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THE EFFECTS OF VIRTUAL LABORATORY ACTIVITIES ON SCIENCE LEARNING

Nathlye Sudlow-Naggie

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Nathlye Sudlow-Naggie

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Nathlye Sudlow -Naggie Dr. Seokhee Cho

ABSTRACT

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Nathlye Sudlow-Naggie

The purpose of this research was to observe the impact of technology on improving science achievement in Elementary students. In specific, this research investigated the effects of virtual science laboratory activities on the science learning of 20 African American children in grades four. Using a quasi-experimental design, students in grades four, were randomly assigned to a treatment (virtual labs) or comparison (traditional hands-on labs) group. Ten children participated in the treatment group and ten students participated in the comparison group. The children conducted science experiments for 50 minutes, one time a week, for 8 weeks. Both groups were given a pretest and posttest using the Terra Nova 3 Survey Assessment in Science grade 4 and students' motivation toward science learning (SMTSL) questionnaire. Gains between the pretest and posttest scores were investigated for each instrument using the Mann Whitney U test. The New York State Intermediate Level Science Assessment Test (ILSAT) for grade 4 was also given to the treatment and comparison group and investigated using the Mann Whitney U test. Children in the treatment group did not show any significant gains in scores, on the Terra Nova 3 Survey Assessment in Science for grade 4 and SMTSL, respectively, than children in the comparison group. Children in the treatment group for the ILSAT showed a significant higher score than children in the comparison group. In conclusion, the intervention had a

significant effect on the ILSAT score gains. The limitations of the research and recommendations for future research were noted.

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CHAPTER 1

INTRODUCTION

As part of a national conversation in the United States (U.S.), authentic and purposeful standards of teaching and learning have been recognized by all levels of education policy makers as valuable underpinnings of Science, Technology, Engineering, and Mathematics (STEM) curriculum (Educational Policy Improvement Center, 2009; National Research Center, 1996, 2010, 2011, 2012, 2013). In the U.S., an educational initiative called STEM (Science, Technology, Engineering, and Mathematics) education has become a hallmark for leading revisions to teaching and learning standards for science and mathematics related content as well as professional development and preservice programs to better prepare teachers in the field of science education to be more authentic and purposeful when approaching teaching and learning (Chiapetta & Koballa, 2010; Luft, Bell, & Gess-Newsome, 2008; Next Generation Science Standards Lead States, 2013; NRC, 1996; National Science Teachers Association, 2002).

Although these national standards and educational initiatives for science learning were developed to advance students in elementary and High School in the U.S., many of these students are failing to obtain college degrees in the areas science, math and engineering especially African American and Latino American students. Figure 1 below shows the percentage of U.S. bachelor's degrees awarded to African Americans in Science, Technology, Engineering, and Mathematics (STEM) fields, as well as the percentage of college-age Black, Non-Hispanics in the U.S. population from 1997 to 2017 (American Physical Society, 2018). In 2017, only 7% of African Americans received a Bachelor's degree in Chemistry, 2% in Earth Science, 4% in Math and Statistics, 8% in Biology, 3% in Physics and 4% in Engineering (American Physical Society, 2018) .

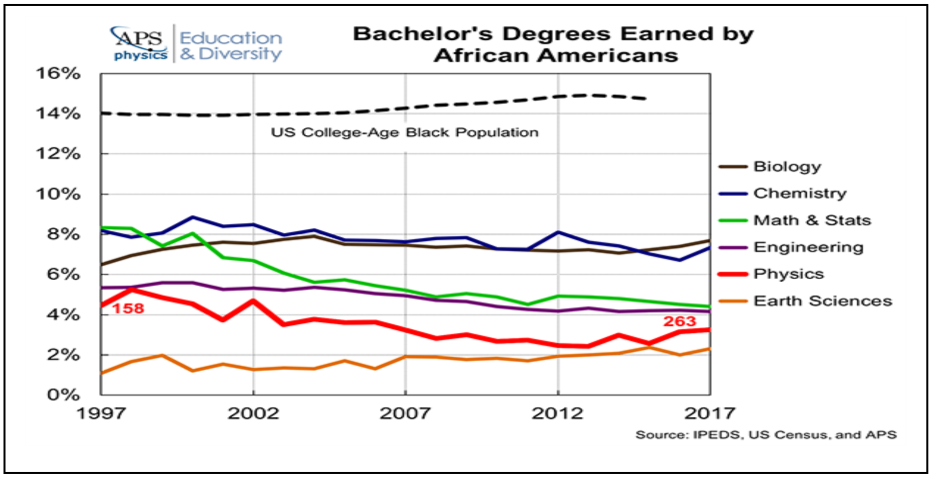


Figure 1: Percentage of U.S. Bachelor's Degrees Awarded to African Americans in STEM Fields

Traditional teaching strategies in science classrooms have leaned heavily towards teacher-centered instruction in which the teacher teaches and the student listens, and this model has been challenged with national guidelines for teaching science (Chiapetta, 2008; Chiapetta & Koballa, 2010; Koch, 2010). However, developers of current science education initiatives are promoting contemporary practices emphasizing student-centered activities using strategies of inquiry and experiential learning in which the student is doing as well as listening (Abrams, Southerland, & Silva, 2008; Chiappetta, 2008; Hodson, 1988; Luft, Bell, & Gess-Newsome, 2008; Rutherford & Ahlgren, 1990; Windschitl, 2008). In this study students conducted virtual laboratory investigations (treatment group) that involved computerized simulation exercises and traditional hands-on inquiry exercises (comparison group) that they were able to do as a student-centered activities.

The current and most innovative approach to national science standards are referred to as Next Generation Science Standards (NGSS Lead States, 2013; NRC, 2012). Continued efforts have been made to improve access to math and science education for all students while also improving the learning experiences that engage young learners to improve literacy in these areas (Hong & Lin, 2011; Koballa, 2011; Koballa & Crawley, 1985; Lynch, 2000; Mayers & Koballa, 2013; Minger & Simpson, 2006; Naiz, 2011; NRC, 2010, 2012; Rutherford & Ahlgren, 1990; Smith & Scharman, 1999). The modern standards for STEM education include using varied teaching strategies with purposeful science information in an authentic learning environment, for example the incorporation of project and community based learning (Barmby, Kind, & Jones, 2008; NGSS Lead States, 2013; NRC, 1996, 2012).

STEM education is an example of a leading U.S. model in science and mathematics education in which advocates encourage instructional practices that provide for learning through constructive processes (NRC, 2012; NSTA, 2015). A committee formed by the National Research Council (NRC, 2011) identified three significant goals to improving STEM education effectiveness in the United States (U.S.) education. According to this same report, national studies report a need to address the importance of preparing students in the U.S. for STEM careers. In a national study, 75% of eighth graders in the U.S. do not demonstrate effective skills in mathematics for their grade level (NRC, 2011). As a result, NRC (2011) provided a framework for teachers and education policy makers from the national to the local levels of education to improve STEM education effectiveness in the U.S. education system.

The NRC (2011) identified goals and criteria for STEM school success. According to the NRC (2010) the three goals to STEM school success were:

1. Expand the number of students who ultimately pursue advanced degrees and careers in STEM fields and broaden the participation of women and minorities in those fields.

2. Expand the STEM-capable workforce and broaden the participation of women and minorities in that workforce.

3. Increase STEM literacy for all students, including those who do not pursue STEM-related careers or additional study in the STEM disciplines.

NRC (2011) identified the key factors necessary to make these goals happen in U.S. K-12 education through effective progress in developing common standards and curriculum, better preparing teachers, development of more effective and relevant assessment tools, adequate instruction time, and accessibility of education for all students.

In science classrooms, inquiry is a teaching methodology that provides varied opportunities for students to move from passive to active learners, engaging authentically with the new and previously gained knowledge (Chiappetta & Koballa, 2010; Koch; 2010; Martin, 1997). Students are able to understand the information from a learning experience because of the active process of learning. According to Frieberg and Driscoll (2005), a constructivist classroom allows for students to build knowledge through experiences such as touch, sound, taste, and hearing. Frieberg and Driscoll (2005) suggested three important aspects to be considered in a learning environment: value of ideas constructed by students, active engagement in higher order questioning strategies as the students are learning, and emphasis on student thinking rather than rote responses from memorization strategies.

Purpose of the Study

The intent of the proposed study is to learn about ways in which African American students can utilize technology in school to improve academically in science. The need for this study is very urgent. Reaching children during these years is critical to reaching science education objectives, because the attitudes and interests that these students form during their middle school years supply the foundation for future academic and personal decisions (Hueftle, Rakow, and Welsh, 1983). Learning science at the elementary level can influence whether or not the student chooses a career (doctor, nurse, medical examiner, science teacher, forensic scientist, astronomer, physicist, pharmacist etc.) in science.

According to recommended guidelines from the National Science Education Standards (NSES, 1996) and related STEM education research, learning science through direct physical experiences must begin early in life and continue as the child matures through knowledge gained from living and academic interactions (Chiapetta & Koballa, 2010; Marzano, Norford, Paynter, Pickering, & Gaddy, 2001; Worth & Grollman, 2003). Educators who provide an opportunity for meaningful experiences for young learners can foster positive memories and experiences that influence a student's perception of science education and can thereby improve science literacy (Barmby et al., 2008; Koch, 2010; Rutherford & Algren, 1990).

The virtual laboratory science activities can allow elementary students to gain exposure to a multitude of scientific experiments and topics that will help them to pique their curiosity at an early age. Many African Americans attend schools that lack science resources that necessitate the utilization of equipment for science experimentation. Because of the nature of the virtual learning platform students can conduct virtual hands on explorations with various virtual laboratory equipment and supplies that are most often unavailable for use at the school level. The expectation is that these students will be exposed to a variety of scientific investigations and conceptual scientific knowledge that will better prepare them for future STEM courses and stimulate their interests towards a career in STEM.

African Americans as well Latinos are currently underrepresented in science, technology, and engineering and math jobs, relative to their presence in the overall U.S. workforce, particularly among workers with a bachelor's degree or higher (Funk & Parker, 2018). According to the research by (Funk & Parker, 2018) most African Americans in STEM positions consider major underlying reasons for the underrepresentation of African Americans and Latinos in science, technology, engineering and math occupations to be limited access to quality education, discrimination in recruitment and promotions and a lack of encouragement to pursue these jobs from an early age.

The data in their report (Funk & Parker, 2018) comes from two sources: 1) a Pew Research Center analysis of the U.S. Census Bureau's 1990 and 2000 decennial censuses as well as aggregated 2014-2016 American Community Survey data and 2) a nationally representative survey of 4,914 U.S. adults, ages 18 and older, conducted July 11-Aug. 10, 2017 which included an oversample of employed adults working in science, technology, engineering and math (STEM) jobs (Funk & Parker, 2018). The STEM jobs include but are not limited to jobs in Health, Life Science, Math, Physical Science, Computers, and Engineering (Funk & Parker, 2018).

Analysis of their report shows that African Americans and Latinos made up around a quarter (27%, 11% for African Americans and 16% for Latinos) of the overall U.S. workforce as of 2016, but together they accounted for only 16% of those employed in a STEM occupation (Funk & Parker, 2018). African Americans make up 11% of the U.S. workforce overall but represent 9% of STEM workers, while Latinos comprise 16% of the U.S. workforce but only 7% of all STEM workers. And among employed adults with a bachelor's degree or higher, African Americans are just 7% and Latinos are 6% of the STEM workforce. The share of African Americans working in STEM jobs has gone from 7% in 1990 to 9% today and that for Latinos has gone up from 4% to 7% (Funk & Parker, 2018). However, African Americans and Latino workers continue to be underrepresented in the STEM workforce.

Past studies have raised a number of possible reasons for this underrepresentation, including the need for racially and ethnically diverse mentors to attract more African Americans and Latinos to these jobs, limited access to advanced science courses, or socioeconomic factors that may disproportionally affect these communities (MacPhee, Farro & Canetto, 2013).

When asked about the underlying reasons why African Americans and Latinos are underrepresented in this type of work, those working in STEM point to factors rooted in educational opportunities (Funk & Parker, 2018). Some 52% of those with a STEM job say a major reason for this underrepresentation is because African Americans and Latinos are less likely to have access to quality education that prepares them for these fields, while 45% attribute these disparities to these groups not being encouraged at an early age to pursue STEM-related subjects (Funk & Parker, 2018).

In addition, 42% of Americans say limited access to quality education to prepare them for these fields is a major reason African Americans and Latinos are underrepresented in the STEM workforce; this view is held by a majority of those working in STEM who are African Americans (73%) and about half of Latinos (53%), Asians (52%) and whites (50%) in STEM jobs (Funk & Parker, 2018).

The majority of STEM workers in the U.S. are white (69%), followed by Asians (13%), African Americans (9%) and Latinos (7%) (Funk & Parker, 2018). According to Figure 2, compared with their shares in the overall workforce whites and Asians are overrepresented; African Americans and Latinos are underrepresented in the STEM workforce as a whole (Funk & Parker, 2018).

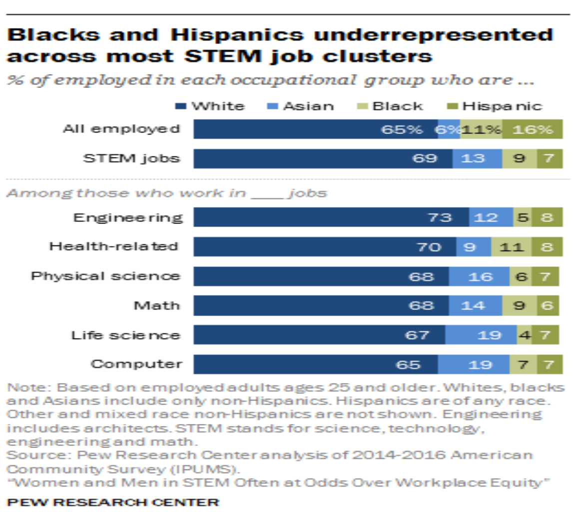


Figure 2: Blacks and Hispanics underrepresented across most STEM job

> [Health technician and nursing jobs have some of the largest shares of African Americans or Latino workers. For example, 37% of licensed practical and licensed vocational nurses are either African American or Latino, as are a quarter or more of health support technicians (27%), medical records and health information technicians (25%), and clinical laboratory technologists and technicians (25%). Among registered nurses, 17% are African Americans or Latinos. By comparison, other health-related jobs have smaller shares of workers who are African Americans or Latinos including physicians and surgeons (11%), pharmacists (10%), dentists (9%), and physical therapists (9%). Just 5% of optometrists, veterinarians and chiropractors are African Americans or Latinos. In the physical sciences, African Americans and Latinos together comprise 22% of chemical technicians but only 14% of chemists and materials scientists, 10% of atmospheric and space scientists, 7% of environmental scientists and 6% of astronomers and physicists. Among mathematical workers, 19% of operations research analysts are African Americans or Latino, compared with just 5% of actuaries] p.2

Of these African American STEM workers, more of them were likely to be foreign born than African American workers overall (22% vs. 14%) (Funk & Parker, 2018).

Earnings of STEM workers outpace those in other kinds of jobs

Among full-time, year-round workers ages 25 and older, median earnings for STEM occupations were $71,000 in 2016 (Fayer, Lacey, & Watson, 2017). Comparable earnings for non-STEM workers were $43,000. According to Figure 3, STEM workers typically earn about two-thirds more than those in non-STEM jobs (Langdon, McKittrick, Beede, Khan, & Doms, 2013).

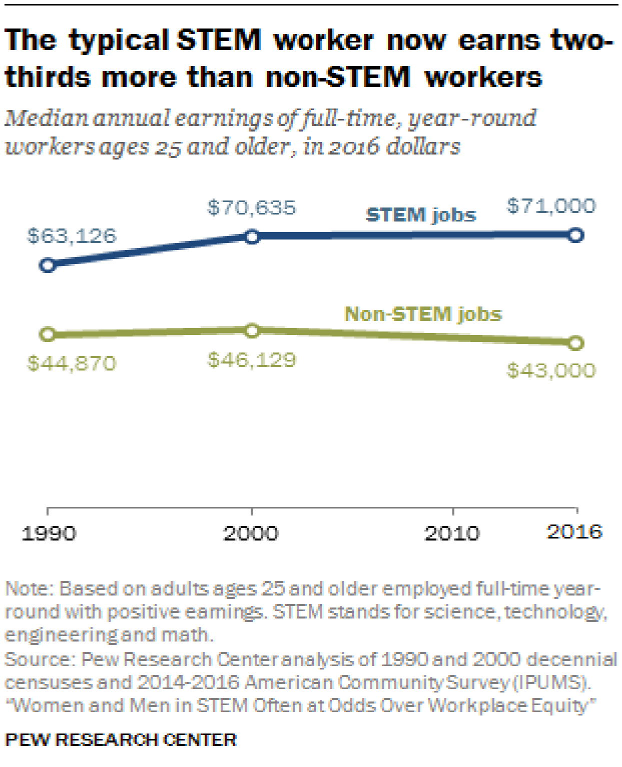


Figure 3: Typical Stem Worker Now Earns Two-Thirds More Than Non-Stem

Even among workers with similar levels of education, STEM workers earn significantly more than non-STEM workers (Funk & Parker, 2018). Figure 4 shows that among those with some college education (including those with an associate but not a bachelor's degree); the typical full-time, year-round STEM worker earns $54,745 (Funk & Parker, 2018). A similar non-STEM worker earns $40,505, 26% less (Funk & Parker, 2018).

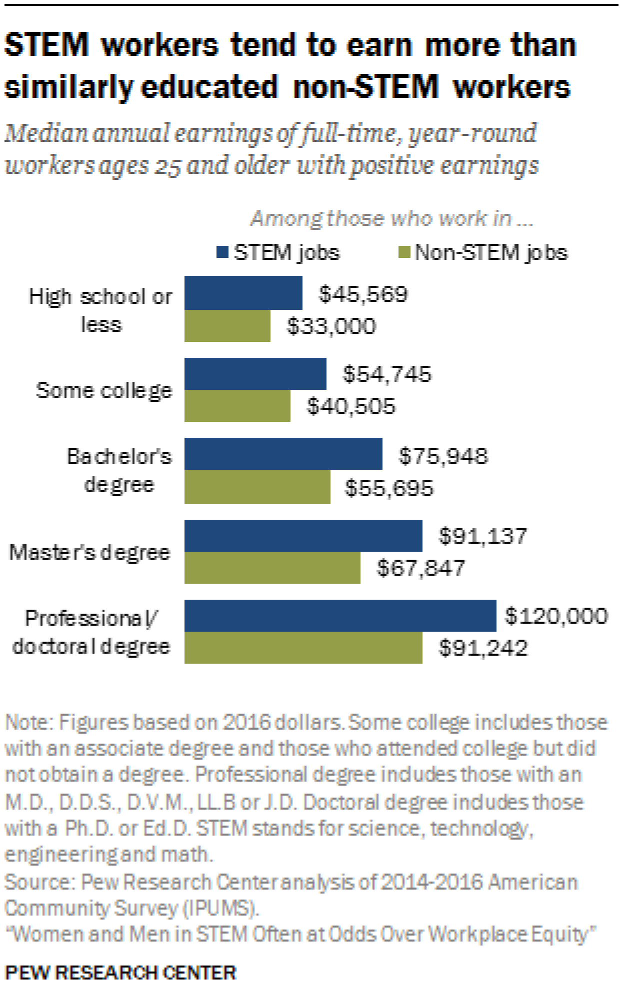


Figure 4: STEM Workers Tend To Earn More Than Similar Educated Non-Stem

African Americans and Latinos would have access to this kind of income if they readily chose STEM careers for their profession. The Funk & Parker's (2018) study revealed that one of the first ways Americans encounters science, technology, engineering and math is through their early education. Figure 5 shows that as Americans look back on their own K-12 experiences, three quarters (75%) report that they generally liked science classes (Funk & Parker, 2018).

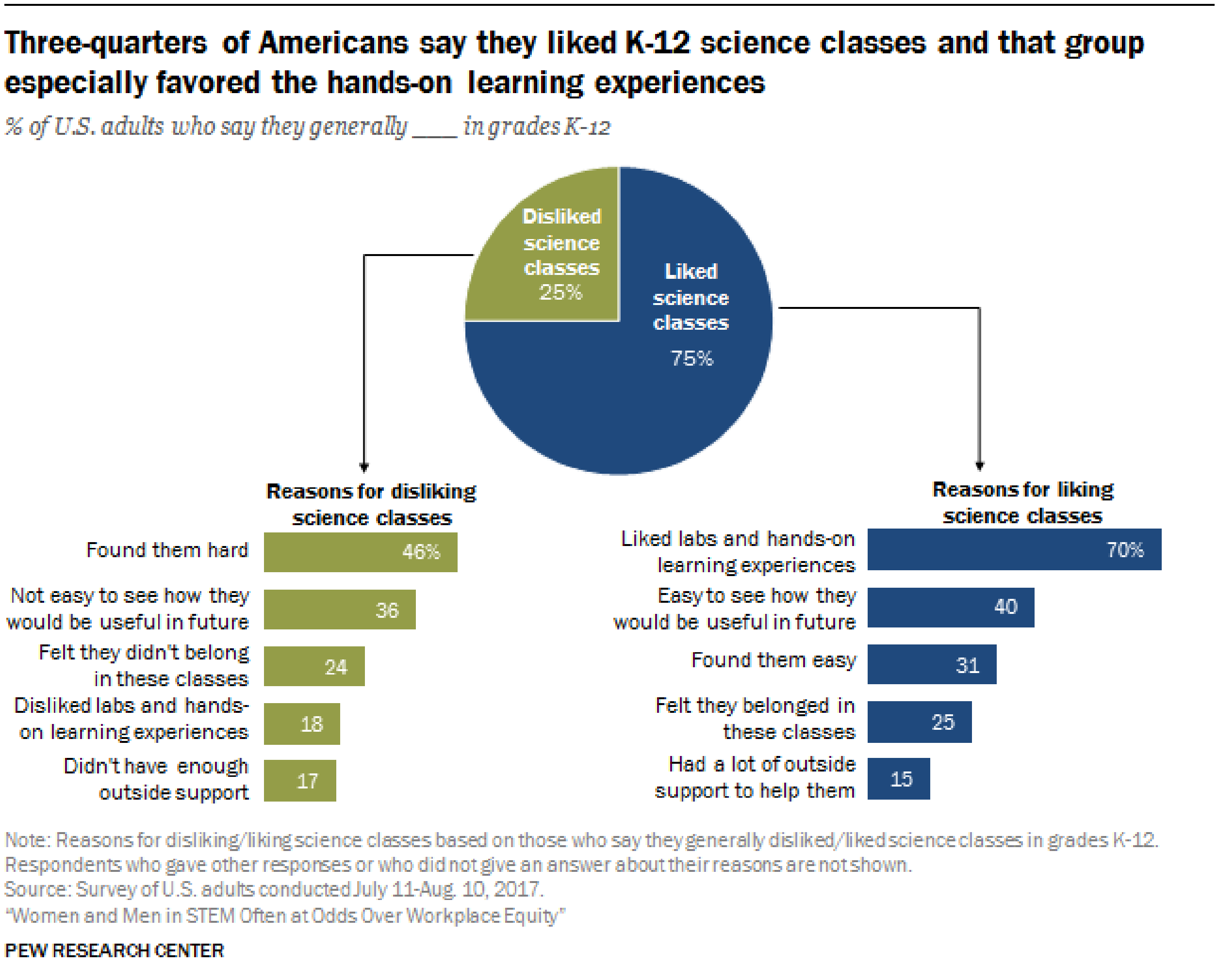


Figure 5: Three Quarters of Americans Say They liked K-12 Science Classes

Science labs and hands-on learning experiences stand out as a key appeal among those who liked science classes (Funk & Parker, 2018). Some 46% of those who disliked science classes in their youth say a reason for their view is that these classes were hard, while another 36% of this group found it hard to see how science classes would be useful to them in the future (Funk & Parker, 2018). STEM workers are more likely than those working in other fields to say they liked science or math classes in school, but still more than four-in-ten non-STEM workers say they liked both subjects in grades K-12 (Funk & Parker, 2018).

