class better?

Student: Just more labs – I mean there wasn't really anything that I was just like oh I wish we could just do more. Or maybe like better computer labs like where we could go back and do things over if we make a mistake, you know like instead of just having to start over again or just giving up on it I guess.

Me: Good. Okay, on a scale of one to five with five being I live it and one being I hate it, how much do you like hands-on labs?

Student: Five

Me: Okay, and on a scale of one to five, how much do you like computer labs?

Student: Like a two.

Me: Okay. On a scale of one to five with five being it's really hard and one being it's super easy, how hard is science for you?

Student: Two-ish. Maybe a one and a half some days, kinda.

Me: Okay. So tell me what you think about this. Is the science that we do in school related to real life?

Student: Umm yeah actually we have a pond in the front of our house and we have that pond dye and it makes it really bright blue- well uh- there was something and it was like depending on how big your pond is you have to have this certain amount and so, you know, again with that stoichiometry I was trying to think back and well this says how many and I did use that and I figured it out. Because it was like if you put too much you're gonna kill all the fish and I was like- I can't kill all the fish and so I was like really stressed out about it.

Me: Do you think being able to physically interact with lab equipment helps you to learn batter than interacting with a computer lab experiment?

Student: I really agree with that. I think I did a whole lot better with seeing it and holding it- like even if we made a mistake, like it was supposed to turn pink but it turned yellow, like you know I could see that and go back and try to do it again. Like I learned better even from my mistakes.

Me: Alright. This is the last one. So thinking about other students- Do you think science is too difficult for most students to understand?

Student: Uh I wouldn't say its too complicated but I do know that most of my friends would say like I'm struggling and I would say- well honestly like I was struggling too but you just have to listen and do your work- and you know sitting in the front where I did, I was paying attention and doing my work and like it was not hard. I think if you are putting in the effort and doing the work it's just not that hard. Engaging yourself and being engaged in the conversations…

Me: Is there anything else you want to tell me about science?

Student: No.

**Transcription Seven: June 4, 2020**

**Seventh Period: White male: Eleventh grade**

Me: Are you sure of yourself when you do science?

Student: Well yeah, sometimes. Maybe not so much with the paperwork and the writing, you know, and the math is hard sometimes. I'm okay. Most of the time I do okay.

Me: Would you consider a career in science?

Student: I dunno Ms. A. I think I might be a welder. That's what my dad does and pretty good at it. You know they get paid a lot. Welding has some science in it with the bonds and the metals and temperature. I wouldn't say that's a science career though.

Me: Do you expect to use science when you get out of school?

Student: Yeah I am gonna use some science. Some science is common sense like don't cut the grass when it's wet and don't put salt in your fish tank, put meat in the refrigerator, use soap to get your truck clean, all that is science, right? That's just part of living though.

Me: Do you think you will need science for your future work?

Student: I guess I already answered that one (laughs).

Me: Do you think you can do well in science?

Student: I do alright. Some of it depends on the teacher and how much I am working. You know have a job and sometimes I'm putting in the hours at work and I don't have a lot of time for doing extra school work.

Me: Do you think science will be important to your life's work?

Student: Yeah, it's kinda important. I need to know some science stuff to do a good job and keep me safe.

Me: How do you feel about this statement: I can handle most science well, but I cannot do a good job in science.

Student: Nah, I don't really like some subjects. Sometimes I do okay and sometimes I don't really do all the work. I don't always get good grades in school, but I pass. I do okay in science.

Me: Do you think you could do advanced work in science?

Student: I don't know if I could or not. I'm probably not going to. I think I'm going to community college to get that 2-year degree and I don't think you have to take science to be a welder. I think it's like trade school and those classes.

Me: Do you like chemistry?

Student: I like it (chemistry). It's better than most of my classes. Sometimes it's hard though and I don't like all the math.

Me: Do you like Chemistry class?

Student: Yep. I like my class. I like the friends in there and it's not boring. We do different stuff in there and I like it.

Me: Do you think participating in hands-on chemistry labs makes you like chemistry more?

Student: Of course. That's why chemistry is good. The labs are like really doing something instead of just sitting there. A lot of my classes we just sit there, but chemistry and shop we do things. I like doing the things.

Me: Do you learn from participating in hands-on chemistry labs?

Student: Yeah! Doing it makes me understand and remember. Mixing stuff and seeing it- what it looks like before, measuring it out, what it looks like after, all of the smell and heat change, that stuff is real. It makes it make more sense to me.