> When asked when in their life they were interested in pursuing a STEM job or career, most pointed to when they were in high school, college or during their 20s. About four-in-ten (41%) say that they had this interest in college or during their 20s and another 28% say they were interested in high school or their teenage years. Fewer say they were interested in pursuing a STEM career early in life, in elementary school or their childhood (10%) or later in life over the age of 30 (5%). When asked why they did not end up pursuing a career or job in STEM, the most commonly cited reason was cost and time barriers (27%), such as the large amount of time and money required for education or a general lack of access to resources and opportunities. Some 14% say that they did not end up in a STEM career because they struggled to do well in STEM classes or just lost interest in STEM. A similar share (11%) cites personal or family circumstances. (p. 7).

A majority of Americans say problems for K-12 STEM education can be attributed to limited parental involvement as well as failings in student work ethic and diminished interest in learning (Funk & Parker, 2018). But, at the same time, many adults believe such problems are the result of teaching methods and curriculum emphasis on meeting state standards (Funk & Parker, 2018). Roughly half of the public says a big problem for STEM education comes from teachers rarely using methods that help students think critically and problem solve (49%), spending too little time on these subjects in elementary school (48%) or not having up-to-date curriculum materials (48%) according to Figure 6 (Funk & Parker, 2018).

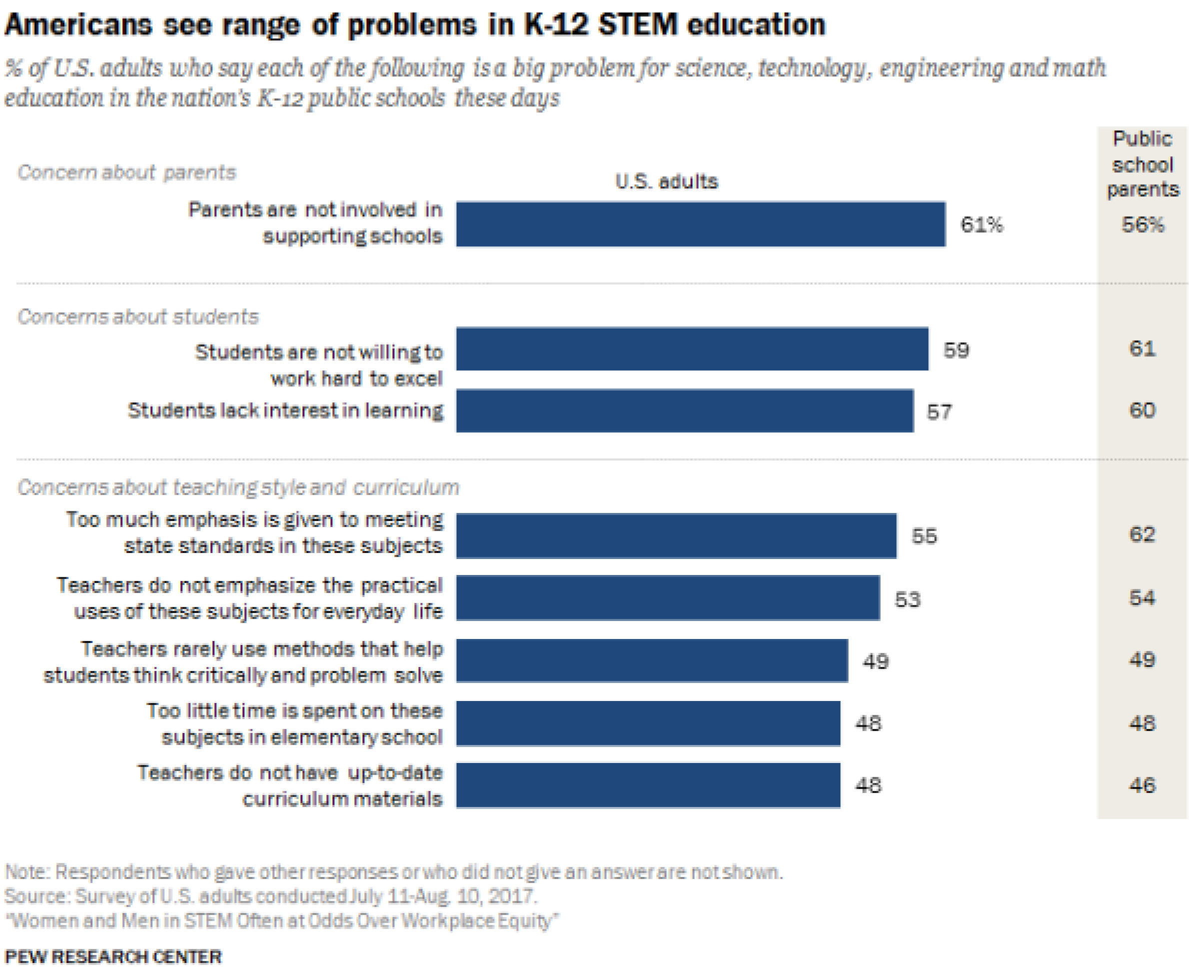


Figure 6: Americans See Range of Problem in K-12 Stem Education

Theoretical Framework

One of the central goals of science education was to promote scientific reasoning in students (AAAS, 1993; National Research Council, 1996). Many schools employed students to participate in science based inquiry activities that facilitated writing observations and/or conducting experiments. The main purpose of these tasks was to allow students to reason in a scientific way and gain cognitive understanding.

In the article *"Epistemologically Authentic Inquiry in Schools: A Theoretical Framework for Evaluating Inquiry Tasks",* Chinn and Maholtra (2002) argued that many scientific inquiry tasks given to students in schools do not reflect the core attributes of authentic scientific reasoning. The underpinnings of their research were based on a theoretical framework that evaluated inquiry tasks in terms of how similar they were to authentic science (Chinn and Maholtra, 2002). The authors delineated their theoretical framework by contrasting authentic scientific inquiry with the simple inquiry tasks found in many textbook-based science curricula (Chinn and Maholtra, 2002). They noted that textbook inquiry tasks continue to be an important influence on science curricula (Driscoll, Moallem, Dick, & Kirby, 1994; Kulm, Roseman, & Treistman, 1999; Stinner, 1995) and are often used by science teachers during classroom instruction.

Theoretical Framework for Analyzing Authentic Scientific Reasoning

The primary objective of science education is to enable students to acquire scientific thinking ability (Chinn and Maholtra, 2002). In order to achieve this goal students take part in science inquiry activities such as performing science investigations (Chinn and Maholtra, 2002). Oversimplified forms of science inquiry activities are often found in schools (AAAS, 1993). Subsequently, students don't learn to develop theories that explain a diverse array of evidence, decide what evidence should be used, and critique explanations and procedures (National Research Council, 1996).

The Benchmarks for Science Literacy(AAAS,1993) and The National Science Education Standards (National Research Council, 1996) highlighted a need to develop a detailed, systematic analysis of the characteristics of authentic scientific reasoning (Chinn & Maholtra, 2002).These recommendations focused on helping students learn authentic scientific inquiry (Chinn & Maholtra, 2002).

Authentic scientific inquiry is a complex activity, employing expensive equipment, elaborate procedures and theories, highly specialized expertise, and advanced techniques for data analysis and modeling (Dunbar, 1995; Galison, 1997; Giere, 1988). Authentic scientific inquiry refers to the research that scientists actually carry out (Chinn & Maholtra, 2002).

Research essentially conducted by scientists takes on many forms; from case studies in ecology to complex experiments using particle accelerators (Chinn & Maholtra, 2002). A description of the experiment below shows how an actual authentic scientific inquiry activity is conducted.

> fMRI study. Hirsch, DeLaPaz, Relkin, Victor, Li, Karl, Olyarchuk, & Georgakakos, (1993) used functional magnetic resonance imaging (fMRI) to investigate the effects of visual stimulation on neural activity, as indicated by increased oxygenated blood flow to specific regions of the brain. To provide an oversimplified overview, in fMRI studies a person lies motionless in a small space surrounded by a magnet that generates a powerful, uniform magnetic field. When placed in this magnetic field, paramagnetic atoms, especially hydrogen atoms, align their polarities with the field, effectively pointing them in the same

> direction. This alignment is then disturbed by introducing a radio wave frequency pulse. As the atoms return to their normal state, they emit signals during their decay that are measured by a detector. Because of differences in magnetic properties of oxygenated and deoxygenated blood, the decay rate in deoxygenated blood is greater than that of oxygenated blood. Through complex mathematical transformations, the decay signals are electronically converted into images in which higher densities of oxygenated blood in the brain are indicated by lighter pixels on an image. The goal of the Hirsch et al. study was to investigate how visual stimulation affects patterns of blood flow in the brain. The researchers expected that visual stimulation would increase blood flow to three regions of the brain, called regions 17, 18, and 19. Participants were placed in a magnetic field that permitted four parallel cross sections of the brain to be imaged. Then a series of radio pulses was introduced. At each radio pulse, the researchers obtained images for each cross section of the brain. Images made during visual stimulation were compared statistically with images taken before and after stimulation, to try to determine which areas of the brain showed increased blood flow during visual stimulation. (p. 177-178)

Schools lack the time and resources to reproduce such research tasks (Chinn & Maholtra, 2002). Instead, educators must necessarily develop simpler tasks that can be carried out within the limitations of space, time, money, and expertise that exist in the classroom (Chinn & Maholtra, 2002). They must develop relatively simple school inquiry tasks that, despite their simplicity, capture core components of scientific reasoning (Chinn &

Maholtra, 2002). Virtual simulated laboratory activities maybe the bridge needed to link authentic science research tasks and simple school inquiry.

Most simple inquiry tasks appear regularly in textbooks (e.g., Daniel, Ortleb, & Biggs, 1995; McFadden & Yager, 1993), trade books (e.g., Murphy, 1991; VanCleave, 1997; Whalley, 1992), educational software (e.g., Houghton Mifflin Interactive, 1997; Theatrix Interactive, 1995), and websites of science activities (e.g., HIRO Science Lessons, n.d.; The Science House, n.d.), and incorporate few if any features of authentic scientific inquiry (Chinn & Maholtra, 2002).

In an analysis of the hands-on research activities in nine middle-school and upper-elementary-school textbooks, Chinn and Maholtra (2002) found that most simple inquiry tasks fell into three categories, which they call simple experiments, simple observations, and simple illustrations (Chinn & Maholtra, 2002). In simple experiments, students conduct a straightforward experiment, usually evaluating the effects of a single independent variable on a single dependent variable (Chinn & Maholtra, 2002). For example, in one experiment in a middle school textbook (McFadden & Yager, 1993), students affix a meter stick to the edge of a table so that the meter stick extends out from the table. Students then hang weights of various sizes to the end of the meter stick (Chinn & Maholtra, 2002). The purpose is to investigate the effect of weight (the sole independent variable) on how far the meter stick bends (the sole dependent variable) (Chin & Maholtra, 2002).

In simple observations, students carefully observe and describe objects (Chin & Maholtra, 2002). In one typical exercise in Warner, Lawson, Bierer, & Cohen (1991), students observe a starfish, measuring features such as its diameter and noting the location of various structures such as the mouth and tube feet. In simple illustrations, students follow a specified procedure, usually without a control condition, and observe the outcome (Chinn & Maholtra, 2002). Thompson, McLaughlin, and Smith, (1995) presented an activity that will be called the bleach task. The experiment illustrates a theoretical principle, and the text clearly specifies what the theoretical principle is (Chinn & Maholtra, 2002).

> For example, Students pour 20 ml of liquid laundry bleach into a large test tube and then add 0.5 g of cobalt chloride to the bleach. Students place their thumbs over the opening of the test tube to feel what happens (there is pressure from gas forming); then they insert a blown-out but still glowing match into the top of the tube. The textbook explains that the match ignites because oxygen is produced in a chemical reaction. Simple illustrations are inquiry tasks only in the narrowest sense. Students do encounter new empirical phenomena when they carry out the procedure, but they have no freedom to explore further. (p. 179).

These simple inquiry tasks are most often conducted by students in a traditional lab setting.

When scientists conduct scientific investigations they engage in six cognitive processes. These cognitive processes are generating a research question, designing a study to address the research question, making observations, explaining results, developing theories, and studying others' research (Chinn & Maholtra, 2002). According to Chinn and Maholtra (2002), the cognitive processes that are needed in authentic scientific inquiry differ with the cognitive processes that are needed in simple inquiry tasks. As shown in Table 1, key differences of cognitive processes across the four types of research tasks: authentic inquiry, simple experiments, simple observations, and simple illustrations are summarized (Chinn & Maholtra, 2002).

Table 1: Summary of Key Differences Across Four Types of Research Tasks

Type of Reasoning Task

Cognitive Process	Authentic Inquiry	Simple Experiments	Simple Observations	Simple Illustrations
Generating research questions	Scientists generate their own research questions.	Research question is provided to students.	Research question is provided to students.	Research question is provided to students.
Designing Studies				
Selecting variables	Scientists select and even invent variables to investigate. There are many possible variables.	Students investigate one or two provided variables.	Students observe prescribed features.	Students employ provided variables.
Planning procedures	Scientists invent complex procedures to address questions of interest.	Students follow simple directions on how to implement a procedure.	Students follow simple directions on what to observe.	Students follow simple directions on how to implement a procedure.
	Scientists often devise analog models to address the research question.	Analog models are sometimes used, but students do not reflect on whether the models are appropriate.	Analog procedures are usually not used.	Analog models are sometimes used, but students do not reflect on whether the models

				are appropriate.
Controlling variables	Scientists often employ multiple controls.	There is a single control group.	Control of variables is not an issue.	Control of variables is not an issue.
	It can be difficult to determine what the controls should be or how to set them up.	Students are usually told what variables to control for and/or how to set up a controlled experiment.	Not applicable	Not applicable
Planning measures	Scientists typically incorporate multiple measures of independent, intermediate, and dependent variables.	Students are told what to measure, and it is usually a single outcome variable.	Students are told what to observe.	Students are told what to measure, and it is usually a single outcome variable.
Making observations	Scientists employ elaborate techniques to guard against observer bias.	Observer bias is not explicitly addressed, although measuring devices such as rulers are used.	Observer bias is not explicitly addressed, although measuring devices such as rulers are used.	Observer bias is not explicitly addressed, although measuring devices such as rulers are used.
Explaining results				
Transforming observations	Observations are often repeatedly transformed into other data	Observations are seldom transformed into other data formats, except	Observations are seldom transformed into other data formats,	Observations are seldom transformed into other data formats,

	formats.	perhaps straightforward graphs.	except perhaps straightfor-ward drawings.	except perhaps straightfor-ward graphs.
Finding flaws	Scientists constantly question whether their own results and others' results are correct or artifact of experimental flaws.	Flaws in experiments are seldom salient.	Flaws in experiments are seldom salient.	If students do not get the expected outcome, they often assume that they did the experiment incorrectly.
Indirect reasoning	Observations are related to research questions by complex chains of inference.	Observations are straightforwardly related to research questions.	Observations are straight-forwardly related to research questions.	Observations are straight-forwardly related to research questions.
	Observed variables are not identical to the theoretical variables of interest.	Observed variables are the variables of interest.	Observed variables are the variables of interest.	Observed variables differ from theoretical variables, but the text explains the link directly.
Generalizations	Scientists must judge whether to generalize to situations that are dissimilar in some respects from the experimental situation.	Students usually generalize only to exactly similar situations.	Students usually generalize only to exactly similar situations.	Students usually generalize only to exactly similar situations.
Types of reasoning	Scientists employ	Students employ simple	Students employ	Students employ

	multiple forms of argument.	contrastive reasoning.	simple inductive reasoning.	simple deductive reasoning.
Developing theories				
Level of theory	Scientists construct theories postulating mechanisms with unobservable entities.	Students usually uncover empirical regularities, not theoretical mechanisms.	Students uncover empirical regularities.	Students do experiments that illustrate theoretical mechanisms, but they do not develop or investigate theories.
Coordinating results from multiple studies	Scientists coordinate results from multiple studies.	Students do just a single experiment.	Students only make a certain range of observations at one time.	Students do just a single demonstration.
	Results from different studies may be partially conflicting, which requires use of strategies to resolve inconsistences.	Not applicable	Not applicable	Not applicable
	There are different types of studies, including studies at the level of mechanism and studies at the level of observable regularities.	Not applicable	Not applicable	Not applicable

Studying research reports	Scientists study other scientists' research reports for several purposes.	Students do not read research reports.	Students do not read research reports.	Students do not read research reports.

Comparing and Contrasting Simple Inquiry Tasks and Authentic Research

The difference between simple inquiry tasks and authentic research tasks is significant. In comparison to authentic research tasks, simple inquiry tasks offer a diluted kind of science exploration that most often impedes the scientific reasoning ability of young students.

According to Chinn and Maholtra (2002) in simple inquiry tasks, students are told what the research question is (e.g., find out what happens when you mix bleach and cobalt chloride). By contrast, in authentic research, scientists must develop and employ strategies to figure out for themselves what their research question is (Chinn & Maholtra, 2002).

In most simple inquiry tasks, students are told which of several variables to investigate, and the variables are usually perceptually salient, such as weight and the distance that a meter stick bends (Chinn & Maholtra, 2002). In authentic research, scientists select their own variables from a very large pool of potential variables, and they often invent or construct variables that are conceptually embedded in the theories being tested (Chinn & Maholtra, 2002).

Procedures in most simple inquiry tasks are straightforward, as students follow a short series of prescribed steps as in a recipe (Chinn & Maholtra, 2002). In authentic research, procedures are complex and often require considerable ingenuity in their development (Chinn & Maholtra, 2002).

> In simple observations and simple illustrations, there are usually no control conditions. In simple experiments, what needs to be controlled is usually straight-forward. For example when conducting experiments to see whether seeds sprout faster in the light or the dark, students consider a few variables such as the type of seed used, the depth of the seed, the type of container, and the amount of water given. Once students understand the control-of-variables strategy, they can almost routinely go down a list of variables and make sure that all untested variables are held constant across the conditions. In authentic research, by contrast, it can be very difficult to know which variables need to be controlled and how to implement proper controls. The reasoner needs a very good causal model of the processes being tested in order to know what to control. (p.183-184)

Controlling variables is much more difficult in authentic science than in simple varieties of school science (Chinn & Maholtra, 2002). Scientists must build up a great deal of knowledge about the causal processes that operate under various conditions in order to determine what the proper controls are. In authentic experimentation, scientists measure many different variables, including measurements that serve as manipulation checks, measurements of intervening variables, and multiple outcome measures (Chinn & Maholtra, 2002). In most simple experiments and simple illustrations, by contrast, there is just a single outcome measure, such as the number of centimeters that a meter stick bends (Chinn & Maholtra, 2002).

In authentic scientific research, methods are complex and uncertain, and scientists spend a great deal of time and effort worrying about possible errors in methods, both in their own work and in the work of others (Chinn & Brewer, 1993; Franklin, 1986). By contrast, simple inquiry tasks are so simple that there is little scope for finding flaws in methods (Chinn & Maholtra, 2002). Relatively little can go wrong when hanging weights from meter sticks. Ironically, simple inquiry tasks can lead students to become aware of experimental error but promote a very unscientific approach to responding to errors (Chinn & Maholtra, 2002). When conducting simple inquiry tasks as part of science labs, students generally assume that if the results do not turn out right, they must have done the experiment wrong (Pickering & Monts, 1982).

In simple inquiry tasks, generalizations are much more straightforward (Chinn & Maholtra, 2002).

> In the meter stick experiment, for example, students are not asked by the textbook to discuss the extent to which this result generalizes to other situations. Simple inquiry tasks require only a limited range of reasoning strategies. Simple experiments require only a simple form of contrastive causal reasoning; for instance, if the meter stick bends more when more weights are hung, then one should conclude that increasing the weight makes the meter stick bend more. In sharp contrast authentic reasoning requires the use of a broad array of diverse reasoning strategies. Examples include postulating unobservable mechanisms that

> could explain existing results, looking for flaws in experiments, finding ways to verify the validity of new methods, making indirect inferences, choosing between two or more theories that each has some explanatory successes, and devising indirect procedures to address questions of interest. Simple inquiry tasks leave out most of the reasoning processes that are characteristic of science. (p.183-184)

A prominent feature of scientists' research life is studying other scientists' research (Brewer & Mishra, 1998; Latour & Woolgar, 1986). Reading and hearing about other scientists' research plays a central role in all of the cognitive processes described above (Dunbar, 1995) in authentic research. For example, other scientists' research helps inform researchers about what variables need to be controlled, what should be measured, how to devise new measures, and what kinds of conclusions will be considered acceptable in the research community (Chinn & Malhotra, 2002).

> In authentic research, scientists' conclusions are grounded in the theoretical and empirical work of other scientists. In real science the ratio of studying other scientists' research to conducting one's own research is relatively high. By contrast, reading expert research reports plays almost no role at all in simple forms of school science. At most, students conduct their own research and make some reports to each other. But even then, students do not study a body of research that has passed review by experts in the field. In textbook science the ratio of studying others' research to conducting one's own research is low (p. 186).

One important implication of Chinn and Maholtra's (2002) analysis is that simple inquiry tasks may not only fail to help students learn to reason scientifically; they may be partly responsible for increasing the likelihood of students being confused about scientific concepts. Their analysis has suggested a need to develop new school tasks that come closer to reflecting the attributes of real science (Chinn & Malhotra, 2002).

> For example, hands-on inquiry comes much closer to authentic science in relatively free inquiry tasks. Free inquiry tasks have the potential to incorporate several key features of authentic scientific reasoning. Students are free to construct more complex models of experiments as they conceptualize their studies. Students can worry about appropriate methods, about whether measures are biased, and about how to control for complex confounds. (p. 206)

When compared with hands-on inquiry, computer simulations offer an important advantage (Chinn & Malhotra, 2002). The advantage is that computers allow students to conduct simulated experiments with complex underlying models that they could not conduct in reality because of lack of time and equipment. This allows computer-simulated experiments to capture several features of authentic reasoning that are hard to capture using hands-on inquiry.

> First, computers allow students to conduct experiments at the level of theoretical mechanism. By partially reducing the complexity of real experiments and by simulating the use of expensive equipment, computer simulations permit students to investigate theoretical entities. A second

feature of authentic science that can be captured easily by computer simulations is the use of different types of experiments. Students can conduct different types of experiments on the same issue in a computer simulated environment. A third feature of authentic reasoning that can be incorporated into computer simulations is the possibility of implementing relatively complex designs. Computer simulations could also be designed to simulate experiments in which methodology is a major concern. In this type of simulation learners use different methods to investigate an issue, and these methods yield conflicting results, which would impel learners to think about how to reconcile the rival methods or how to decide which is more reliable. (p. 208)

Chinn and Malhotra (2002) concluded that in order to promote authentic scientific reasoning in schools, schools must develop,

1. reasoning tasks that afford authentic reasoning,
2. a better understanding of the strategies that scientists use when reasoning on such tasks and
3. instructional strategies that ensure that students learn these authentic reasoning strategies when they engage in authentic inquiry tasks.

Students who learn authentic science reasoning skills at a young age may also be afforded with more realistic science investigations that may serve to increase their content knowledge and interest in particular areas of science for future studies.

Significance of Study

A focus on science, technology, engineering and mathematics (hereinafter referred to as STEM) fields in education is needed for the United States to maintain its competitive position in a global economy (Chen & Weko, 2009). Analysts predict that the United States needs to produce approximately one million more STEM professionals over the next ten years, which equates to increasing the number of students earning STEM degrees by nearly 35% per year over current rates (President's Council of Advisors on Science and Technology, 2012). Colleges and universities are therefore facing an unprecedented need to increase the number of undergraduate students who are interested in majoring in STEM disciplines (Wang, 2012).

There is a large portion of students who are currently not fully participating in science and engineering (Sevo, 2009). The United States currently has one of the lowest rates of STEM to non-STEM bachelor's degree production worldwide, with STEM accounting for 17% of all degrees awarded in the United States in 2002 compared to the international average of 26% (Kuenzi, 2008). The demand for skilled workers in STEM fields will be difficult, if not impossible, to meet if the nation's future mathematicians, scientists, engineers, information technologists, computer programmers, and health care workers do not reflect the diversity of the population (Institute for Higher Education Policy (IHEP), 2010). Latinos are the fastest growing and youngest group in the United States. It is estimated that Latinos will comprise 30 percent of the U.S. population by 2040 and will be the majority group in several states (U.S. Census Bureau, 2008).

At the same time however, Latino students are underrepresented in STEM fields (U.S. Commission on Civil Rights, 2010). As such, filling the pool of qualified applicants for employment in STEM fields will require a growing number of Latino students studying STEM fields and earning STEM degrees (Oakes, 1990). Increasing the percentage of Latinos and other traditionally underrepresented minorities in STEM occupations is not only ethically and morally correct, as these groups deserve equal access to STEM fields, but allows minority groups to serve as role models and mentors for younger members of their own ethnic/racial group (Bonous-Hammarth, 2000; Grandy, 1998).

The number of students (both Latino and non-Latino) enrolling in STEM fields is on the rise. Enrollment in STEM fields from 1995-1996 to 2003-2004 increased 21 percent, compared to an increase of 11 percent in non-STEM areas. During that same time, the percent of Latino students enrolling in STEM fields increased by 33 percent, representing nearly ten percent of students in STEM fields (United States Government Accountability Office, 2005). At the same time however, disproportionately low numbers of Latinos currently persist in STEM (Oakes, 1990; Young, 2005). Although Latino students have been shown to be equally likely as White students to major in STEM, they are significantly less likely to earn a degree or certificate in STEM field (Chen & Weko, 2009). According to recent data from the Institute for Higher Education Policy (2010), 16 percent of Latino students who began college in 2004 as STEM majors completed a STEM degree by 2009, compared to 25 percent of White students.

Data from the Integrated Postsecondary Education Data System (IPEDS) Completion Survey for the 1999-2000 academic year points out that the most popular majors in which Latino students earned bachelor's degrees are in the social sciences, business, psychology, and education (Crisp & Nora, 2012). In contrast, Latino students are less likely to earn undergraduate degrees in biological and life sciences, computer and information sciences, engineering, and the health professions and related sciences (Crisp & Nora, 2012). These discrepancies that exist at the undergraduate level are also seen at the master's and doctoral levels, as Latino students are more likely to earn degrees in education and are less likely to earn a master's degree in the health professions, engineering, computer information sciences, and business (Llagas & Snyder, 2003).

African Americans are disproportionately represented in STEM fields as well as Latinos. In 2007 JBHE (Journal of Black Higher Education) reported that there were 2,275 doctorates awarded by universities in the United States in the fields of geometry, computing theory and practice, astronomy, meteorology, theoretical chemistry, geochemistry, geophysics and seismology, paleontology, mineralogy and petrology, stratigraphy and sedimentation, geomorphology and glacial geology, acoustics, elementary particle physics, biophysics, nuclear physics, plasma/fusion physics, polymer physics, hydrology and water resources, oceanography, petroleum engineering, polymer and plastics engineering, communications engineering, engineering mechanics, ceramic science engineering, metallurgical engineering, agricultural engineering, engineering physics, mining and mineral engineering, ocean engineering, animal breeding, animal nutrition, agricultural plant breeding, plant pathology, horticultural science, fishing and fisheries science, forest science and biology, forest resources management, wildlife/range management, biotechnology, bacteriology, plant genetics, plant pathology biology, plant physiology, botany, anatomy, entomology, zoology, and veterinary medicine; not one of these 2,275 doctoral degrees went to an African American.

As reported in a recent JBHE (2017), data for the annual *Survey of Earned Doctorates* shows that universities in the United States conferred 54,641 doctorates in 2017. Of these, 2,963, or 5.4 percent were awarded to African American students (JBHE, 2017).

> But African Americans are vastly underrepresented among doctoral degree recipients in some disciplines. For example, African Americans earned only 1.2 percent of all doctorates awarded in physics to U.S. citizens and permanent residents. African Americans earned 0.9 percent of all mathematics and statistics doctorates, 1 percent of all doctorates in computer science, 2 percent of all doctorates in chemistry, and only 1.7 percent of all doctorates awarded in engineering disciplines. In 2017, there were 1,176 doctorates awarded by U.S. universities in the fields of plant genetics, wildlife biology, medical physics, atmospheric physics, chemical and physical oceanography, plasma/high temperature physics, geometry, logic, number theory, robotics, structural engineering, English as a second language, Italian, Middle/Near East history, classics, music, and music performance. Not one went to an African American (p. 1).

The statistics regarding the progress of Latinos and African Americans in STEM fields is disheartening to say the least in an advanced society such as the United States. The data suggested that there may be an underlying problem with the educational opportunities in STEM or lack thereof afforded to these disenfranchised groups in their early years of schooling. This study was conducted for African American students. However, my research regarding the impact of technology on improving science achievement in

Elementary students may be beneficial to Latino students, as they too are disproportionately represented in STEM fields.

Research Questions

The following research questions and hypotheses were analyzed.

Research Question 1: Will students who conduct science investigations with computerized virtual science laboratory experiments (treatment group) get significantly higher scores on Standardized science achievement tests such as the Terra Nova 3 Survey Assessment in Science for grade 4 than students who conduct science investigations utilizing traditional hands-on science laboratory experiments (comparison group)?

Hypothesis 1: Students who conduct science investigations with computerized virtual science laboratory experiments (treatment group) will get significantly higher scores on Standardized science achievement tests such as the Terra Nova 3 Survey Assessment in Science for grade 4 than students who conduct science investigations utilizing traditional hands-on science laboratory experiments (comparison group).

Research Question 2: Will students in the treatment group score significantly higher on the ILSAT than students in the comparison group?

Hypothesis 2: Students in the treatment group will get significantly higher scores on the ILSAT than students in the comparison group?

Research Question 3: Will students in the treatment group score significantly higher on their attitudes to science learning and self-efficacy than students in the comparison group?

Hypothesis 3: Students in the treatment group will score significantly higher on their attitudes to science learning and self-efficacy than students in the comparison group.

Students were assessed using the Terra Nova 3 Survey Assessment in Science for grade 4 for Pre and Post-test. Students' ILSAT examination scores for grade 4 were also analyzed. SMSTL questionnaires were given as a Pre and Post-test and were analyzed. Two groups were studied: One group participated in virtual science laboratory activities and was randomly assigned to a treatment group while one group participated in the science laboratory activities using traditional hands-on methods and were assigned to a comparison group.

Definition of Terms

1. ***Terra Nova 3 Survey Assessment in Science for grade 4***- An abbreviated version of the Complete Battery and provides a general measure of achievement, with a minimum amount of testing time. The Survey generates norm-referenced achievement scores, criterion-referenced objective mastery scores, and performance-level information.
2. ***Virtual Science lab activities***- Virtual Labs help students learn basic laboratory techniques and practice methods used by lab technicians and researchers in a variety of careers. (https://www.explorelearning.com/)

3. ***New York Intermediate Level Science Assessment Test Grade 4-*** The assessment asks students to demonstrate general knowledge of science, apply scientific concepts, formulate hypotheses, make predictions, and use other scientific techniques. The fourth grade science performance test is a timed test consisting of multiple parts, the written portion of the test and a laboratory performance examination which evaluates students' ability to use hands-on equipment and materials to record observations and answer scientific questions.

4. ***Explorer Learning Gizmos-*** Gizmos are interactive math and science simulations for grades 3-12. Over 400 Gizmos aligned to the latest standards help educators bring powerful new learning experiences to the classroom.

5. ***Traditional Hands on Lab Activities-*** Traditionally, the terms "laboratory" or "experiment" have been used to describe practical work done by students during science class in place of such other methods of instruction as lecture, reading, recitation, worksheets, and teacher demonstration.

6. ***STEM***- "STEM" is the acronym of science, technology, engineering, and mathematics. STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global

enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy. (Tsupros, 2009*)*

7. ***Science Inquiry***- Inquiry-based science adopts an investigative approach to teaching and learning where students are provided with opportunities to investigate a problem, search for possible solutions, make observations, ask questions, test out ideas, and think creatively and use their intuition. In this sense, inquiry-based science involves students doing science where they have opportunities to explore possible solutions, develop explanations for the phenomena under investigation, elaborate on concepts and processes, and evaluate or assess their understandings in the light of available evidence. This approach to teaching relies on teachers recognizing the importance of presenting problems to students that will challenge their current conceptual understandings so they are forced to reconcile anomalous thinking and construct new understandings (Bulba, n.d.)

8. ***Metastrategy***- An overarching strategy determining which other strategies to use in a given situation (Your dictionary.com, 2018)

CHAPTER 2

Review of Related Literature

Educational scholars who have examined the factors that contribute to the academic success of African Americans have focused on primarily two schools of thought (Bush & Bush, 2010). The first school of thought analyzes individual characteristics and the second focuses on pre-college indicators, known as cognitive and non-cognitive variables, respectively (Bush & Bush, 2010). Cognitive variables are factors such as high school grade point average, level of math completed, test scores, and placement scores (Bush & Bush, 2010). Non-cognitive variables are factors such as social interaction, motivation, and a student's self-concept (Brooks-Leonard, 1991). Johnson (1993), in his study of success factors for African Americans at the University of South Carolina, defined cognitive variables, "as those variables that objectively measure intellectual ability and are exhibited by some numerical score, rank or range" (p. 31). Johnson defines non-cognitive variables "as affective, psychosocial constructs, subjective in nature that describe the feeling, perceptions, and/or attitudes" (p. 31).

Research suggests that indicators, such as high school grade point average, test scores, parental education level, and a positive self-efficacy, are correlated to the success of African Americans in higher education (Bush & Bush, 2010). In this study, I aim to propose the use of technology, in the form of computerized virtual lab activities, to increase science standardized test scores (a cognitive variable) of African American elementary school children.

Challenges for Science Education at the Elementary School Level

According to the research, elementary and middle school students present a unique challenge for science education. Spanning grades K-8, they are a diverse group, more varied, physically, intellectually, and socially than any other school age group (DeHart, Hurd, Robinson, McConnell, & Ross, 1981). Children often lose their early interest in science during these tumultuous years (Von Blum, 1992). The computer can serve as an effective technological bridge to help science education meet its goals. For example, for science & technology computers can simulate laboratory experiences that are otherwise difficult, dangerous, or impossible to perform in usual classroom settings. They can provide tools for gathering and analyzing data from simulated experiments or from hands-on investigations (for example, via probeware) (Von Blum, 1992).

It is generally accepted that students learn best by doing – particularly in science courses (Dalton, Morocco, Tivnan & Rawson Mead, 1997). In the article, *Changing How and What Children Learn in School with Computer-Based Technologies* by Roschelle, Pea, Hoadley, Gordin, and Means (2000), when students are engaged in "actively constructing knowledge from a combination of experience, interpretation and structured interactions with peers and teachers" (Roschelle et al., 2000, p.79), they are more likely to gain an expert understanding of science concepts. The authors state, that technology tools are one way to expose children to this type of learning (Roschelle et al., 2000) because "the structure and resources of traditional classrooms" are often inadequate. With that being said, "Technology – when used effectively – can enable ways of teaching that are much better matched to how children learn" (Roschelle et al., 2000, p.79). While many studies of technology use in the classroom have reported mixed results, the largest gains seem to occur when technology tools are used to teach science and mathematics (Roschelle et al., 2000).

Much of science learning is hands on, but there are instances when it is impractical or impossible for students to participate in certain science activities. When because of cost, time, safety issues, or accessibility–students are unable to engage in certain activities, computer simulations can be an effective approach (Huppert, Lomask, & Lazarowitz, 2002). These types of simulations are generally a software program or online applet “with which children play and discover concepts and cause-effect relationships through exploration and experimentation” (Henderson, Klemes & Eshet, 2000).

Enhancing How Children Learn

A major scientific accomplishment of the twentieth century has been the great advancements in understanding cognition that is, the mental processes of thinking, perceiving, and remembering (Bransford, Brown, & Cocking, 1999). For example, cognitive research has shown that learning is most effective when four fundamental characteristics are pre- sent: (1) active engagement, (2) participation in groups, (3) frequent interaction and feedback, and (4) connections to real- world contexts (Roschelle et al., 2000).

As scientists have understood more about the fundamental characteristics of learning, they have realized that the structure and resources of traditional classrooms often provide quite poor support for learning, whereas technology, when used effectively, can enable ways of teaching that are much better matched to how children learn (Roschelle et al., 2000).

Actively Engaging Children Learning

Learning research has shown that students learn best by actively "constructing" knowledge from a combination of experience, interpretation, and structured interactions with peers and teachers (Bransford, Brown, and Cocking, 1999). When students are placed in the relatively passive role of receiving information from lectures and texts (the "transmission" model of learning), they often fail to develop sufficient understanding to apply what they have learned to situations outside their texts and classrooms (Bransford &Schwartz, 1999). In addition, children have different learning styles. The use of methods beyond lectures and books can help reach children who learn best from a combination of teaching approaches (Tyack & Cuban, 1986). Today's theories of learning differ in some details according to White House Publication Services, (2000) but educational reformers appear to agree with the theoreticians and experts that to enhance learning, more attention should be given to actively engaging children in the learning process. Curricular frameworks now expect students to take active roles in solving problems, communicating effectively, analyzing information, and designing solutions--skills that go far beyond the mere recitation of correct responses (Bruer, 1993).

Computer Based Technologies in Laboratories

A present day methodology of investigative activities for student acquisition in science is the incorporation of traditional (hands-on) and virtual (computerized) in the laboratory setting. These inquiry-based scientific practices should take place in the laboratory, the classroom, or the field where students are given opportunities to interact directly with naturally occurring phenomena or with data originating from such phenomena (Pyatt & Sims, 2012).

Research has shown that students could be provided effective learning experience of science through the use of actual inquiry-based experimentation (Hofstein & Lunetta, 2004) and through the use of virtual laboratory environments that support experimentation (Zacharia & Anderson, 2003). Although active constructive learning can be integrated in classrooms with or without computers, the characteristics of computer-based technologies make them a particularly useful tool for this type of learning (Roschelle et al., 2000). For example,

> Students certainly can actively engage in experiments without computers, yet nearly two decades of research has shown that students can make significant gains when computers are incorporated into labs under a design called the "Microcomputer-Based Laboratory" (MBL). Two sixth-grade science classes grab their palmtop computers with chemical sensors attached, and head out for a field trip to the local creek. For more than five years, teachers at this school have taken their sixth-grade science classes on this field trip. But before the advent of palmtop computers, their students collected water samples and jotted down observations during the field trip, then returned to the classroom to analyze the pH, oxygenation, and other measures of the health of the creek. These tests took days of dripping indicator solutions into test tubes of creek water and laborious charting of the outcomes. Today, with the help of the palmtop computers, students can measure the creek and see the results of their data gathering while still in the

field. The computers store and graph the data immediately, allowing students to see how the graphs unfold in real time, directly related to their observations. The immediacy of the process helps students understand what the graph's time axis means, a challenge for many students who have only recently learned how to plot points. In addition, students are able to develop their critical thinking skills by analyzing their initial results and running follow-up experiments the same day (p. 80).

As illustrated by the description of an MBL, students conducting experiments can use computers to instantaneously graph their data, thus reducing the time between gathering data and beginning to interpret it (Roschelle et al., 2000).

In fairly widely replicated studies, researchers have noted significant improvements in students' graph-interpretation skills, understanding of scientific concepts, and motivation when using the software (Svec, 1994). For example, one study of 125 seventh and eighth graders found that use of MBL software resulted in an 81% gain in the students' ability to interpret and use graphs (Mokros & Tinker, 1987). In another study of 249 eighth graders, experience with MBL was found to produce significant gains in the students' ability to identify some of the reasons why graphs may be inaccurate (Nachmias & Linn, 1987).

Although previous media technologies generally placed children in the role of passive observers, these new technologies make content construction much more accessible to students, and research indicates that such uses of technology can have significant positive effects (Roschelle et al., 2000).

Science: Visualization, Modeling, and Simulation Studies

Computer-based applications using visualization, modeling, and simulation have been proven to be powerful tools for teaching scientific concepts (Roschelle et al., 2000). Technologies using dynamic diagrams-that is, pictures that can move in response to a range of input-can help students visualize and understand the forces underlying various phenomena (Roschelle et al., 2000). One example of this work is ThinkerTools, http://thinkertools.org/Pages/curricula.html, a simulation program that allows "middle school students to visualize the concepts of velocity and acceleration…by [showing] students what they cannot see in the real world" (Roschelle et al., 2000. p.86). Simulated objects on the screen move according to the laws of physics, with or without gravity and friction, depending on the settings (Roschelle et al., 2000). Using the computer, students can add arrows representing, "force, acceleration, and/or velocity, so that for the first time students can actually 'see' the equation F=ma" (Roschelle et al., 2000, p.87). These types of simulations are not intended to replace classroom experience or traditional lab work; rather they provide students with the opportunity for repetition and exposure to multiple representations (Huppert, Lomask, & Lazarowitz, 2002).

In controlled studies, researchers found that middle school students who used ThinkerTools, developed the ability to give correct scientific explanations of Newtonian principles several grade levels before the concept usually is taught (Roschelle et al., 2000). Middle school students who participated in ThinkerTools outperformed high school physics students in their ability to apply the basic principles of Newtonian mechanics to real-world situations: the middle schoolers averaged 68% correct answers on a six-item, multiple-choice compared with 50% for the high school physics students

(White and Fredriksen, 1998). Researchers concluded that the use of the ThinkerTools software appeared to make science interesting and accessible to a wider range of students than was possible with more traditional approaches (Roschelle et al., 2000).

In the study, *Virtual and Physical Experimentation in Inquiry-Based Science Labs: Attitudes, Performance and Access*, Pyatt and Sims (2012), investigated the learning experiences that occur in physical and virtual inquiry-based lab investigations, in first-year secondary chemistry classes. The researchers in this study investigated how physical (also known as traditional) and virtual inquiry-based lab investigations can be effectively used in an inquiry-based science environment to promote conceptual change and access (Pyatt & Sims, 2012).

The lab investigations chosen for this study were recommended laboratory investigations for students in preparation of advanced placement chemistry and were previously adopted and integrated into the existing chemistry curriculum where the study took place (Pyatt & Sims, 2012). These investigations focused on the topic of stoichiometry, which has been shown to be a particularly significant and challenging concept for students and one which hands-on experimentation can facilitate the formation of conceptual understanding (Pyatt & Sims, 2012).

This study utilized an experimental crossover design (Kenward, 2005) which consisted of two separate trials of laboratory investigation: trial 1 Empirical Formula of a Hydrate; trial 2 Stoichiometry by Loss of CO_2.

The crossover design was chosen because it allowed comparisons between control and treatment groups for each trial, while at the same time allowed each

> participant to experience two different independent lab experiences. Each of the two trials used in this study consisted of a treatment (virtual lab experience) and control (physical experience) for a lab investigation involving chemical stoichiometry. The laboratory procedures, background material, and required materials and equipment were identical for the control and experimental group. The only difference was that the control group ran the laboratory investigation using actual equipment and materials, while the experimental group ran the laboratory investigation using only laptop computers. The computers had a simulation of the same lab. (p. 136)

The simulation software selected for this study was from Late Nite Labs (2008). This software has been widely used in college-level and high-school level chemistry courses, and includes a suite of laboratory experiences consistent with those recommend for preparation of advanced placement chemistry (Late Nite Labs, 2008). Student performance (cognitive domain) for each laboratory investigation was measured as were student attitudes (affective domain) towards the virtual and physical laboratory investigations (Pyatt & Sims, 2012).