Me: Does participating in computer simulated labs make you like science more?

Student: I don't know. Sometimes the computer is confusing. I don't know how to make it work or do the things it's supposed to do. I have to read a lot of instructions that don't have anything to do with the experiment, they just have to do with how to make the computer work. Do you know what I'm saying? So, I don't like that. It's like this is not computer class. This is science class.

Me: Do you learn from participating in computer simulated lab activities?

Student: Probably something. Maybe not what I'm supposed to be learning. You know when we have the computer out a lot of us are not paying 100% attention. It's easy to just click on over and look at other stuff. I mostly get the answers though.

Me: What do you like about chemistry?

Student: I like that's it's not the same old thing every day, and we get to work together and do things that react. I like the fire and the big reactions. I like it when you do demos, and when something happens that I didn't expect like when you mix clear liquids and get a red one and other things.

Me: What is your least favorite part of chemistry?

Student: Sometimes it's hard and I don't understand at first.

Me: What would make chemistry class better?
Student: If we had longer. Sometimes we run out of time before we get finished.

Me: On a scale of one to five with five being I love it and one being I despise it, how much do you like hands-on labs?

Student: Five

Me: On the same scale, how much do you like computer simulated labs?

Student: One or two

| | |
|---|---|
| Me: | How hard is science for you? |
| Student: | Not too bad- maybe a two or a three |
| Me: | Do you think the science in school is related to everyday life? |
| Student: | Yeah. I use a lot of the science we learn. I'm not gonna say all the stuff I use, but I do use a lot of it. Now there's a lot of stuff I don't use- like photosynthesis. Who uses that? |
| Me: | Do you think being able to physically interact with the lab equipment helps you learn better than interacting in a computer lab experience? |
| Student: | Yep. It sure does. That's for sure. |
| Me: | Do you think science is too complicated for most students to understand? |
| Student: | Not if they are trying and doing their work. In science you have to pay attention and do the things or it's really hard, but if you do the work it's not that hard because you go over the stuff different days and times. |
| Me: | Can you explain that a little more? |
| Student: | Okay, so like we do group stuff and we have to think about the stuff and write about it and maybe answer questions, you know. We do experiments about the stuff and make presentations and there's just a lot going on in there, so you have to do the work, but if you do it then you get it. |

# APPENDIX H

## Key Word Analysis

| Primary Word | Frequency | | | Primary word | Frequency |
|---|---|---|---|---|---|
| science | 161 | | | life | 20 |
| think | 93 | | | favorite | 14 |
| chemistry | 93 | | | interact/interacting | 14 |
| know | 90 | | | easy | 13 |
| well/good | 76 | | | hate | 9 |
| labs | 75 | | | experiment/experiments | 9 |
| hands | 55 | | | equipment | 8 |
| work | 54 | | | confident | 7 |
| learn | 54 | | | great | 6 |
| lab | 41 | | | important | 6 |
| understand | 39 | | | reaction | 4 |
| doing | 38 | | | mixing | 4 |
| use | 37 | | | awesome | 4 |
| make | 37 | | | interesting | 4 |
| better | 37 | | | touch | 3 |
| help/helps | 36 | | | test | 3 |
| five | 31 | | | dissect | 3 |
| sure | 28 | | | apply | 3 |
| see/seeing | 25 | | | measurement | 3 |
| learning/learned | 25 | | | focused | 3 |
| participating | 22 | | | reactions | 3 |
| love | 21 | | | intriguing | 2 |
| yeah | 21 | | | | |

## VITA

Donna Gretchenn Adkins graduated from Bainbridge High School in 1985. She attended Georgia Southwestern State University, and received her Bachelor of Science in Biology in 1999 while concurrently working in ecological restoration of wetlands. In 2004, she completed the Postbaccalaureate Accelerated Certification for Teachers (PACT), which provides an opportunity for professionals with a bachelor's degree to receive initial certification in an accelerated format. She began teaching that same year. She received her Master of Arts degree in curriculum and instruction from the University of Phoenix in 2009. She was accepted into the 2017 Doctoral Cohort at Stephen F. Austin State University, where she earned a Doctorate of Education in Educational Leadership in 2020. She has taught grades five through twelve science at both public and private schools and is currently serving as the Chemistry teacher at Tatum High School.

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