> This study took place in a public suburban high-school in southwestern USA. The duration of the study was a 2 year period and involved a total of 8 first-year chemistry classes ($N = 184$): 4 classes participated in year one ($N = 96$); and 4 participated in year two ($N = 88$). The same instructor taught all 8 of these classes. Participants were randomly assigned participants to either a control (physical lab investigation) or treatment group (virtual lab investigation) for the trial- 1 laboratory investigation. A total of ($N = 184$) students completed the trial-

1 laboratory experience: Empirical Formula of a Hydrate. Ninety-eight students were assigned to the control group and 86 were assigned to the treatment group. Trial- 1 was then carried out by participants in each class. The class periods were approximately 55 min. (p. 136-137)

Following the trial- 1 lab investigation, participants completed a lab assessment which measured student performance (cognitive domain) (Pyatt & Sims, 2012). It required students to analyze, interpret and formulate hypotheses from data collected throughout their lab experience, virtual or physical (Pyatt & Sims, 2012). The assessment was the same for the control and for the treatment groups (Pyatt & Sims, 2012).

Trial-2 Approximately 1 week later, participants who were assigned to the control group for trial- 1, crossed-over to the treatment group for trial-2. Similarly, trial- 1 participants who were assigned to the treatment group, crossed-over to the control group for trial-2. A total of ($N = 184$) students conducted the laboratory experience: Stoichiometry by Loss of C02. Eighty- six students ($N=86$) were assigned to the control group and ($N = 98$) were assigned to the treatment group. The laboratory investigation was then carried out by students in each of the participating classes. The class periods were 55 min. Following the laboratory investigation, participants completed a lab assessment which measured student performance (cognitive domain) and required students to analyze, interpret and formulate hypotheses from data collected, virtual or physical. Following the completion of the assessment, participants completed a survey which measured student attitudes towards the virtual and physical lab experiences for the laboratory investigation. (p. 138-139)

The mean lab performance score for Trial 1, the control group was ($M = .49$, $SD = .50$) and the mean lab performance score for the treatment group was ($M = .64$, $SD = .48$) (Pyatt & Sims, 2012). A t Test was conducted for this sample to determine whether or not significant differences existed between the mean performance scores for the control and treatment group. Based on the *t* Test, $\check{r}$ (l) = 1.71, ($p < .09$), there was no significant difference between mean assessment scores for the control (physical lab) group and for the treatment (virtual lab) group (Pyatt & Sims, 2012). Students who conducted the trial-1 lab virtual investigation scored the same as students who performed the identical lab using physical equipment and materials (Pyatt & Sims, 2021).

> However, for Trial 2, students who conducted the virtual version of the lab investigation significantly outperformed students who performed the same lab using physical equipment and material. The mean lab performance score for the control group was ($M = .068, SD = .25$) and the mean lab performance score for the treatment group was ($M = 1.2, SD = 1.3$). A *t* Test was conducted for this sample to determine whether or not significant differences existed between the mean performance scores for the control and treatment group. Based on the *t* Test, $t(1) = 6.50$, ($p < .0001$), the mean assessment scores for the control (physical lab) group were significantly lower than the mean assessment scores for the treatment (virtual lab) group. Virtual lab experiences resulted in greater learning gains above and beyond those achieved in comparable physical lab experiences. The findings form this study indicates that, in terms of learning outcomes, virtual lab experiences were equal to or greater than physical lab experiences. (p. 139)

A total of ($N = 173$) students completed the Virtual and Physical Experimentation Questionnaire (VPEQ) which measured learner attitudes (affective domain) towards experimentation in virtual and physical environments (Pyatt & Simms, 2012) in five scales, usefulness of computers, anxiety towards computers, open-endedness, usability of lab equipment, usefulness of lab for physical and virtual environments. The survey data were gathered and analyzed with the statistical analysis package SPSS (Pyatt & Simms, 2012). Pyatt and Simms, (2012) findings revealed that students demonstrated an above average comfort level with computer use in lab settings ($M=3.7, SD=1.1$). Moreover, Pyatt and Simms, (2012) found that students had little or no anxiety towards the use of computers in classroom and laboratory settings **(**$M = 1.8, SD = 1.0$**)** According to Pyatt and Simms, (2012), students found the virtual equipment easier to use than the physical equipment **(**$M_P=2.5, SD_P=1.1; M_V=3.5, SD_V=1.1$**).** Students also found virtual experimentation more open-ended than physical experimentation **(**$M_P=2.3, SD_P=1.2; M_V=3.7, SD_V=1.1$**)** (Pyatt & Simms, 2011). Additionally, Pyatt and Simms', (2012) data established that the usefulness of virtual labs and physical labs to be similar, if not the same for students **(**$M_P=3.2, SD_P=.086; M_V=3.3, SD_V=.085$**)**.

In the paper, *Developing and Implementing a Framework of Participatory Simulation for Mobile Learning Using Scaffolding,* Yin, Song, Tabata, Ogata, & Hwang (2013) discusses how simulation software can be used to enhance learning in Computer Science. The underpinnings of their paper stems from research that hypothesizes that more and more participatory simulations have been developed on mobile devices for educational use (Klopfer, 2008; Klopfer & Squire, 2008; Squire & Jan, 2007) that can provide models of real-world settings for students to construct knowledge through active participation in learning activities (Patten, Arnedillo-Sanchez & Tangney, 2006).

Yin et al., (2013) developed an innovative framework called scaffolding participatory simulation for mobile learning (SPSML), a context-aware participatory simulation for mobile learning using scaffolding and fading approaches whereby students can be scaffolded when needed, and the fading strategies are initiated when the students have achieved what they want to learn.

Yin et al., (2013) uses prior research in describing all aspects of their framework. For example, according to Dey (2001, p.5) a system is considered context-aware "if the system uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task". Klopfer & Squire (2008) states that mobile devices are well suited to context-aware applications due to their sensitivity in gathering and responding to real or simulated data unique to a particular location, environment and time

The authors also delineated past research that support their framework in their article. For example, according to past research by Klopfer & Squire (2008) and Patten et al., (2006), participatory simulations provide models of real-world settings in which students can construct knowledge through active participation in learning activities. Additionally, Naismith, Lonsdale, Vavoula, and Sharples, (2004) concluded in their research that context-aware participatory simulation encourages more active participation and interaction among students because students "do not just watch the simulation, they are the simulation" (p.13). According to Dede (2005), participatory simulations (a) support collaboratively sieving and synthesizing experiences rather than individually locating and retrieving information, (b) enhance active learning based on real and simulated experiences that offer opportunities for reflection, and (c) facilitate the co-design of learning experiences personalized to individual needs and preferences.

Yin et al., (2013) states that these approaches which have been incorporated into the SPSML framework, enables students to become immersed in an augmented learning environment in which they take an active role in their learning process and enhance their understanding of abstract concepts in complex learning situations.

SPSML Design

The pedagogical design of the SPSML is premised on Kolb's experiential learning model, which focuses on experience as the main force driving learning because "learning is the process whereby knowledge is created through the transformation of experience" (Kolb, 1984, p. 38). It happens in a cyclical model (see Figure 7) consisting of four stages: concrete experience, reflective observation, abstract conceptualization, and testing in new situations (de Freitas & Neumann, 2009; Kolb, 1984; Lai, Yang, Chen, Ho, Liang & Wai, 2007).

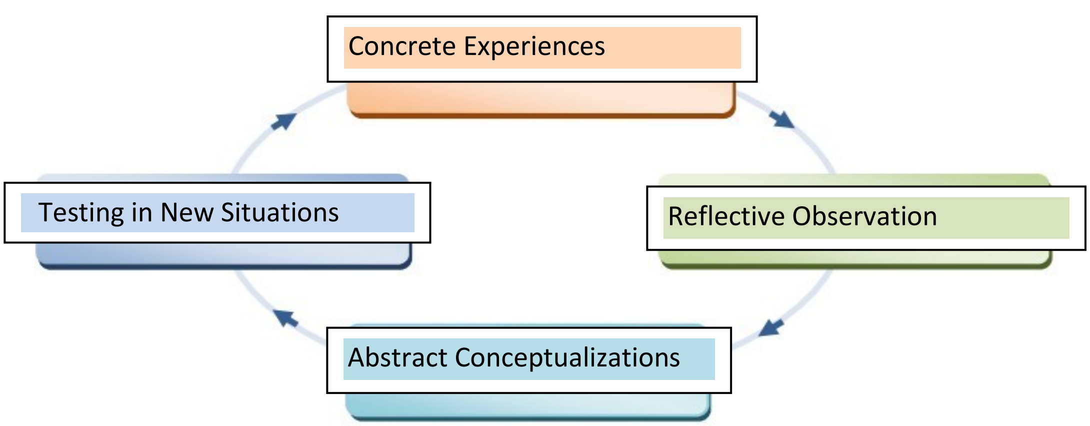


Figure 7: Kolb's Experiential Learning Model

In order to facilitate the pedagogical design predicated on Kolb's (1984) experiential learning model, the SPSML-based system was trialed and evaluated in a computer science application called learning sorting algorithms with mobile devices (LSAMD) (Yin et al, 2013). The LSAMD is designed to help students learn abstract concepts presented in face-to-face classrooms (Yin et al, 2013) with the support of computerized mobile devices such as tablets and PDAs.

The following describes the four stages of the experiential learning model:

1. Concrete experience: Student experiences can fluctuate between the virtual environment and real life by enabling digital simulations in authentic problem-solving situations in which learners play different roles to interact with other entities that have different skills (Dede, 2009).

2. Reflective observation: Reflection may involve revisiting learning activities. Although reflection can occur during any stage of the experiential learning cycle, these explicit virtual tasks ensure that students can engage in reflection (de Freitas & Neumann, 2009).

3. Abstract conceptualization: Students gain new knowledge by integrating previous observations, interactions and reflections into logically sound concepts, which provides contexts in which they can consciously create structured understandings of their experience (Yin et al., 2013). The focus should be on what kinds of abstractions would be most relevant in student learning contexts, using experiential learning models with a view to the particular learning outcomes (Yin et al., 2013).

4. Testing in new situations: In the on-going iterative cycle, students are expected to be able to test and practice these concepts by actively experimenting, for example, in a follow-up practice in new situations (Yin et al., 2013). Thus, as a component of a course curriculum, the participatory simulation provides a virtual space that complements their learning in real life and within which they can engage experientially to construct conceptual knowledge (Yin et al., 2013).

Although comprehensive, the experiential learning model (Kolb, 1984) has its downsides. First, it lacks a mechanism for making students focus on the learning objectives in context (Kolb, 1984). Second, students may lack the skills and pay inadequate attention to abstraction of concepts from experience (Kolb, 1984). In order to overcome for the shortcomings in the learning model, Yin et al (2013) adopted (a) Squire's (2006) and Schank, Fano, Bell, and Jona (1994) goal based approach to participatory simulations (a constructivist view) was built into to SPMSL based system. They also built-in scaffolding and fading strategies which will be discussed later.

According to Yin et al., (2013), the important aspects of the goal-based approach are to focus on the learning goals that should be intrinsically motivating and the role that the learner plays.

The criteria for the goal based design of learning are as follows:

• Thematic coherence. The process of achieving the goal is thematically consistent with the goal itself.

• Realism. The design must be authentic to produce varied opportunities for learning the target skills and knowledge.

• Empowerment. The design puts students in control to increase the sense of agency.

• Responsiveness. Prompt feedback is provided to help students acquire skills and knowledge.

• Pedagogical goal support. The proposed design is compatible with and supports the acquisition of skills and knowledge.

• Pedagogical goal resources. Students are provided with appropriate help. (p.139)

Additionally, the role that the learner plays is important because it necessitates the reinforcement and exploration of difficult concepts that is often times presented in teacher-student classroom situations. The participatory simulations provide students with an opportunity to experience, observe and reflect, form abstract concepts, and test their solutions in new situations (Yin et al., 2013).

Scaffolding and Fading

Scaffolding and fading built into the participatory simulations is another important approach utilized into the SPSML based system (Yin et al., 2013). Scaffolding enables learners to realize their potential by providing assistance when needed, and then fading out this assistance as meaningful learning takes place (Collins, Brown, & Newman, 1989). Fading ensures that the child does not become overly dependent on a particular prompt when learning a new skill (Cooper, Heron, & Heward, 2007).

According to Yin et al., (2013), the notion of scaffolding is associated with the work of Vygotsky (1978) who concludes that a novice learns with a more capable peer, and learning happens within the novice's zone of proximal development (ZPD). With the development of technology, scaffolding tools are specially designed to help students learn in the complex learning environment (Yin et al., 2013). Different learners in the same class may have different ZPDs (Yin et al., 2013).

However, in many cases, support for learning provided by the tools "focuses on providing 'blanket support' (i.e., the amount and type of support is constant for everyone and is not sensitive to the changing level of understanding in learners)" (Puntambekar & Hübscher, 2005, pp. 7–8). To cater to the different needs of students, in designing scaffolding in tools, it is important to consider (a) the multiple ZPDs of students, (b) building fading into the system so that the tools themselves may be removed when students do not need them anymore, and (c) teacher's orchestration and facilitation of the learning process so that students can make good use of the scaffolding tools and resources for learning (Puntambekar & Hübscher, 2005).

Pedagogical design of the SPSML framework

In Yin et al., (2013) study the author's propose a context-aware participatory simulation framework called SPSML for designing learning systems on mobile devices using scaffolding and fading strategies. The SPSML is designed to facilitate students' experiential learning in either complex social contexts or face-to-face classrooms (Yin et al., 2013). The scaffolding and fading instructional strategies are used to help students' experiential learning processes (Yin et al., 2013). It provides opportunities for students to be involved in active participation and interaction and increases motivation (Yin et al., 2013). The SPSML framework consists of five sequential but cyclic steps that use Squire's (2006) goal-based approach and scaffolding and fading strategy.

Step 1. Initial process -Before implementing the SPSML-based system, the teacher will define: (a) the learning objectives of the activity, (b) the simulation tasks, and (c) the rules and participant roles for playing the simulation (Squire, 2006).

> The learning objectives are to help the students to reach their goals, and they need to be identified in order to help the students accomplish the tasks successfully. To begin the activity, the teacher will set up rules and participant roles to configure the system. The teacher will explain to the students the general ideas of concepts to be learned in face-to-face classrooms and provide examples to guide them. The teacher will also explain to the students the learning objectives of the activity and how to use the system on their mobile devices such as personal digital assistants (PDAs). (p. 140-141)

Step2. Concrete experience Concrete experience is composed of scaffolding and fading procedures (Yin et. al., 2013).

Scaffolding

> When students start experiencing and acting during the activity, the teacher will assign different tasks and roles for them to play in the simulation, according to the rules. The system on the mobile device will guide the students in how to do the tasks and play the roles if they need help. This step acts like a bridge used to enable the students to master the conceptual knowledge in face-to-face classrooms. The system assists students by providing information about where the

mistakes are and how to correct them so that they are able to achieve the goals of the task. This system is composed of three stages: point out mistakes, help to correct, and discuss (see Figure 8)**:** (p. 141)

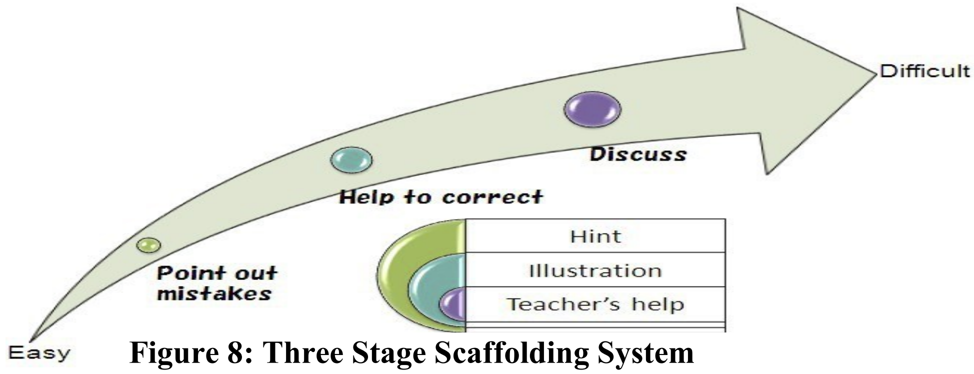


Figure 8: Three Stage Scaffolding System

1. Point out mistakes. The scaffolding system will assist students by providing some instructions about where the mistake is immediately after they make the mistake. It helps the students complete the task effectively.

2. Help to correct. When the students cannot solve the problem themselves, the system will facilitate them in this regard.

There are three kinds of scaffolds at this stage: **hint, illustration and teacher's help**, as shown in Figure 8**.** (p. 141)

• **Hint**. The system will offer a hint about a solution to help the student find out ways to perform the tasks and play the roles based on an ongoing diagnosis of student learning (Yin et. al., 2013).

• **Illustration**. The system will describe the goals of the tasks or provide key information about how to play the role with a simple example (Yin et. al., 2013).

• **Teacher's help**. If the students want to make an inquiry to a teacher, the system allows the teacher to provide facilitation (Yin et. al., 2013). The teacher can observe the status of each student's participation and the roles they are playing on the mobile device in order to respond to the inquiry (Yin et. al., 2013).

3. *Discuss.* The students are allowed to discuss with partners via mobile devices. Discussion is a source of ideas for other students, using evidence in support of claims, getting advice, and providing explanations that others can understand, as well as a vehicle for some of the reflection necessary to turn one's experiences into well-informed and well-indexed cases in one's memory. The students will construct the learning goals collaboratively via discussion. They construct initial understandings of the concepts by participating in the discussion after the concrete experience. (p. 141-142)

Fading

After participatory role play on the mobile device, students will gradually be able to understand the methods and strategies to solve the problems and become more experienced with the conceptual knowledge. At this point, the fading process starts. The students use the fading mode to practice independently. Then, the system reduces the help messages gradually, and more responsibilities are shifted to the students. Finally, they will be able to solve the problems themselves without the scaffolding of the system. In the meantime, the teacher can also help orchestrate the gradual reduction of the system's help function according to the level of understanding of the students**.** (p.142)

Yin et al., (2013) designed the fading mode as three levels depending on the different ZPDs of learners:

• **Level 1.** Point out the mistakes only, but require the students to find out how to correct them. They can discuss with their role-play partners at this level. They can also seek help from the teacher.

• **Level 2**. Do not point out the mistakes, but have the students correct them by themselves. They cannot get help from the teacher, but they can discuss with their partners.

• **Level 3**. Do not provide help and discussion, but have everyone complete the task by him/herself at this level. After all the students pass Level 3, it means that they have mastered the conceptual knowledge. (P.142)

Step 3. Observation and reflection. After completing the concrete experience of participatory roles in the simulations, the students carry out discussions and reflections. They reflect on what they have learned, how well they have understood, and what else they want to learn. If they need more experience in participatory simulations, they can restart the simulation from any step such as from the scaffolding or fading step rather than from the initial step because all their prior experience has been saved in the database.

Step 4. Abstract conceptualization. Because the student experience in the participatory simulation is recorded and stored in the database and these records can be converted to a video, the students can review their learning progress by watching the video or looking at the history record. This step helps the students transform their learning experience and construct conceptual knowledge to achieve their learning goals.

Step 5. Testing in new situations. After conceptualizing what they have learned, the students can try out the concepts in their real-life situations to deepen their understanding of the conceptual knowledge. (p.142)

To find out if the SPSML-based system would be helpful for the learning process, Yin et al., (2013) designed an experiment using an SPSML-based learning system called LSAMD, learning sorting algorithms with mobile devices designed to help students learn abstract concepts presented in face-to-face classrooms in a Computer Science setting.

> The students were given four sorting algorithms in the system: bubble sort, insertion sort, selection sort, and quick sort. Using this system, all the students stand in a line with a PDA, and the teacher assigns an array of numbers to the students and asks them to sort these numbers according to a certain algorithm. The new position of each step is sent to the server. They receive these tasks, collaborate, and exchange physical positions according to the algorithm. (p. 142)

As part of the experiment, Yin et al., (2013) set up a control group and an experiment group to compare the accuracy rate of every sort algorithm (every step was recorded).

Participants A, total of 41 master's students with prior algorithm-sorting experience, participated in the experiment. The students had learned the sorting algorithms about three years earlier, when they were undergraduate students. However, most of them had not used sorting algorithms for a long time so they had forgotten the rules. The average age of the students was 22 years old. Their past examination on sorting algorithms was used as the pretest. They were divided into two groups according to their average achievement: 21 students were assigned to be the experimental group ($M_{achievement} = 72.5$), and 20 students formed the control group ($M_{achievement} = 73$). According to their pretest achievement, it can be inferred that these two groups did not significantly differ prior to the experiment. (p. 144)

The students in the control group learned with a sorting algorithm system, which did not provide them with participatory simulations or scaffolding. When using the system, the students first selected a sorting algorithm, and then the system generated numbers in an array. The students performed the sorting operations by exchanging the position of the numbers in the array. If the sorting was wrong, the system only provided an error message such as "There are some mistakes," but did not point out where the mistakes were. These mistakes were stored in the database. The students could also refer to books before using the system. For the experiment group, the students learned with LSAMD. They stood in a line with a PDA and participated in participatory simulations. They could use the scaffolds "Point out mistakes," "Hint," "Illustration," "Teacher's help," and "Discussion."

> The mistakes they made as well as the types of scaffolds they used to solve the problem were stored in the database. (p. 144)

> The accuracy rates of the two groups of students who sorted the data with different algorithms were compared by an independent t-test. For the quick sort, the average accuracy rate and standard deviation were 81.86 and 10.12 for the experimental group, and 52.30 and 9.29 for the control group. The average accuracy rate of the experiment group is higher than that of the control group, and the difference between the two groups is statistically very significant ($t = 9.73$, $p < 0.01$), indicating that the LSAMD system is helpful to students in enhancing their conceptual understanding of this sorting algorithm. (p. 145)

On the other hand, for the bubble sort, insertion sort, and selection sort, the average accuracy rates of the two groups do not show significant difference (Yin et al., 2013). Because the "quick sort" has been recognized as more complicated than the other sorting algorithms, it could be concluded that the SPSML framework was helpful to the students in improving their learning achievement in terms of complicated conceptual understandings and hence, enhancing their learning (Yin et al., 2013).

In the study, *Are Virtual Labs as Effective as Hands-on Labs for Undergraduate Physics? A Comparative Study at Two Major Universities,* Darrah, Humbert, Finstein, Simon and Hopkins (2014), the researchers investigated how the learning from virtual experiences compares to learning acquired through hands-on experience. Their research sought to prove that virtual physics lab experiences can provide for a more cost and time saving virtual alternative or supplement to traditional hands on physics labs which have become more increasingly expensive to upkeep and staff (Darrah et. al, 2014).

The underpinnings of their research are based on the premise that providing meaningful laboratory experiences in an introductory physics lab course is necessary to introduce, demonstrate, and reinforce physics concepts (Darrah et. al, 2014). Moreover, these meaningful laboratory experiences can be conducted with a well-developed and pedagogically sound virtual laboratory experience that can serve to supplement or even replace existing hands-on lab experiences; thereby reducing the need for equipment and lab space while offering a suitable alternative (Darrah et. al, 2014).

> For example, traditional hands on, physics laboratory courses have been taught in labs equipped with various levels of instrumentation. However as budget cuts become more prevalent, it has become increasingly difficult, especially for small colleges, to afford the expense of upgrading lab equipment [while] maintaining adequate teaching staff. Additionally, in cases where students miss labs for various reasons, professors find it difficult to set up the labs again for makeup purposes. (p. 803-804).

Furthermore, with the increased number of online courses being offered, there also exists a need for the implementation of online or virtual labs as supplements or replacements for the traditional high school and college labs (Bhargava, Antonakakis, Cunningham & Zehnder (2006). Darrah et al.,'s (2014) study revealed that virtual physics lab experiences can provide an alternative or supplement to traditional hands-on labs which have become of major investments of time and money.

The researchers evaluated a comprehensive set of virtual labs for introductory level college physics courses and compared them to a hands-on physics lab experience (Darrah et al., 2014). They conducted their research with 224 students from two large universities and investigated the learning that occurred with students using the virtual labs either in a lab setting or as a supplement to hands-on labs versus a control group of students using the traditional hands-on lab only (Darrah et al., 2014).

The *Virtual Physics Lab* is a next generation computerized resource that seeks to incorporate research-based active-learning characteristics as described in Meltzer and Thornton (2012) and also utilizes the most recent technologies (i.e., videos with real people, 3D interactive game-like simulations) making the experiments more "real world" and engaging for students.

> The labs were developed to provide a variety of problem-solving activities that can be completed during class time. Students can work alone or in small groups to complete the labs and receive rapid feedback from the computer simulation. The simulations require active engagement and provide the material in context. Conceptual thinking is emphasized, and students have the ability to complete the experiments over and over to increase understanding. This study seeks to further illustrate the point that when virtual labs are developed properly to contain all necessary components, they can be just as effective in producing learning as hands on labs. The authors wish to address the need for virtual labs while highlighting the facts that virtual labs are shown to produce positive learning outcomes for many students in this study (p. 805).

Through a Small Business Innovation Research (SBIR) contract funded by the US Department of Education, Polyhedron Learning Media, Inc. created the *Virtual Physics Lab™,* a set of online labs suitable for college level physics (Darrah et al, 2014). This software incorporates the strategies of the "Five E Cycle" of engagement, exploration, explanation, elaboration, and evaluation (Bybee, 2003).

> In this sequence, students are motivated by a question of interest, such as might be presented in a physics laboratory experiment, and then apply process skills to describe findings and apply them in developing deeper understanding. The labs were developed following a planned sequence that focused on content, technology integration, and formative assessment. Throughout the development process, formative assessment for usability, feasibility, and content was completed using a heuristic approach (p. 805)

Each lab included general background information, theory, objectives, pre-lab questions, a list of equipment needed to conduct the experiment hands-on, brief video clips demonstrating an overview of the lab, post-lab questions, and a post-lab quiz (Darrah et. al 2014). The primary components of the labs are the virtual laboratory experiments, featuring interactive, real-time 3D simulations of laboratory equipment along with data collection, analysis, graphing, and reporting tools that will allow users to perform all phases of the experiment online using simulated equipment (Darrah et al., 2014).

The virtual labs were selected to be part of the testing based on the ability of each university to provide a true one-to-one comparison in terms of real lab equipment versus virtual lab equipment (Darrah et al., 2014).

The following labs from Virtual Physics Lab were tested at the two locations:

Auburn University

• Uniformly Accelerated Motion on the Air Table

• Simple Harmonic Motion

• Ideal Gas Law

• Torques and Rotational Equilibrium

And Penn State University

• Uniformly Accelerated Motion on the Air Table

• Newton's Second Law of Motion

• Moment of Inertia and Rotational Motion

• Torques and Rotational Equilibrium of a Rigid Body

• Conservation of Momentum

• Conservation of Energy (p.806-807)

In every case, the analysis portion of the hands-on lab was modified to be identical to the virtual lab analysis (Darrah et al., 2014). All questions, the procedure followed, the data taking process and the data table, calculation, and questions asked were the same for the hands-on and the virtual labs (Darrah et al., 2014). Each lab was accompanied by a video demonstration of how the lab simulation was to be carried out. Additionally, as each lab was completed, a printable lab report was generated, providing students with hard copy of their data and graphs, and instructors with a convenient way to assess student work (Darrah et al., 2014).

> Two different sets of participants were used during the first and second phases of testing. The first set of participants included 68 students from Auburn University. The students were enrolled in different sections of Physics I. One group of these students ($n = 21$) used the labs as a replacement to traditional labs, one group ($n = 18$) used the labs as a supplement to their traditional lab experience, and two groups of students ($n = 17$ *and* $n= 19$) were used as control groups and completed traditional hands-on labs. The groups were assigned at random to one of the two treatments or control. The second set of participants included 156 students from Penn State University enrolled in 16 different sections of Physics I. As in the previous testing at Auburn University, lab sections were randomly assigned to treatments. Students ($n = 60$) completed the hands-on labs and were used as a control group; students ($n = 49$) completed the virtual labs; and students in sections ($n = 47$) used the virtual labs as a supplement to the hands-on lab (p. 808).

For the Auburn University, a t- test was used to compare the Lab Quiz Average (the average of four post-lab quiz grades) of the various sections (Darrah et al., 2014).

> First, lab section 1 (*M = 59.37, SD = 16.97, n = 23*) was compared to section 2 (*M = 58.16, SD = 20.86, n = 26*). Lab section 1 did only the virtual labs, and lab section 2 did the hands-on labs. The t-test shows that there is no evidence to suggest that there is any significant difference between the quiz averages for the two groups (*two tailed p = 0.826*). Lab section 3 (*M = 52.06, SD = 17.18, n = 24*) completing the hands-on labs with the supplement of the virtual labs and lab section 4 (*M = 49.40, SD = 22.46, n = 21*) completing the hands-on labs were compared to each other. The t-test shows that there is no evidence to suggest that there is any significant difference between the Average Lab Quiz Scores for the two groups (*two tailed p = 0.66*). Lab sections 1 and 3 had access to the virtual labs in some way, and lab sections 2 and 4 did only the hands-on labs. The t-test shows that there is no evidence to suggest that there is any significant difference between the Average Lab Quiz Scores for the two groups (p. 811).

A one-way Analysis of Variance was completed for Test Scores with all students completing all three tests (Darrah et. al 2014).

> First, the Hands-on Group was compared to the Virtual Group. There was no significant difference found between the groups. Second, the Hands-on Group, the Virtual Group, and the Supplemental Group Test Scores were all compared using a one-way Analysis of Variance. There was no significant difference found among the three groups. A one-way Analysis of Covariance revealed that the

> difference between Virtual (*M = 42.68, SD = 15.30, n = 28*) and Hands-on (*M = 43.91, SD = 16.58, n = 23*) Groups' Test Scores was not statistically significant, *F = 0.43, p = 0.51*. A one-way Analysis of Covariance revealed that the difference among Virtual (*M = 42.68, SD = 15.30, n = 28*), Hands-on (*M = 43.91, SD = 16.58, n = 23*), and Supplemental (*M = 47.92, SD = 15.94, n = 24*) groups' Test Scores was not statistically significant, *F = 0.43, p — 0.65*. (p. 811).

The analyses of the data at both universities show no evidence that one of the treatments (virtual or hands-on) was more effective than the other in conveying the concepts of the labs to the students and that there was no significant difference noted in any of the tests, except to say there were significant learning gains for all groups from the Pre-FCME (Force-Motion Conceptual Evaluation) to the Post-FMCE tests (Darrah et al., 2014).

> Sixty-seven students completed both the FMCE—a widely used and accepted multiple-choice test to evaluate physics instruction (Sokoloff, Laws & Thornton, 2007). This test was given at the beginning of the semester and also at the end at the beginning of the semester and at the end of the semester. A paired t- test run for each individual group (Virtual, Hands-on, and Supplemental) showed that all groups had significant learning gains from the Pre-FMCE to the Post FMCE. From this, the researchers concluded that the Virtual Physics Lab software used in these two introductory physics courses produced similar learning out comes as the traditional hands-on traditional lab experience (p. 812).

Other studies in Darrah et al., (2014) focused on additional benefits of virtual labs. Bhargava et al., (2006) tested the effectiveness of web based labs and noted that virtual labs reduced equipment needs, were available at any time from any place, offered more information to students, and offered students the opportunity to work at their own pace while exploring difficult or interesting sections. Pyatt and Sims (2007) found evidence to suggest that the hands-on lab has lost instructional value, while emerging technologies such as simulations can be used as viable replacements. Wieman and Perkins (2005) pointed out that the use of a real-life demonstration or lab often includes an enormous amount of peripheral information, which can be avoided in a carefully designed computer simulation.

It is evident from past and current research that simulated labs had many benefits over the hands-on equivalents in that they (1) were perceived to be more open-ended, (2) easier to use, (3) easier to generate usable data , (4) took less time than hands-on labs, (5) greatly reduce the cognitive load for the students trying to determine what is important in the experiment , (6) were readily available to students who were unable to physically attend class, (7) produce positive learning outcomes for many students (Darrah et al., 2014).

CHAPTER 3

Methodology

The Virtual Lab used in this study is called Explorer Learning Gizmos. Explorer Learning Gizmo is an online computerized lab program that students utilize to conduct virtual laboratory experiments. There are over 400 Gizmos aligned to the math and science curriculum in grades 3-12. Teachers and/or students can search Gizmos according to academic state standards (NY Standards Grade 4-see Appendix A), grade/topic and/or textbook publisher.

For this study five Explorer Learning Labs were chosen based on their similarity to traditional hands-on labs and the science objectives utilized by the classroom teacher (see Table 2).

Table 2: Traditional (Comparison) Vs. Virtual Group (Treatment Group)

Lab Number	**New York State Core Curriculum Standards**	**Major Understandings/ Objectives**	**Traditional**	**Virtual**
1	*4.P3: Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.* *4.P3.1a: Matter takes up space and has mass.*	Students will observe, describe, and explore the physical properties of water: Changes in the amount of space occupied (compare using containers of different shapes and sizes),	***Unit –Volume/ Capacity***	***Measuring Volume***

	Two objects cannot occupy the same place at the same time. *4.P3.1c:Objects have properties that can be observed, described, and/ or measured: length, width, volume, size, shape, mass or weight, temperature, texture, flexibility, reflectiveness of light.*	Volume, mass (weight)		
2	*4.P3.1e: The material(s) an object is made up of determine some specific properties of the object (sink/ float, conductivity, magnetism). Properties can be observed or measured with tools such as hand lenses, metric rulers, thermometers, balances, magnets, circuit testers, and graduated cylinders.*	Students will observe, describe, and investigate the evidence of energy transfer in electrical circuits: Simple circuits Open and closed circuits Switches	***Completing the Circuit***	***Circuit Builder***
3	*4.P3.1e: The material(s) an object is made up of determine some*	Students will observe, describe, and explore the	**Measuring Lengths**	**Measuring**

	specific properties of the object (sink/ float, conductivity, magnetism). Properties can be observed or measured with tools such as hand lenses, metric rulers, thermometers, balances, magnets, circuit testers, and graduated cylinders.	physical properties of solids: Measuring length, height, diameter, circumference		**Trees**
4	*4.P3.1e: The material(s) an object is made up of determine some specific properties of the object (sink/ float, conductivity, magnetism). Properties can be observed or measured with tools such as hand lenses, metric rulers, thermometers, balances, magnets, circuit testers, and graduated cylinders.*	Students will compare the electrical and magnetic properties of different materials.	**Amazing Magnets**	**Magnetism**
5	*4.P3: Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.*	Students will observe, describe, and explore the physical properties of matter by differentiating between weight and mass.	**Measurement : Weight and Mass**	**Weight and Mass**

4.P3.1a: Matter takes up space and has mass. Two objects cannot occupy the same place at the same time.

4.P3.1c: Objects have properties that can be observed, described, and/ or measured: length, width, volume, size, shape, mass or weight, temperature, texture, flexibility, reflectiveness of light.

Before students began the lab experiment, they were given a class User ID and Password to log on to the Explorer Learning website. After the students logged in to the website, they searched for the virtual laboratory experiment required for the lesson. Students were given a lab worksheet with one to three prior knowledge questions. For example, in the Weight and Mass lab experiment students may be asked to describe what happens to an object when it sinks or floats. These questions were to be answered by the students themselves, with a partner or as a class before they utilize the computerized lab program.

After they read and answered the prior knowledge questions, students were directed by their teacher to read and carry out the virtual tasks of the lab experiment using their tablets. As the students conducted the virtual lab experiment they answered questions and wrote down their results. For the remainder of the lab students worked with a partner.

Different Explorer Learning virtual lab activities were given to the ten students in the Treatment group each week. Students completed each of the virtual lab experiments and the accompanying worksheets. The labs allowed students to conduct various experiments. Students were able to solve problems and make connections to prior learning. Students worked by themselves or in pairs while carrying out the lab activities. The virtual lab simulations kept the students engaged and expanded on their conceptual knowledge. Critical thinking was emphasized, and students learning was assessed, reinforced and enriched during the lab by the various virtual activities. A Pre-test and Post-test Terra Nova 3 Survey Assessment in Science grade 4 were given before the students began the study and after the study, respectively.

The Virtual labs tasks were similar to the Traditional hands on labs. For example if the Treatment group was conducting an experiment with measuring using virtual rulers. The comparison group was conducting an experiment with measuring using actual rulers. The teacher distributed the lab sheets which had instructions to carry out various tasks, a data table to record data and follow-up questions to answers to the comparison group. Students performed the lab tasks listed on the lab sheets. Each week the students in the comparison group conducted a different experiment at the same time as their classmates in the Treatment group. The traditional group was also given a Pre-test and Post-test Terra Nova 3 Survey Assessment in Science grade 4 before they began the study and after the study, respectively.

The teacher provided the ten different students-comparison group (*n=10*) students with lab equipment in the classroom for each lab tasks. She demonstrated how the lab was to be done using the lab equipment for each lab, answered questions that students had and posed questions about the lab to assess the students understanding, in the beginning, middle and end of the lab. The teacher provided positive or negative feedback about the students' participation in the lab.

This study sought to illustrate that virtual labs are more effective in producing science learning then traditional hands on labs. The research questions that guided the study are listed below.

Research Questions

Research Question 1: Will students who conduct science investigations with computerized virtual science laboratory experiments (treatment group) get significantly higher scores on Standardized science achievement tests such as the Terra Nova 3 Survey Assessment in Science grade 4 than students who conduct science investigations utilizing traditional hands-on science laboratory experiments (comparison group)?

Hypothesis 1: Students who conduct science investigations with computerized virtual science laboratory experiments (treatment group) will get significantly higher scores on Standardized science achievement tests such as the Terra Nova Science Survey for grade 4 than students who conduct science investigations utilizing traditional hands-on science laboratory experiments (comparison group).

Research Question 2: Will students in the treatment group score significantly higher on the ILSAT than students in the comparison group?

Hypothesis 2: Students in the treatment group will get significantly higher scores on the ILSAT than students in the comparison group?

Research Question 3: Will students in the treatment group score significantly higher on their attitudes to science learning and self-efficacy than students in the comparison group?

Hypothesis 3: Students in the treatment group will score significantly higher on their attitudes to science learning and self-efficacy than students in the comparison group.

Sample and Population

All of the participating students received all of their content instruction in a general education classroom. There were a total of 20 fourth grade students, ten in the science treatment group and ten in the comparison group. Their age range was from nine to ten. There were 12 male students and eight female students. All of the participating students in the study were African American. 100% of them are eligible for free or reduced lunch. All students used English as their primary language. One female teacher taught both treatment and comparison groups. The teacher who participated in the study had a mean 10 years of teaching experience. The teacher is considered "highly effective," with state's licensure to teach students in elementary/middle school science.

The study was conducted in a small urban school in the northeastern United States. The intervention was conducted in a 4th grade general education by a general education teacher in a general education fourth grade classroom where the students regularly received 4th grade instruction. Participants (see Table 3) were selected to participate in the Treatment group and Comparison group randomly with a coin toss. The teacher asked the 20 students to choose heads or tails before the coin toss. Those who chose heads used the computerized virtual laboratory experiments and those students who chose tails before the coin toss used traditional methods to perform hands on laboratory experiments.

Both classes were scheduled to receive 50 minutes of computerized virtual laboratory experiments or traditional hands on experiment once a week for 8 weeks. Students in the treatment and comparison group were given the Terra Nova Science Survey for grade 4 before and after the intervention. The STMSL questionnaire was administered pre and post as well. Additionally, both groups continued to receive regular science instruction for the remainder of the week. The Intermediate Level Science Assessment Test was administered to each group in May for the Lab Performance Test and in June for Written Test. Scores from both sections (tests) was added together for a final score.

Table 3: Description of Participants

	Group	Number	%
Group	Treatment	10	50%
	Comparison	10	50%
Gender	Male	13	60%
	Female	7	40%
Primary Language	English	20	100%
Ethnicity	African American	20	100%

Research Design and Data Analysis

Treatment/Intervention Virtual Computerized Science Experience

Explore Learning Gizmos is the world's largest library of interactive online simulations for math and science education in grades 3-12. Gizmos Virtual Labs help students develop a deep understanding of challenging concepts through inquiry and exploration, ideal for small group work, individual exploration, and whole class instruction using an LCD projector or interactive whiteboard, designed to supplement the existing curriculum that are correlated to New York State curriculum standards.

This software incorporates the strategies of the "Five E Cycle" of engagement, exploration, explanation, elaboration, and evaluation (Bybee 2003). In this sequence, students are motivated by a question of interest, such as might be presented in a laboratory experiment, and then apply process skills to describe findings and apply them in developing deeper understanding (Darrah et. al 2014). The labs focused on content, technology integration, and formative assessment (Darrah et. al 2014).

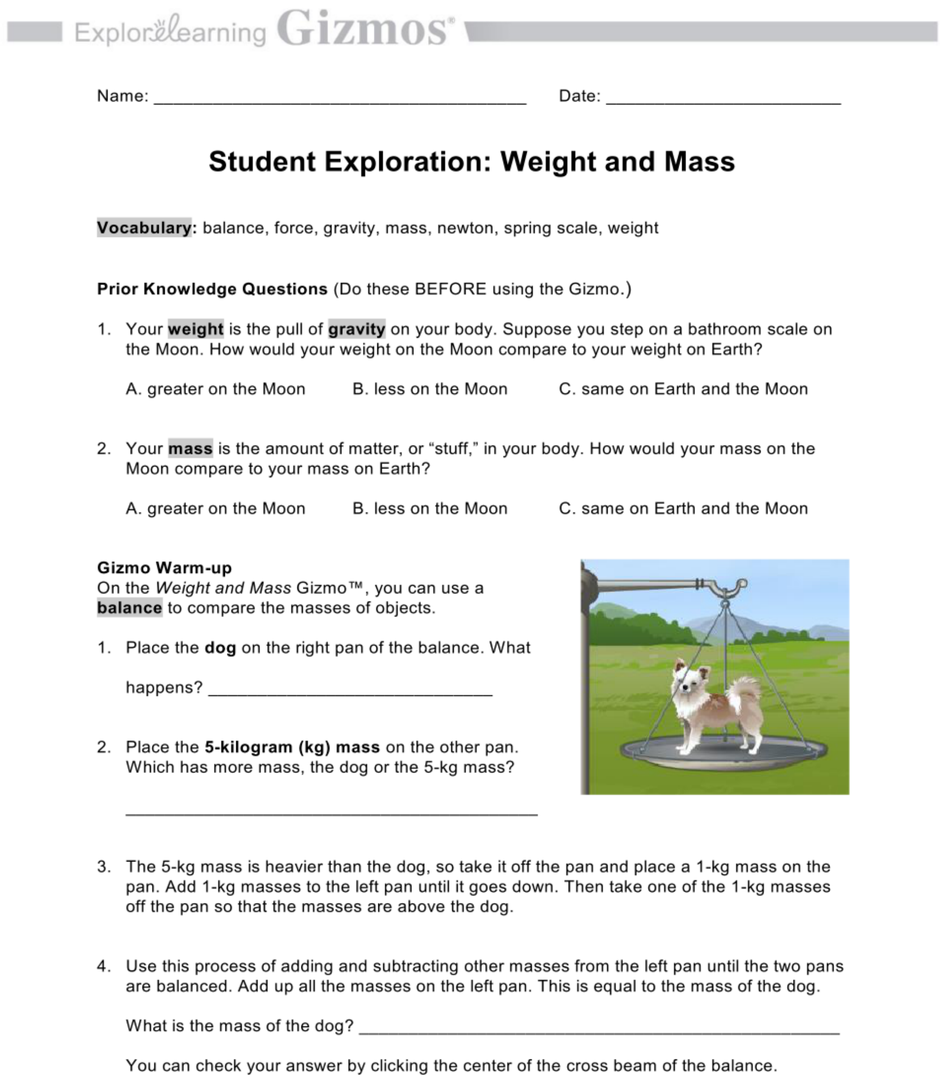
Each lab includes a teacher's guide, student lab sheet, and a vocabulary list. The teacher's guide are comprised of learning objectives, vocabulary list, lesson overview, pre activity suggestions, step by step instructions on how to prepare students to use online virtual labs and student lab sheet, discussion questions, follow up activities, background information about the topic, technology connection and web resources. The student lab sheet contains the title of the lab, vocabulary list with definitions, prior knowledge questions, directions for utilization of the virtual lab and short response questions about the virtual lab. The primary features of the virtual laboratory experiments provided students with an interactive, simulation of laboratory investigations involving data collection, analyses, graphing, and journaling that allowed students to utilize virtual equipment to perform online labs that go beyond the scope of the traditional elementary classroom. Screen captures below illustrate one specific lab within the Virtual Lab.

The screen shot in Figure 9 shows how the lab—Weight and Mass simulated a puppy being weighed on a balance beam. On this screen a large balance scale is in the middle of a grassy area. Below the balance scale are weights of various measures, i.e. 5kg, 1kg, 500g, 100g 50g and 10g and five different objects i.e., a flower, watermelon, pumpkin and baseball. Above the balance scale is a drop down menu with different locations i.e. Earth, Mars, Jupiter. Next to the change location drop down menu is a button to clear scales and another separate scale that is measured in the units Newton. The student lab sheet has the procedures for the lab and instructions for doing the experiment using the simulation.

In this lab students were able to compare the weights of various objects using a virtual balance. Students placed the object they wanted to find on one side of the scale and then used the weights on the bottom to balance out the object. The amount of weights used to balance the object determined the weight/mass of the object. Students were able to virtually change the location from Earth to other plants i.e. Jupiter etc., to observe how the weight of the object changed as the location changed. Students were also able to find the weight of objects using the units Newton by placing the object on a virtual scale measured in Newton.

Figure 9: Screenshot of Weight & Mass Simulation

Figure 10 illustrates a sample of the student lab sheet. The student lab sheet directs the students to carry out specific virtual activities as part of the lab experiment. This section (Gizmo-Warm Up) helped students to become familiar with using the virtual tools to conduct various lab tasks.



ExploreLearning Gizmos

Name: ______________________________ Date: ____________________

Student Exploration: Weight and Mass

Vocabulary: balance, force, gravity, mass, newton, spring scale, weight

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)

1. Your **weight** is the pull of **gravity** on your body. Suppose you step on a bathroom scale on the Moon. How would your weight on the Moon compare to your weight on Earth?

   A. greater on the Moon B. less on the Moon C. same on Earth and the Moon

2. Your **mass** is the amount of matter, or "stuff," in your body. How would your mass on the Moon compare to your mass on Earth?

   A. greater on the Moon B. less on the Moon C. same on Earth and the Moon

Gizmo Warm-up
On the *Weight and Mass* Gizmo™, you can use a **balance** to compare the masses of objects.

1. Place the **dog** on the right pan of the balance. What happens? ________________________

2. Place the **5-kilogram (kg) mass** on the other pan. Which has more mass, the dog or the 5-kg mass?

   ____

3. The 5-kg mass is heavier than the dog, so take it off the pan and place a 1-kg mass on the pan. Add 1-kg masses to the left pan until it goes down. Then take one of the 1-kg masses off the pan so that the masses are above the dog.

4. Use this process of adding and subtracting other masses from the left pan until the two pans are balanced. Add up all the masses on the left pan. This is equal to the mass of the dog.

   What is the mass of the dog? ________________________________

   You can check your answer by clicking the center of the cross beam of the balance.

Figure 10: Sample of Student Exploration Lab Sheet Intro

Figure 11 shows a screen from the Weight and Mass that shows a sample of student data collection as it pertains to the virtual lab. In the Activity A box students are given specific instructions on how to prepare the virtual tools for the next task i.e. finding the weight of objects on different planets. These directives accompany each of the labs.

Activity A: **Weight on different planets**	Get the Gizmo ready: • Click **Clear scales** to remove all objects from the spring scale and the balance. • Click the center of the cross beam of the balance to turn off the mass display.	

Introduction: A **spring scale** is used to measure **force**. Since weight is a type of force, a spring scale can measure weight. The metric unit of force is the **newton** (N).

Question: Will an object's weight change on different planets?

1. Measure: Place the **pumpkin** on the spring scale. Click the red line on the scale to see the weight measured to the nearest newton.

   What is the weight of the pumpkin? _______________________________________

2. Predict: If you take an object to a different planet, do you think its weight will stay the same or be different? (Circle your answer.)

   Same　　　　　Different

3. Collect data: Measure the weights of the following objects on Earth, the Moon, Mars, and Jupiter. Record your measurements in the data table below.

	Pumpkin	Dog	Watermelon
Weight on Earth			
Weight on Moon			
Weight on Mars			
Weight on Jupiter			

4. Analyze: Does the weight of an object change when it is moved to a different planet?

   ____

5. Extend your thinking: Which celestial body had the strongest gravity, Earth, the Moon, Mars, or Jupiter? Explain how you know. ______________________________________

   ____

   ____

   ____

Figure 11: Sample of Student Exploration Lab Sheet Activity A

As each lab is completed, the students return the student lab sheet to their teacher. The hard copies of student lab sheets provide instructors with a convenient way to assess student work. The following labs from Virtual Lab were tested: • Measuring Volume • Circuit Builder • Measuring Trees • Magnetism • Weight and Mass. A great deal of effort was put into making the hands-on labs and the virtual labs as similar as possible. The virtual labs listed above were selected to be part of the testing based on the ability of the teacher to provide a true one-to-one comparison in terms of real lab equipment versus virtual lab equipment.

In every case, the hands-on lab objectives were identical to the virtual lab objectives. All questions, the procedure followed, the data taking process and the data table, calculation, and questions asked were similar for the hands-on and the virtual labs.

The virtual labs focused on content area, use of technology (simulations), and assessments. The main components of the virtual labs were the simulated interactive science investigations that used virtual laboratory equipment along with data collection, analysis, graphing, and reporting tools allowing users to perform all phases of the experiment online. Each lab includes general background information, theory, objectives, prelab questions, a list of equipment needed to conduct the experiment, postlab questions, and a postlab quiz. Screen captures below illustrated one specific lab within the Virtual Lab.

The screen shot as shown in Figure 12 shows the virtual lab equipment i.e. faucet, beaker, graduated cylinders, droppers, rulers, magnifying glass etc., used in Lab 1—

Student Exploration: Measuring Volume to simulate measuring volume of different amounts of water with various measuring tools.

Figure 12: Screenshot of Lab 1 Student Exploration Measuring Volume Simulation

The simulation screen, as shown in figure 12, shows various measuring tools that can be dragged from a lab cabinet or lab bench to measure volume.

As shown in Figure 13, the simulation illustrated a graduated cylinder that was dragged underneath a faucet and filled with virtual water.

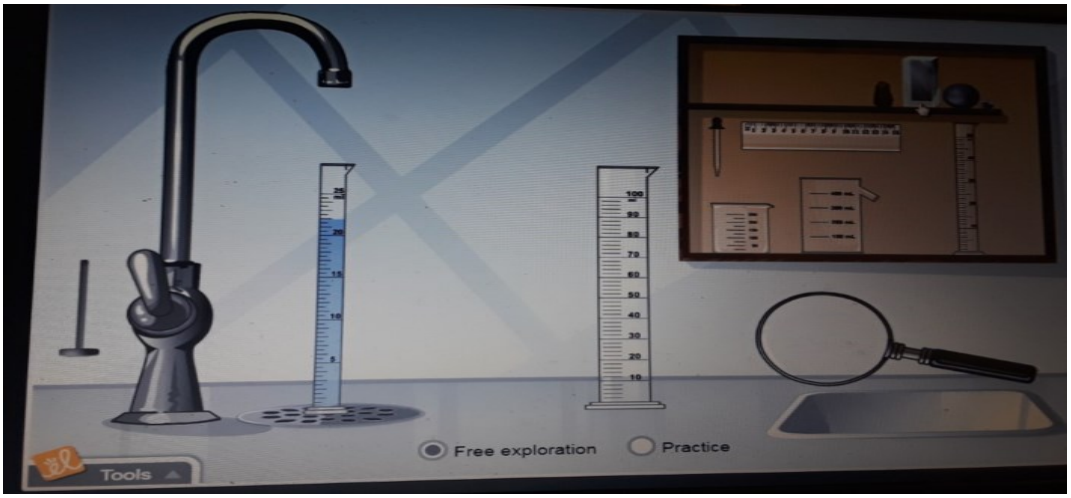


Figure 13: Screenshot of Lab 1 Student Exploration Measuring Volume Simulation of a graduated cylinder underneath a faucet filled with water

As shown in Figure 14, the magnifying glass was dragged from the lab bench and positioned in front of the 25 mL graduated cylinder in order to get an enlarged view of the measurements on the graduated cylinder. The close up view of the graduations on the cylinder provided by the magnifying glass, allowed for a more accurate measurement of the volume of water, 7.8 mL.

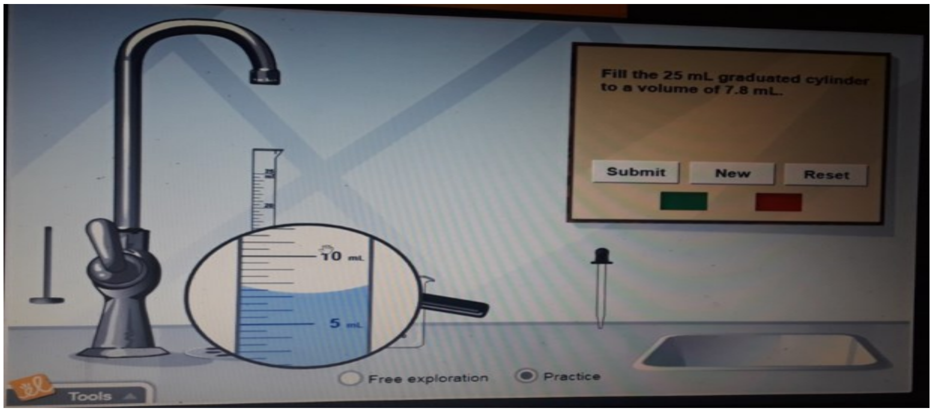


Figure 14: Screenshot of Lab 1 Student Exploration Measuring Volume Simulation Enlargement of Graduations

During each lab students complete statements, questions, data tables, graphs, drawings and/or diagrams related to the virtual experiment. The student exploration sheet allowed the student (Figure 10-11), easy to follow instructions to seamlessly carry out the simulated lab investigations. A great deal of effort was put into making the traditional hands-on labs and the virtual labs the similar. In every case, the data collection and analysis section of the traditional hands-on lab was revised to resemble those on the virtual lab. Additionally, the problem, hypotheses, experiment, and conclusion questions were similar for both traditional hands-on and the virtual lab.

Instrument(s)

The instrument for the Pre Test/Post Test will be the Terra Nova 3 Survey Assessment in Science grade 4. Students will also be given the New York State ILSAT – Performance Based for grade 4 in May and the New York State ILSAT –Written Examination for grade 4 in June. Both tests were combined for one score. A questionnaire used for Pretest and Posttest was the SMTSL- which measures Students'

Motivation Toward Science Learning in the categories for Self-Efficacy and Science Learning Value. Table 4 lists the validity for each instrument.

Table 4: Instrument Validity

SMTSL	The Cronbach alpha for the entire questionnaire was 0.89; for each scale, alpha ranged from 0.70 to 0.89 (Tuan , Chin, & Shieh, 2005).
Terra Nova	As reported in the Terra Nova 3 Technical Report (2009), the reliability coefficients are typically at the high 0.80s for the Survey tests and around the 0.90s for the Complete Battery and Multiple Assessments.
ILSAT	The alphas for overall student responses ranged from 0.83 to 0.88 for science indicating that the tests are highly reliable.

Procedures

Students were told the purpose of the study being conducted and were asked to fill out a consent form and return it to their teacher. The students' parents, teacher and principal were also given consent forms to be completed and returned to the researcher. For this study, all students and their parents agreed to participate in the study.

Students performed the lab activities in their regular science classes. The Terra Nova 3 Survey Assessment in Science grade 4 was used to assess the students' knowledge of the grade 4 science content related to before the study as a pretest and after the study as a posttest. The same assessment was used with all students. The scores for the ILSAT were collected for each student from the school.

The SMTSL Questionnaire was administered to measure students' motivation toward science learning (SMTSL) before the study and after the study. Out of the SMTSL questionnaire, two scales were used to measure: self-efficacy and science learning value (Tuan et al., 2005). For this study only results from self-efficacy and student learning value were utilized.

Data Collection and Statistical Analysis

The following data were collected to be used for quantitative analysis:

- Intermediate Level Science Assessment Test (ILSAT) grade 4—A standardized written and performance level test given to all fourth grade students in New York once a year in May and June respectively. The ILSAT written examination was composed of scientific questions for students to respond to and the performance level test contained laboratory investigations data collections.
- The Terra Nova 3 Survey Assessment in Science Grade 4—The students' Terra Nova Survey in Science grade 4 was given before the study began and after the study ended. This Standardized Norm-Referenced Achievement Test (2011 Norms) provides a general measure of science achievement with a minimum amount of required testing time.
- SMTSL—a 35 question questionnaire that measures students' motivation toward science learning (Tuan et. al, 2005). The items were constituted using five-point Likert-type scales. Items on the scales are anchored at 1 =

strongly disagree, 2 = disagree, 3 = no opinion, 4 = agree and 5 = strongly agree. This test was given at the beginning of the study and also at the end.

Students' self-efficacy, science learning value (or task values), students' learning strategies, the individual's learning goal, and the learning environment are important motivational factors that constitute students' science learning motivation (Tuan et. al, 2005). Thus, the six categories on the SMTSL were self-efficacy, active learning strategies, science learning value, performance goal, achievement goal, and learning environment stimulation (Tuan et. al, 2005). Research on motivational theories and studies of students' learning (Brophy, 1998, Pintrich and Schunk, 1996) revealed that self-efficacy; the individual's goals toward tasks, task value and the learning environment dominate students' learning motivation (Tuan et. al, 2005). In this study, two of the four dominant motivational factors investigated were self-efficacy and science learning value (or task values).

> Self-efficacy assesses students' belief in their own ability to perform well in science learning task. Science learning value assesses the value of science learning which lets students acquire problem-solving competency, experience the inquiry activity, stimulate their own thinking, and find the relevance of science with daily life. If they can perceive these important values, they will be motivated to learn science. (p.643)

Fidelity of program implementation was monitored. For each of the labs used in the classroom i.e. Virtual and Traditional, a non-participatory observation was conducted for the duration of each lesson by the researcher to assure fidelity of program implementation and to determine that the students and teacher were participating in the correct manner. Both Treatment and Comparison groups were taught by the same teacher.

A Non parametric independent sample Mann-Whitney U Test was performed to analyze the significance of the difference in the gain scores of Terra Nova 3 Survey Assessment in Science grade 4 and its sub categories i.e. Terra Nova Science Inquiry (TN_{SciInq}), Terra Nova Physical Science ($TN_{PhysSci}$), Terra Nova Life Science ($TN_{LifeSci}$) and Terra Nova Earth Science ($TN_{EarthSci}$) between treatment and the comparison groups. A Non parametric independent sample Mann-Whitney U Test was performed to analyze the significance of the difference in the gain scores of SMTSL questionnaire, sub-categories self-efficacy and science learning value. The dependent variables were gain scores from pretests to posttests for the treatment group and the comparison group. A Mann-Whitney U test was performed on the ILSAT to analyze the gains between treatment and the comparison group. A Mann-Whitney U test was also performed to examine the intervention effectiveness mediated by Gender.

CHAPTER 4

Results

Research Question 1: Will students in the treatment group get significantly higher gain scores on the Terra Nova 3 Survey Assessment in Science grade 4 than students in the comparison group?

Hypothesis 1:

A Non Parametric independent sample Mann Whitney U test was conducted to evaluate the first null hypothesis that students in the treatment group will demonstrate significantly more gains in their Terra Nova 3 Survey Assessment in Science grade 4 test scores when compared with students in the comparison group (N=20).

A Mann-Whitney U test was run for the total gains and gains in each sub category of the Terra Nova Science 3 Survey Assessment in Science grade 4 test scores. The test revealed that the differences in the learning gains between two groups (treatment, comparison) were not significant in any Terra Nova 3 Survey Assessment in Science grade 4 (See Table 5, Table 6, Table 7, Table 8, Table 9, and Table 10).

An independent Mann Whitney U test for Terra Nova 3 Survey Assessment in Science grade 4 Pre-Test Science Score between the treatment and comparison groups shows that there was no significant difference between the groups before the program started (*U=79.00, p=.029*). Therefore, the significant difference between the treatment and comparison groups in ILSAT might be very meaningful.

Table 5: Descriptive Statistics for Terra Nova Pre and Post Survey Tests and Mann-Whitney U Test on the Difference in the Gains between Comparison and Treatment Groups.

Group	N	Pre-test M (SD)	Post-test M (SD)	Gain M (SD)	U	p
Comparison	10	610.70(21.62)	628.30(23.14)	17.60(24.13)	68.00	.19
Treatment	10	642.70 (33.00)	673.80 (46.23)	31.10(23.20)		
Total	20	626.70 (31.73)	651.05(42.56)	24.35(24.06)		

Table 6: Descriptive Statistics for Terra Nova Science Inquiry Pre and Post Survey Tests and Mann-Whitney U Test on the Difference in the Gains between Comparison and Treatment Groups.

Group	N	Pre-test M (SD)	Post-test M (SD)	Gain M (SD)	U	P
Comparison	10	52.70 (18.86)	69.80(18.86)	17.10(19.84)	40.00	.481
Treatment	10	76.20 (21.99)	84.10(19.64)	7.90(9.67)		
Total	20	64.45 (23.30)	76.95(20.13)	12.50(15.91)		

Table 7: Descriptive Statistics for Terra Nova Physical Science Inquiry Pre and Post Survey Tests and Mann-Whitney U Test on the Difference in the Gains between Comparison and Treatment Groups.

Group	N	Pre-test M (SD)	Post-test M (SD)	Gain M (SD)	U	p
Comparison	10	59.80(6.54)	64.50(6.81)	4.70(6.80)	31.00	.165
Treatment	10	70.40(13.29)	79.60(15.51)	9.20(7.94)		
Total	20	65.10(11.54)	72.05(13.95)	6.95(7.56)		

Table 8: Descriptive Statistics for Terra Nova Life Science Inquiry Pre and Post Survey Tests and Mann-Whitney U Test on the Difference in the Gains between Comparison and Treatment Groups.

Group	N	Pre-test M (SD)	Post-test M (SD)	Gain M (SD)	U	p
Comparison	10	79.40(8.69)	86.20(8.00)	6.50(8.98)	46.00	.796
Treatment	10	87.30(10.38)	91.80(8.01)	4.50(6.02)		
Total	20	5.50(7.51)	89.00(8.30)	5.50(7.51)		

Table 9: Descriptive Statistics for Terra Nova Earth Science Inquiry Pre and Post Survey Tests and Mann-Whitney U Test on the Difference in the Gains between Comparison and Treatment Groups.

Group	N	Pre-test M (SD)	Post-test M (SD)	Gain M (SD)	U	p
Comparison	10	29.20(5.37)	33.90(7.25)	4.70(7.69)	31.50	.165
Treatment	10	45.20(18.86)	61.80(27.39)	16.60(16.47)		
Total	20	37.20(15.80)	47.85(24.19)	10.65(13.92)		

Research Question 2: Will students in the treatment group score significantly higher on the New York State Intermediate Level Science Assessment Test than students in the comparison group?

Hypothesis 2: A Non Parametric Mann Whitney U test was conducted to evaluate the null hypothesis that students in the treatment group will get significantly higher scores on the ILSAT than students in the Comparison group. This test revealed that the difference between $\text{Comparison}_{\text{ILSAT}}$ ($M = 73.10, SD=11.08, n = 10$) and $\text{Treatment}_{\text{ILSAT}}$ ($M = 85.50, SD=8.82, n = 10$) groups' Independent-Samples Mann Whitney U Test scores were statistically significant, ($U=83.50, p = .009$). The test revealed that the students in the Treatment group had significantly higher scores on the ILSAT than the Comparison Group as shown in Table 10.

Table 10: Descriptive Statistics for The Intermediate Level Science Assessment Tests and Mann-Whitney U Test on the Significant Difference between Comparison and Treatment Groups.

Group	N	Mean	SD	U	p
Comparison	10	73.10	11.08	83.50	.009
Treatment	10	85.50	8.82		
Total	20	79.30	11.64		

Research Question 3: Will students in the treatment group score significantly higher on their attitudes to Science Learning Value and Self-Efficacy in learning science than students in the comparison group?

Hypothesis 3: A Non Parametric Mann Whitney U test was conducted to evaluate the null hypothesis that the students in the treatment group will score significantly higher on their attitudes to Science Learning Value (SciLearnVal) and Self-Efficacy (Self-Eff) in learning science than students in the comparison group.

The test revealed that for each individual group $Treatment_{SciLearnVal}$ ($M = -1.50$, $SD = 3.72$, $n = 10$) and $Comparison_{SciLearnVal}$ ($M = 2.10$, $SD = 3.96$, $n = 10$) there were no significant attitude gains for Science Learning ($U = 27.00$, $p = .089$). The test also showed that for each individual group $Treatment_{Self\text{-}Eff}$ ($M = -.70$, $SD = 6.73$, $n = 10$) and $Comparison_{Self\text{-}Eff}$ ($M = -2.50$, $SD = 6.64$, $n = 10$) there were no significant learning gains for Self-Efficacy ($U = 57.00$, $p = .631$) (See Table 11 and Table 12).

Table 11: Descriptive Statistics for SMTSL Questionnaire Science Learning Value and Mann-Whitney U Test on the Difference in the Gains between Comparison and Treatment Science Lab Classes

Group	N	Pre-test *M (SD)*	Post-test *M (SD)*	Gain *M (SD)*	*U*	*p*
Comparison	10	17.50(4.45)	19.60(3.06)	2.10(3.96)	27.00	.089
Treatment	10	20.04(4.55)	18.50(4.55)	-1.50(3.72)		
Total	20	18.75(4.56)	19.05(3.82)	.30(4.17)		

Table 12: Descriptive Statistics for SMTSL Questionnaire Science Efficacy and Mann-Whitney U Test on the Difference in the Gains between Comparison and Treatment Groups.

Group	N	Pre-test M (SD)	Post-test M (SD)	Gain M (SD)	U	p
Comparison	10	29.80(4.10)	27.30(7.21)	-2.50(6.64)	57.00	.631
Treatment	10	27.70(6.67)	27.00(3.83)	-.70(6.73)		
Total	20	28.75(5.50)	27.15(5.62)	-1.60(6.57)		

The Terra Nova 3 Survey Assessment in Science grade 4 mean score gains were higher for the boys than the girls. However there were no significant gains for boys over girls for the Terra Nova 3 Survey Assessment in Science grade 4 total and in each of the science subcategories i.e. $TN_{PhysSci}$, TN_{SciInq}, $TN_{LifeSci}$, $TN_{EarthSci}$, as shown in Table 13.

Table 13: Descriptive Statistics for Terra Nova Survey and Subcategories Mann-Whitney U Test on the Difference in the Gains by Gender.

	Gender	N	Pre-test M (SD)	Post-test M (SD)	Gain M (SD)	U	p
Terra Nova Gain	Male	13	628.62(35.28)	658.54(46.82)	29.92(22.93)	28.00	.183
	Female	7	623.14(26.00)	637.14(31.67)	14.00(24.26)		
	Total	20	626.70(31.73)	651.05(42.56)	24.35(24.06)		
TNPhys Sci Gain	Male	13	66.15(13.32)	74.85(15.48)	8.69(7.45)	26.00	.135
	Female	7	63.14(7.76)	66.86(9.62)	3.71(713)		
	Total	20	65.10(11.54)	72.05(14.00)	6.95(7.56)		
TNSci Inq Gain	Male	13	64.62(24.75)	79.38(21.33)	14.76(15.34)	32.00	.311
	Female	7	64.14(22.23)	72.43(18.33)	8.29(17.28)		
	Total	20	64.45(23.30)	76.95(20.13)	12.50(15.91)		
TNLife Sci Gain	Male	13	83.00(10.34)	89.69(8.85)	6.69(7.57)	32.50	.311
	Female	7	84.43(10.35)	87.71(7.68)	3.28(7.43)		
	Total	20	83.50(10.10)	89.00(8.30)	5.50(13.92)		
TNEarth Sci Gain	Male	13	39.38(18.63)	52.31(26.37)	12.92(13.59)	32.50	.311
	Female	7	33.14(8.17)	39.57(18.43)	6.43(14.56)		
	Total	20	37.20(15.78)	47.85(24.19)	10.65(13.92)		

Table 14: Descriptive Statistics for ILSAT Score and Mann-Whitney U Test on the Significant Difference by Sex (Gender).

Sex	N	Mean	SD	U	p
Male	13	79.54	12.67	39.50	.643
Female	7	78.86	10.36		
Total	20	79.30	11.64		

The male students had a higher mean score on the ILSAT exam than females as shown in Table 14. However, the Mann Whitney U test also revealed that the difference between the mean score was not significant.

The Science Learning Value Mean score gains were higher for males than females, according to the Mann-Whitney U Test and Self Efficacy Mean score gains were higher for females than males. There were no significant differences in gains on the STMSL questionnaire for males and females in the Science Learning Value and Self Efficacy subcategories.

Table 15: Descriptive Statistics for Science Learning Value and Self Efficacy Gain and Mann-Whitney U Test on Test on the Difference in the Gains between Comparison and Experimental Science Lab Classes by Sex (Gender).

	Sex	N	Pre-test M (SD)	Post-test M (SD)	Gain M (SD)	U	p
SCIENCE	Male	13	18.15(5.30)	18.54(4.20)	.38(4.91)	44.50	.938
LEARING	Female	7	19.86(2.73)	20.00(3.05)	.14(2.61)		
VALUE GAIN	Total	20	18.75(4.56)	19.05(3.82)	.30(4.17)		
SELF	Male	13	27.54(6.32)	25.92(6.22)	-1.62(7.67)	39.00	.643
EFFICACY	Female	7	31.00(2.58)	29.43(3.65)	-1.57(4.39)		
GAIN	Total	20	28.75(5.50)	27.15(5.62)	-1.60(6.57)		

CHAPTER 5

Interpretation of Results

The purpose of this study was to determine if virtual lab experimentation was more effective than the use of traditional lab experimentation in an elementary science classroom by measuring the pretest and posttest scores of science achievement tests of students that participated in a virtual lab experience and those that did not. A total of 20 students (13 males and 7 females) were part of this study of which 10 were in the experimental group and 10 were in the comparison group. All students were in a regular science class and were asked to participate in pre and posttests exams and questionnaires.

Due to the small sample size n=10 in each of experimental and comparison group, Mann Whitney U Test, a non- parametric statistical analysis, was performed, on the results of the Terra Nova 3 Survey Assessment in Science grade 4 and the Terra Nova Science 3 Survey Assessment in Science grade 4 subcategories. For the research question, will students in the treatment group get significantly higher scores on the Terra Nova 3 Survey Assessment in Science grade 4 than students in the comparison group, the hypothesis was that students in the treatment group will get significantly higher gain scores on the Terra Nova 3 Survey Assessment in Science grade 4 than students in the comparison group.

The study found that students who participated in the treatment group demonstrated the tendency of higher mean gain scores than students who participated in the comparison group. The non-parametric statistical analysis Mann Whitney U Test was used in evaluating the first null hypothesis, that students in the treatment group will not demonstrate significant differences in gains on the Terra Nova 3 Survey Assessment in Science grade 4 scores when compared to students in the comparison group. The researcher retained the null hypothesis and concluded that 4th grade elementary students in the treatment group did not demonstrate significantly higher gain scores in Terra Nova 3 Survey Assessment in Science grade 4 and the Terra Nova 3 Survey Assessment in Science grade 4 subcategories when compared to the comparison group.

For the research question will students in the treatment group score significantly higher on the ILSAT than students in the comparison group, the hypothesis was that students in the treatment group will get significantly higher scores on the ILSAT than students in the comparison group.

According to the statistical analysis performed on the results of the ILSAT exam, the study found that participating in the treatment group contributed positively toward increasing the post-test scores. A non-parametric Mann-Whitney U Test was conducted to evaluate the first null hypothesis that grade 4 elementary students who participated in the treatment group will not demonstrate a significant difference in test scores when compared with the comparison group. The researcher was able to reject the null hypothesis and conclude that grade 4 students that participated in the treatment group attained higher mean test scores when compared to students in the comparison group suggesting that the Virtual Lab contributed positively toward increasing the ILSAT scores.

For the research question will students in the treatment group score significantly higher gains on their attitudes to science learning and self-efficacy in learning science than students in the comparison group, the hypothesis was that students in the treatment group will score significantly higher gains on their attitudes to science learning and self-efficacy in learning science than students in the comparison group.

A Mann Whitney U Test was conducted to evaluate the first null hypothesis that students in the treatment group will not demonstrate significant difference in the gains on the Science Learning Value and Science Efficacy scores (subcategories of the STMSL questionnaire)when compared with students in the comparison group (N = 20). The researcher had to retain the null hypothesis and conclude that grade 4 elementary students who participated in the treatment group did not demonstrate significant gains from Pretest to Posttest when compared to grade 4 students in the comparison group.

Self-efficacy refers to the individual's perception of his/her ability in accomplishing learning tasks (Bandura 1981, 1982, 1997, Pajares 1996). When students have high self-efficacy, they believe they are capable of accomplishing learning tasks, whether tasks are difficult or easy (Tuan et. al, 2005). Science learning value refers to whether or not students can perceive the value of science learning they engage (Tuan et. al, 2005). In science class, there are many unique features highlighting the value of science learning, such as problem-solving, science inquiry, thinking, and the relevance of science knowledge in students' daily lives (American Association for the Advancement of Science 1993, NRC 1996).

The Self Efficacy score gains in this study demonstrated that the students' perception of their ability in accomplishing learning tasks whether difficult or easy were not significant from pretest to posttest for the treatment group or comparison group, suggesting that the students' attitude towards being motivated to learn science tasks in the treatment group did not differ significantly from students' attitude towards being motivated to learn science tasks in the comparison group. The Science learning Value score gains demonstrated that the students' problem solving, science inquiry, thinking skills and relevancy of science knowledge in their daily lives were not significant from pretest to posttest for the treatment and comparison group suggesting that the students' motivation towards science learning in the treatment group did not differ significantly from students' motivation towards science learning in the comparison group.

In terms of gender the mean scores for the Terra Nova 3 Survey Assessment for Science grade 4, ILSAT and STMSL-Science Learning Value were higher for the males than for the females, while the STMSL-Self Efficacy mean scores were higher for females than for males. However, the gain scores were not significant.

We can conclude that the Intervention had a significant impact on the ILSAT score gains with a Mean gain of nearly 7 points.

Summary of Findings and Discussion

Recent attention has been brought to light in the United States regarding low numbers of students pursing STEM (Science, Technology, Engineering and Math) disciplines and degree programs (National Science Board, 2010). There is a great need in America for talented scientists and engineers (Dejarnette, 2012). Numerous programs abound for high school and middle school students in regard to STEM initiatives; however, fewer opportunities exist for elementary students and their teachers (Dejarnette, 2012). Research has shown that early exposure to STEM initiatives and activities positively impacts elementary students' perceptions and dispositions (Bagiati, Yoon, Evangelou, & Ngambeki, 2010; Bybee, & Fuchs, 2006).

For question 1, the research examined whether Elementary students conducting virtual lab activities (treatment group) will get significantly higher gain scores on the Terra Nova 3 Survey Assessment in Science grade 4 than students conducting traditional lab experiences the comparison group.

The study concluded that 4th grade elementary students in the treatment group demonstrated the tendency of higher mean gain scores in Terra Nova 3 Survey Assessment in Science grade 4 than students in the comparison group and that the gain scores were not statistically significant. The statistical insignificance could be the result of two factors. One, the study utilized a small number of participants. Perhaps a larger number of participants or sample size would yield more meaningful results or significantly higher gains.

Two, research (Darrah et al., 2014) has showed that there was no evidence that one of the treatments (virtual or traditional hands-on) was more effective than the other in conveying the concepts of the labs to the students and that there was no significant difference noted in any of the tests. Similarly, research (Pyatt and Simms, 2012) has showed the usefulness of virtual labs and physical labs to be similar, if not the same for students.

This study, consistent with prior research, established that schools can get similar effects with both virtual and traditional hands on labs without making those big purchases for science laboratory equipment. Oftentimes schools where African American and

Latino students are educated can't afford to purchase lab equipment for experimentation and research. Subsequently, these students, at an early age, are not afforded with opportunities that enable them to conduct scientific investigations and increase their scientific reasoning skills. According to the research, schools can utilize either virtual laboratory experiments or traditional laboratory experiments in the science classroom, because neither is more effective than the other for increasing student learning in science.

For question 2, the research examined whether students conducting virtual lab experiences (treatment group) will get significantly higher scores on the ILSAT than students conducting traditional hands-on experiences (comparison group). The study found that grade 4 students who participated in the treatment group attained significantly higher mean test scores when compared to students in the comparison group. The statistical significance suggests that students who conducted virtual lab experiences may have gained scientific experiences that contributed positively toward increasing their ILSAT scores than students who conducted traditional lab experiences.

This is consistent with research that found that middle school students who used virtual labs, developed the ability to give correct scientific explanations of Newtonian principles several grade levels before the concept usually is taught (Roschelle et al., 2000). Also, middle school students who participated in virtual labs outperformed high school physics students in their ability to apply the basic principles of Newtonian mechanics to real-world situations: the middle schoolers averaged 68% correct answers on a six-item, multiple-choice compared with 50% for the high school physics students (White and Fredriksen, 1998).

This study and prior research concluded that the use of the virtual labs software appeared to make science interesting and accessible to a wider range of students than was possible with more traditional approaches (Roschelle et al., 2000).

The ILSAT scores were comprised of a written section (multiple choice and short extended response questions) and performance (Laboratory stations) section that pertained to various 4th grade science standards based concepts. Therefore, the ILSAT may have measured both conceptual knowledge and scientific reasoning, skills that could have been better accomplished through the virtual lab experience. Due to the fact, that there was no pretest demonstrating that students started from the same level in the beginning of the study on the ILSAT (given in June only), it is not evident whether the virtual lab contributed to higher ILSAT mean scores observed in the treatment group.

For question 3, the research examined whether students conducting virtual lab activities (treatment group) will score significantly higher gains on their attitudes to science learning and self-efficacy in learning science than students conducting traditional hands-on lab activities (comparison group). The findings showed the tendency of higher mean gain score on the Science Learning Value Scale for the comparison group than the treatment group and the tendency of higher mean gains score on the Self Efficacy Scale for the treatment group than the comparison group.

The findings also showed that grade 4 elementary students who participated in the treatment group did not demonstrate significantly higher gains from Pretest to Posttest when compared to grade 4 students in the comparison group which suggesting that students' attitude towards being motivated to learn science tasks in the treatment group did not differ significantly from students' attitude towards being motivated to learn science tasks in the comparison group.

The reason for these results could be from two factors. One, the study utilized a small number of participants. Perhaps a larger number of participants or sample size would yield more meaningful results or significantly higher gains.

Second, there needs to be more immediate or nurturing feedback for virtual labs, to be motivating for elementary students. When immediate or nurturing feedback is provided in the traditional lab; more often it is done by the teacher. Virtual lab creators need to add more feedback, in the form of loud claps, cheers, even visual praise such as a virtual teacher nodding in agreement and/or smiling. Much prior research has been done with older students; hence scientists did not cater to the needs of younger students by adding immediate or nurturing feedback to the virtual labs.

Tuan et al. (2005) indicated that teacher's teaching strategies and the science content such as concrete, relevant and perceptual science concepts presented in the class stimulated students' motivation toward science learning.

By capturing students' interest in STEM content at an earlier age, a proactive approach can ensure that students are on track through middle and high school to complete the needed coursework for adequate preparation to enter STEM degree programs at institutions of higher learning (Dejarnette, 2012). As a result, programs focusing on STEM initiatives and content are a growing priority in American schools with aims to provide early exposure for elementary students (Dejarnette, 2012).

Early exposure may motivate students to enroll in more advanced science and math courses when they are available in middle and high school (Dejarnette, 2012). Elementary students have the cognitive abilities to engage in STEM content and problem solving activities which in turn will whet their appetites for more (Dejarnette, 2012). Not only do STEM lessons and activities excite young learners, but they also build their confidence and self-efficacy in relation to their own abilities to be successful in more advanced math and science courses in later school years (Dejarnette, 2012).

Impact on Elementary Teacher Education in STEM Disciplines Teaching inquiry science is not a common approach used in elementary science classrooms today (Weiss, 2006). The emphasis on standardized testing in America has hampered the growth of scientific pedagogy in the elementary schools to include inquiry-based projects (Dejarnette, 2012). Elementary students often learn about scientific theory and the nature of science rather than doing scientific investigations for themselves. As a result, students are relying on the knowledge, products and conclusions of others rather than experiencing it for themselves (Dejarnette, 2012).

Universities around the country as well as public and private organizations are beginning to offer STEM initiative programs for K-12 students and their teachers (Dejarnette, 2012). Many of these programs continue to focus on middle and high school students and often overlook elementary students (Vasquez, 2005; Yasar, Baker, Robinson, Kurpius, Krause, & Roberts, 2006). However, STEM programs focusing on elementary students are beginning to surface more and more (Dejarnette, 2012). The first line of attack should be in teacher education. STEM concepts such as scientific inquiry, problem-based learning, engineering design and technological activities should encompass the methodology that every elementary preservice teacher receives in their teacher education programs (Dejarnette, 2012). The United States demands that their teachers are highly qualified, but many lack confidence to teach scientific inquiry in the elementary classroom (Bencze, 2010).

Preservice teachers need to be thoroughly prepared to incorporate STEM initiatives into the existing curriculum wherever they teach (Dejarnette, 2012). By preparing the preservice teachers of tomorrow, we lay the foundation for change (Dejarnette, 2012). Second, university teacher educators need to reach out to their community schools' and provide staff development for veteran teachers (Dejarnette, 2012). Providing instruction and pedagogy on scientific inquiry and technological design in the elementary classroom will help elementary teachers feel more confident to alter their existing curricula to incorporate STEM initiatives (Dejarnette, 2012). When teachers have positive self-efficacy towards instructional methods, they are more likely to engage students using that method (Ross, 1998). Implementing STEM concepts in the elementary school curricula involves teaching students through problem-based learning and collaboration which resembles the workplace of the future (Dejarnette, 2012).

The third suggestion to help motivate American youth to begin rigorous academic tracks that lead to higher education and careers in STEM disciplines is to provide ample and equal opportunities for early exposure to STEM related concepts. Developing summer camps, classes, and workshops for elementary students to experience hands-on scientific inquiry and technological design activities will engage young learners with STEM disciplines and content that they might not otherwise experience. While students are engaged in STEM activities, they will

> also gain experience with 21st Century skills such as critical thinking, collaboration and communication that will help prepare them to compete on the global level. Interactive problem-based learning activities in STEM disciplines are innovative and exciting for young learners. It is hypothesized that this type of environment will spark motivation to pursue more advanced math and science courses and lay the foundation for STEM careers. More research needs to be done in this area as the United States moves forward to reclaim their status as global leaders in math and science (p.82).

Providing exposure to even the youngest learners may be the key to long-term success for American education (Dejarnette, 2012). The opportunity for America to achieve high ranking status in STEM disciplines in the world markets lies in the hands of our youth (Dejarnette, 2012). We can achieve these lofty goals by implementing STEM initiatives as an integral part of the elementary level curricula in America today (Dejarnette, 2012).

Increasing the STEM initiatives will increase the gains in science achievement scores for elementary students and science motivation.

Limitations of the Study

Technology integration is thought to be directly influenced by the following four barriers: (a) teacher's attitudes and beliefs towards using technology, (b) the teacher's knowledge and skills (c) the institution and (d) resources (Brush & Hew, 2007). Professional development can influence a teacher's attitudes and beliefs towards technology (Shaunessy, 2005); as well as provide teachers with the knowledge and skills to employ technology in classroom practice (Fishman & Pinkard, 2001). A review of relevant literature showed that effective professional development related to technology integration: (a) focuses on content, (b) gives teachers opportunities for "hands-on" work and (c) is highly consistent with teachers' needs (Brush & Hew, 2007).

Yet, even the best courseware is of limited value unless teachers are knowledgeable about the content and comfortable with the technology used to deliver it (Von Blum, 1992). Teachers must have strategies for integrating courseware within their other classroom activities (Shavelson et al., 1984). Technology integration cannot occur if the teacher lacks the knowledge or skills to operate computers and software (Brush & Hew, 2007). In this study there was difficulty in selecting a teacher who had technological skills as well as science skills adept enough to teach the students. More professional development in science and technology can help teachers who need assistance in infusing technology into their science classroom. This limitation did not allow for the study to accommodate more treatment groups i.e. grades 5, 6, 7 and 8. The sample size was small n=20 because of this limitation as well.

Oftentimes administrators cite budgetary constraints for not funding science labs. By using computerized software to conduct lab experiments, administrators can utilize the numerous computers in the building and prolong the purchases of expensive lab equipment used in dissections, magnifications and /or chemical titrations. However, even sometimes when computers are available, they may be off limits to other subject teachers. The computers may be broken or outdated. Additionally, some of the computers could be unable to support the internet or certain graphic software. Administrators need to ensure that there technological resources are available for use by other teachers besides the technology teacher. They also need to ensure that they are up to date and repaired or replaced when needed.

In this study, many of the tablets used in this experiment had to be updated in order to support the virtual labs. Laptops would have been better for students to use or computers with large screens but they weren't readily available.

An additional limitation was that the school had very limited science equipment for students to utilize. The equipment was practically new but very few in numbers to accommodate students working in pairs. Additionally, there was not a wide variety of equipment to accommodate the various lab activities. Therefore, the lab choices for both Virtual and Traditional were limited to the equipment that could be used by traditional groups since students in both groups must to carry out the same science objectives.

Another limitation was the time frame for the study. Due to the school being a faith based school the teacher who also doubles as the choir director had to plan her schedule around the church activities. The study would have been more weeks if the time for science did not have to be missed due to the teacher instructing choir rehearsal for church, recitals and/or plays. The study was conducted for 8 weeks.

Directions for Future Research

There is not much research done in the areas of elementary school science and technology. Many of the research regarding science and technology are directed towards middle school, high school, undergraduate and graduate science classes. More research has to be done in the areas of elementary school and science learning utilizing technology. Elementary school students are different from Middle school, High School and College students in the way that they learn. The Elementary school classroom is more teachers centered. The elementary students constantly look for feedback, guidance, encouragement, constructive criticism from their teacher. The elementary students are children looking for nurturing and hand holding from their teachers. Elementary school students expect their teacher to be very active in their learning i.e. reading to them, praising them for good work or letting them know when they have make mistakes. High school and college students require less "hand holding" from their teachers. With proper instructions High school and college students can conduct classroom labs by themselves with little or no praise or feedback. Hence, the virtual group which is pretty much self - lead, may pose a small challenge to elementary school students. The virtual lab, however, keeps more students in engaged and for a longer time. There needs to be more qualitative data collected during instruction with technological infused learning.

Many of the computerized virtual software may have a feedback mechanism that states "nice job". Yet, a computerized program can't give a high five or a pat on the back for a job well done. The computerized program can't smile at the student or give them a treat for doing a good job. These types of praise are common for elementary students to expect from their teacher. Elementary students need this type "nurturing feedback".

The computerized science programs can afford elementary students laboratory experiences with virtual equipment and tasks that go far beyond the scope of the laboratory experiences that they could be done in class. Yet, the computerized science program cannot provide elementary school students with the feedback they need regarding using certain science equipment correctly such as balances and/ or microscopes. The computerized version calibrates the balances automatically to get the weight of an object once the object is placed on the virtual balance. Even after the virtual lab the students would not be able to utilize, calibrate, or trouble shoot problems with the balance. The students would have to learn that from their teacher.

In the virtual lab, the microscope zooms in on the specimen, once the specimen is placed on the slide automatically at the power the student chooses. In a traditional lab, the students would have to zoom on the specimen by physically adjusting the course objective knobs, diaphragm, and slide. Also, in a traditional lab, a glass slide may break, if the student uses the high power objective to close to the slide or while taking the slide to his seat. In a traditional lab, the student would have to retrieve another slide from the teacher, prepare a new slide, and/or follow the correct lab safety procedures to deal with the breakage. They would have to learn these procedures from their teacher as well.

A computerized program cannot provide feedback as to the pace the lab should be conducted. In Physical Chemistry labs the timely mixing of chemicals are necessary to attain a certain reaction. In a virtual lab, these nuances are not an issue because the program doesn't allow for those real life occurrences. Yet, these real life experiences will occur if these students decide to take high school or college science classes, pursue a career as a pharmacist, phlebotomist, doctor, lab technician, biologist or chemist. Virtual labs that correct for these nuances should be researched to better fit the reality of traditional labs and elementary students. Virtual labs should also provide an immediate, yet nurturing feedback mechanism for elementary students.

Research shows that there is an advantage of using the videos as a prelab activity for students—even for those students who perform the lab with actual equipment (Darrah et al., 2014). Professors in one study reported that a great deal of time is typically spent at the beginning of each lab period explaining the procedures to the students (Darrah et al., 2014). Using the videos to provide this preliminary explanation can save time in class, which can be better used to debrief after the lab is completed (Darrah et al., 2014). However, elementary students have a short attention span and have usually had a “mother/child relationship with the teacher. The actual teacher would probably have to record herself doing the lab in order for the students to pay attention.

Based on this study, computerized labs programs should be done in tandem with traditional labs. On an elementary school level traditional labs and computerized labs should be done as a mixed method as well as be teacher centered.

Implications for Future Practice

The research literature abounds with successful computer applications that have enabled students to master concepts usually considered too sophisticated for their grade level (Rochelle et. al, 2000). Based on my research, virtual labs help more advanced Elementary students to progress. Many of the appropriate scaffolding, fading and feedback mechanisms should be incorporated into the virtual lab especially for Elementary school students. Scaffolding enables learners to realize their potential by providing assistance when needed, and then fading out this assistance as meaningful learning takes place (Collin et. al., 1989). Fading ensures that the child does not become overly dependent on a particular prompt when learning a new skill (Cooper, Heron, & Heward, 2007).

Feedback mechanisms should be more readily built into virtual programs as well as verbal/visual cues and narration. Prompt feedback is provided to help students acquire skills and knowledge (Yin et. al., 2013). Mandatory surveys at the end of each lab should be utilized to assess usability. Students in every group should discuss how they felt doing labs. A qualitative interview can also be done by the teacher.

More Math, ELA, and elective classes such as Spanish should have virtual and traditional methods of learning. In this way, students who are able to advance in the course would be afforded the opportunity to increase their learning instead of waiting for other students who might not be on their level. Additionally, 3rd, 4th, 5th graders, typically elementary school grades, when standardized testing begins should experience virtual, traditional and mixed methods of learning during instruction and research data on pretest /posttest gains should be collected.

The tablets used should be roughly the size of a notebook and touch screen enabled. The tablets/Chromebooks or IPADS given to elementary students in schools have screens that are too small and aren't touch screen. The larger screens help younger students to better see the virtual activities. Touch screen assists them with usability. A narrative or closed captioning should be available to help them listen to or read directions. Additionally, the virtual labs should be in different languages to accommodate second language learners.

The research should take place from September to June, the entire school year. In an elementary class the same teacher should utilize traditional, virtual and mixed methods. A researcher could then compare student gains, for each group. For example, a third of the semester, traditional methods are used; the second third of the semester virtual methods are used. For the last 3 months, students will be taught with both traditional and virtual methods. This procedure can be used for differing subjects i.e.

Math, Ela, Spanish and elementary grades, 3, 4, 5. Pretest/Posttest gains from each class, subject and grade could then be analyzed to determine how the same class with same teacher (since one teacher teaches all subjects in one elementary class) progressed using the varying methods of instruction.

The Elementary school teacher is important to students' learning at a small age. This is because elementary students rely greatly on teacher feedback and nurturing. The teacher can make the lab interesting and make students want to learn more about the science lab in elementary setting providing that she is well versed in the subjects that she teaches. The teacher must be able to impart the appropriate knowledge and deliver the instruction in a fashion suitable for piquing the interest in young learners. Schools in lower socioeconomic areas, often times have inexperienced teachers, due to high turnover rate, and/or lack of experience (5years or less), that are not well versed in their content area. This puts elementary students of color who are learning science at a disadvantage. In order to meet the academic needs of these students, schools in which African American and Latino attend should employ teachers with proficient content knowledge in Science.

Virtual and traditional labs should be utilized together such that the students' experience using both methods to conduct the same type of lab. For example, if the students are learning about magnets, the teacher should allow the students in lab class to use magnets so that the students can actually experience the pull of attraction and push of repulsion, respectively, when the north and south poles are close together or when the north and North Pole or south and south poles are together. The teacher should also allow the students to observe the patterns of attraction and repulsion of a magnet when using iron filings. Students should be allowed to explore what surfaces “stick” to the magnet and which ones don’t.

After the traditional lab on magnets, students should then be afforded the opportunity to conduct a virtual lab. The virtual lab will enable students to go above and beyond the use of magnets in the classroom. For example, they will be able to see attraction/repulsion using virtual magnets and iron filings. Additionally, they will be able to use a virtual wrecker car magnet to pick up and move virtual cars and measure the force using a virtual spring scale.

Schools in which African American and Latino students attend should be outfitted with the appropriate laboratory equipment for traditional labs and up to date technology for virtual labs. Often times, African American and Latino students are placed in schools that fail to provide necessary scientific resources for students in the science classroom. For example, in many of these schools science lab equipment used in the traditional setting may be broken, outdated or few in number. To conduct the virtual labs, Wi-Fi connectivity may be slow or weak, computers may be broken or contain outdated software and /or mobile devices such as tablets and chrome books may be too few for the number of students in the science classroom. This puts elementary students of color who are learning science at a disadvantage. Schools in which African American and Latino students attend should have upgraded and sufficient science lab/technological equipment to meet the scientific academic needs of their elementary students.

The students should be assessed before and after each lab activity and they should explain the pros and cons of both methods as it pertains to self- efficacy and science learning for that particular lab. A pre and post-test questionnaire such as the STMSL could be utilized. A qualitative and quantitative study (mixed method research) would be better for determining the effects of virtual laboratory activities on science learning for elementary school students.

APPENDIX A

New York State Standards for Grade 4

Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science.

4.E: Energy

4-PS3-1: Use evidence to construct an explanation relating the speed of an object to the energy of that object.

4-PS3-2: Make observations to provide evidence that energy is conserved as it is transferred and/or converted from one form to another.

4-PS3-4: Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

4-ESS3-1: Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.

4.W: Waves: Waves and Information

4-PS4-1: Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move.

4.SFI: Structure, Function, and Information Processing

4-LS1-1: Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

4-LS1-2: Use a model to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways.

4.ES: Earth's Systems: Processes that Shape the Earth

4-ESS1-1: Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time.

4-ESS2-1: Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation.

4-ESS2-2: Analyze and interpret data from maps to describe patterns of Earth's features.

4.P1: The Earth and celestial phenomena can be described by principles of relative motion and perspective.

4.P1.1a: Natural cycles and patterns include:

4.P1.1a.1: Earth spinning around once every 24 hours (rotation), resulting in day and night

4.P1.1a.3: the length of daylight and darkness varying with the seasons

4.P2: Many of the phenomena that we observe on Earth involve interactions among components of air, water, and land.

4.P2.1c: Water is recycled by natural processes on Earth.

4.P2.1c.1: evaporation: changing of water (liquid) into water vapor (gas)

4.P2.1c.2: condensation: changing of water vapor (gas) into water (liquid)

4.P2.1c.3: precipitation: rain, sleet, snow, hail

4.P2.1c.4: runoff: water flowing on Earth s surface

4.P2.1c.5: groundwater: water that moves downward into the ground

4.P3: Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

4.P3.1a: Matter takes up space and has mass. Two objects cannot occupy the same place at the same time.

4.P3.1c: Objects have properties that can be observed, described, and/ or measured: length, width, volume, size, shape, mass or weight, temperature, texture, flexibility, reflective- ness of light.

4.P3.1e: The material(s) an object is made up of determine some specific properties of the object (sink/ float, conductivity, magnetism). Properties can be observed or measured with tools such as hand lenses, metric rulers, thermometers, balances, magnets, circuit testers, and graduated cylinders.

4.P3.1f: Objects and/ or materials can be sorted or classified according to their properties.

4.P3.1g: Some properties of an object are dependent on the conditions of the present surroundings in which the object exists. For example:

4.P3.1g.2: lighting -shadows, color

4.P3.2b: Temperature can affect the state of matter of a substance.

4.P4: Energy exists in many forms, and when these forms change energy is conserved.

4.P4.1a: Energy exists in various forms: heat, electric, sound, chemical, mechanical, light.

4.P4.1b: Energy can be transferred from one place to another.

4.P4.1c: Some materials transfer energy better than others (heat and electricity).

4.P4.1d: Energy and matter interact: water is evaporated by the Sun s heat; a bulb is lighted by means of electrical current; a musical instrument is played to produce sound; dark colors may absorb light, light colors may reflect light.

4.P4.1e: Electricity travels in a closed circuit.

4.P5: Energy and matter interact through forces that result in changes in motion.

4.P5.1b: The position or direction of motion of an object can be changed by pushing or pulling.

4.P5.1c: The force of gravity pulls objects toward the center of Earth.

4.P5.1d: The amount of change in the motion of an object is affected by friction.

4.P5.1f: Mechanical energy may cause change in motion through the application of force and through the use of simple machines such as pulleys, levers, and inclined planes.

4.L1: Living things are both similar to and different from each other and from nonliving things.

4.L1.1b: Plants require air, water, nutrients, and light in order to live and thrive.

4.L1.2a: Living things grow, take in nutrients, breathe, reproduce, eliminate waste, and die.

4.L2: Organisms inherit genetic information in a variety of ways that result in continuity of structure and function between parents and offspring.

4.L2.1a: Some traits of living things have been inherited (e.g., color of flowers and number of limbs of animals).

4.L2.2a: Plants and animals closely resemble their parents and other individuals in their species.

4.L2.2b: Plants and animals can transfer specific traits to their offspring when they reproduce.

4.L3: Individual organisms and species change over time.

4.L3.1b: Each plant has different structures that serve different functions in growth, survival, and reproduction.

4.L3.1b.3: stems, stalks, trunks, and other similar structures provide support for the plant

4.L3.1b.5: flowers are reproductive structures of plants that produce fruit which contains seeds

4.L4: The continuity of life is sustained through reproduction and development.

4.L4.1a: Plants and animals have life cycles. These may include beginning of a life, development into an adult, reproduction as an adult, and eventually death.

4.L4.1d: Life cycles of some plants include changes from seed to mature plant.

4.L4.2a: Growth is the process by which plants and animals increase in size.

4.L5: Organisms maintain a dynamic equilibrium that sustains life.

4.L5.1a: All living things grow, take in nutrients, breathe, reproduce, and eliminate waste.

4.L6: Plants and animals depend on each other and their physical environment.

4.L6.1a: Green plants are producers because they provide the basic food supply for them- selves and animals.

4.L6.1b: All animals depend on plants. Some animals (predators) eat other animals (prey).

4.L6.1c: Animals that eat plants for food may in turn become food for other animals. This sequence is called a food chain.

4.L6.1d: Decomposers are living things that play a vital role in recycling nutrients.

4.L6.2b: The Sun s energy is transferred on Earth from plants to animals through the food chain.

4.L6.2c: Heat energy from the Sun powers the water cycle (see Physical Science Key Idea 2).

APPENDIX B

Classroom Observation Notes

Week	Duration	Observations
1	**50 min**	**Traditional Lab-Volume**
		Teacher gave students who were placed in groups of four their graduated measuring cups. Teacher directed students to conduct the Volume lab. She went from group to group to check for understanding. Teacher explained how to measure liquids with a measuring cup using graduations. Students filled out lab sheet. The teacher had students use graduated measuring cups to measure different amounts of water. The teacher asked "how close can you get to the correct amount of liquid". Students shared equipment, but the lab was mostly teacher directed. Students struggled with counting graduations but teacher kept redirecting the students and assisting them with the lab for the entire time. The traditional lab was confusing because students used graduated measuring cups and not actual graduated cylinders to measure volume which the lab activity recommended. The graduated containers they used, however, were similar to those that would be used on the 4th grade State exam, but not what the lab called for. This left some students confused even though the teacher tried showing them how to use it. When the teacher asked a student what he was doing, he said that he was measuring liquids (water) using the measuring cups. Many students had not completed all of the questions, but they were able to measure out different amounts of water in different amounts of measuring containers. The group was talking loudly. Perhaps it would have been better if they worked in pairs. However, this is how the teacher conducts lab work with her students in the traditional sense. At the end of 50 minutes the teacher collected all of the students work. The two groups within the traditional lab did not completely finish. Teacher directed one group mostly, even though both groups needed direction. Teacher explained how to measure with measuring cups using graduations. Students filled out lab sheet. Teacher asked, "How close can you get?" Teacher helped students arrive at the answer. Students struggled with counting graduations. Students were not using graduated cylinder, they were using graduated containers where the graduations weren't that pronounced. Traditional labs were

		confusing because students did not use graduated cylinder, as school did not have them in 4th grade science class. The lab was very teacher directed and some students still didn't understand it because she couldn't really explain how to students should arrive at the answers for the questions regarding volume using containers rather than graduated cylinder.
1	**50 min**	**Virtual Lab-Volume**
		Students were told to utilize one tablet per pair since some students had difficulty with getting their tablet started. Upon entering the classroom the teacher was conducting a whole class instruction on how use different graduated measuring cups. Students were already separated in groups virtual vs. traditional lab. Students received lab manuals/worksheets for virtual labs and traditional. Students worked with a partner to complete Explorer Learning virtual labs. Students were instructed to read the directions and follow exactly what it said to do. At first students were waiting for teacher but she told them to begin by reading the student exploration sheet. The students worked diligently to complete the lab working with each other in pairs, yet they mostly arrived at the answer to the questions by themselves. Some students read to their partner. They read the sentences on the Explorer Learning virtual lab to their partner. The teacher did not assist. She just supervised and encouraged students to complete the Explorer learning activity on measuring Volume. One student asked "What is a pipette". The teacher directed them to the picture on the Explorer Learning virtual lab. Another student asked "what does each tick mark represent." The teacher pointed to the graduations on the virtual graduated cylinder. Some students in some pairs worked faster while others worked shower. Yet, they worked at their own pace. A student asked "Which graduated cylinder should they use, 100, 250, or 500 ml?" Students were able to see and understand what the graduations were used for more clearly on the virtual lab. Students had difficulty with tablets. A few (3) tablets didn't work. Students worked in pairs. Students were better off using one tablet. Students were self- directed after about 10 minutes. They read out loud each directive and did exactly what Virtual Lab said. Some students worked faster some worked slower. Teacher did not direct students in the Virtual group at all. Students were self-directed. Students were able to see what the graduations were more clearly as they proceeded with the labs especially with close up view.

2	**50 min**	**Traditional Lab-Volume**
		Teacher wanted students to count by 5 in the Volume Lab. In Part A: Count your drops. Teacher said, ‘When it increases what were we testing”? Teacher used one demo to instruct traditional labs students. Students did not do the lab themselves. The group was asked questions. Teacher directed students throughout the entire labs. Students were given a survey-Self Efficacy Scales.
2	**50 min**	**Virtual Lab-Volume**
		Passwords were changed after the lab so that students only used Virtual Labs during class. Students were allowed to do assessment Activity: A and B. Students wanted to complete other unrelated Virtual labs when they were finished but weren’t allowed to. Students were engaged for entire lab. Students were self-directed. Students completed the lab questions in pairs. Worksheets were mostly completed. Students were self- directed, they were able to work by themselves with little teacher assistance. One student took longer than the others to complete lab but other students worked together. Students were given a survey-Self Efficacy Scales.
3&4	**100 min**	**Traditional Lab- Circuits**
		Students received handouts on traditional lab. Teacher read directions and proceeded to Mini Lesson. Mini Lesson was done to explain how to do lab. Teacher called students from one group (five students) within traditional group to make a circuit. Students from the group constructed a series circuit using the materials given. While one group constructed the series circuit the other group of five students began learning how to construct a parallel circuit. Teacher than allowed that group to demonstrate to the second group with in the traditional group. The teacher instructed the students to create series circuit as shown in the picture on the lab. Students worked as a whole small group. Mostly teacher directed. Students were allowed to discuss and speak about lab and answer questions. Most students were engaged but were not completing the labs. They were mostly observing. “Can’t put negative on negative and positive on positive” teacher said. Students observed teacher and asked questions. Teacher did not allow students to write on lab sheet right away. Students in traditional lab had the teacher’s attention the entire time. As elementary students that could be more favorable as they are little and some students were competing to talk to teacher

		about lab. “If the circuit is open, will the circuit work?” the teacher said. Teacher had students’ attention. After teacher demonstration, students completed the lab worksheet. Teacher asked, “While it is a conductor, light bulb will light up but if it’s an insulator the light bulb will not light up. Why did the paper clip light up the bulb?” Teacher assisted students with response. Students had to leave the lab to go to Chorus practice.
3&4	**100 min**	**Virtual Lab-Circuits**
		Students were given the lab and they quickly signed on and began working in pairs to complete the lab. Virtual Lab students worked very well independently. They were able to navigate through the various instructions in order to carry out the experiments. Students worked in pairs. Students read the directions and relied on each other for help. Most students were engaged for the entire period; 9 out of 10 students specifically. Students conducted the different experiments for electricity and they were all engaged for the duration of the lab. Students were eager to show their virtual circuits to the teacher.
5	**50min**	**Traditional Lab-Circuits**
		Students begin after teacher directed them. Teacher directed students, yet half of the students were not engaged. They were talking or waiting for the teacher. One student was waiting after teacher told him to draw a series circuit on their papers. At most 5 out of 10 children were not engaged. Some students followed the teachers’ instruction and drew the circuits, she asked them to draw. One student said that “It was hard”. 5/10 students were not engaged at about 20 minutes into period. Students just waited for the teacher to answer the questions on the lab. Teacher worked with five students at a time, while the other five remained disengaged. After she showed 5 students how to do the lab, she left them and went to the other group to show the other 5 students. The other 5 students sat and socialized until the teacher came back. Teacher explained the differences and similarities of parallel and series circuit. She spoke to one group of 5 students. She said, “What do you notice about wires? Each wire has two sides”. Teacher provided feedback to students’ pictures and made corrections to their paper, while the other 5 students waited for her to come back to them. Students waited for teacher to come back from working with other group, even though she left that group with materials to work independently as a group.

		Teacher showed 5 students what a series circuit was and she actually put it together herself while the students watched. 3 students from the other group came over to watch the bulbs light up in a series circuit. The teacher than brought both groups together to model making a parallel and series circuit. Teacher told students "Connect wires to make a parallel circuit". She then asked, "Why didn't bulb light up?" The teacher discussed similarities between series and parallel circuits. She went to 5 students to introduce the portion of the lab, by saying "What is the conductor and what is an insulator? The others finished the series and parallel circuits' portion. About 5 minutes later, she put both groups together to conduct lab. She instructed all the students how to fill in the table. Teacher asked, "What is the battery source?" She then said, "Complete the table for what objects you predicted will conduct electricity and what object actually did". It was evident that the teacher's back was getting tired, because she was doing the lab for the students, testing each object herself for conductivity. A student said "Magnets are made out of metal will it conduct electricity". Teacher said, "You are supposed to write magnet, we will wait for you". Teacher had all groups together as a group of 10. Teacher said, "Did you guys put your prediction first?" Teacher helped students complete data table. She said, "you guys all guessed what? It's an insulator". Everybody write down aluminum foil on table. "You guys got the prediction wrong for aluminum foil." Teacher gave immediate feedback. Teacher instructed each student had to write down what their predictions were for each item being tested. Teacher had students test rubber bands for conductivity by having them watch her do the testing. She instructed them to write down the actual observations, whether the rubber bands were conductors or insulators. Some students said nickel is a metal. Teacher said, "What is conductor we are using?" Students replied, "penny". The teacher then gave out the setups to groups of two to test each item. Teacher, said "I didn't say to start yet" because she wanted to see each group working simultaneously. Teacher checked each pair to make sure they had the correct setup, then she told them to start. "Good job," she praised them. "Good team work", she said. "There you go"; "good job", teacher said. "You deserve a round of applause", teacher said. "Which insulator should be used spoon or paper clip", teacher asked? Students replied, "paper clip". Students began arguing with others about the answer, paper clip. She asked students to unplug and redo the testing. She said," Ready, Set, Go". Some students finished right away and then began to talk. Teacher

		praised students by saying, "Good job". Teacher waited for the group to write nail, for the next test item. Teacher then walked away from the group. Students did not engage when teacher walked away, instead they waited until she came back to begin working.
5	**50min**	**Virtual Lab-Circuits**
		Students logged on to explore learning and began reading instructions for activity B&C. Some students had problems with the tablets, some students worked with a partner, others worked alone. Cyber lab students relied on each other or themselves for answers to the questions in the activity. "How does that make any sense", said a student and then he asked another student for help. Students asked, "What does orientation mean?" Another student asked," Does the conductor have a different effect on the light bulb lighting up?" By 9:35am only one student did not complete cyber lab. Students were self-directed for the entire lab. All students were engaged at 9:07. Students were self-directed for the entire duration of cyber lab. Most students were almost finished with Cyber lab activity A&B. Students were all up to C by 9:25. Student showed another student that if she charged the lightbulb with too much power the light bulb blew out. By 9:30, 5 students had finished.
6	**50 min**	**Traditional Lab- Measuring**
		Students were learning how to use a ruler. Teacher used the Smart Board to show students how to do the math as it pertains to the ruler such as measuring in between the lines of the ruler graduations. In the measure length lab, students practice making metric measurements. Five out of 10 were engaged, only 5 students were raising their hands. Students waited for teacher directions to complete table. Students only engaged when teacher is present at the group. Teacher will show students how to measure in inches. Students were allowed to move closer to the teacher so that they could watch her demonstrate how to use a ruler. Measuring the distance using a meter-stick between 2 objects. It goes over the ruler you mark it and then start it again. Teacher counted with students the lines on the ruler to measure the object with the ruler in inches. The measured 16 lines like " 1…2…3…". Some students were looking around at least 5 out of 10 of them. Someone's paper even fell through the window. Teacher would work with 5 students and leave the others then go back. While in traditional, they had to work together and the teacher said that they worked too slow especially some of

		them. Teacher set up items with different distances and asked students to measure each one from 1…2…3…etc., The entire group of students worked as a team to complete the labs. 10 students were huddled at one station. Teacher said, use large ruler, for farther distances. Teacher included Math, Simplify, 9/36, 5/35, 8/36, 8/32, 10/20, to reinforce the fractions on the ruler in inches.
6	**50 min**	**Virtual Lab- Measuring**
		Students were doing a whole group instruction on measuring afterwards. Students broke up into their group to do the Cyber Lab on Measuring trees. Student asked questions like "Which ring should be counted". Students worked in pairs or alone. They used the virtual ruler to measure the diameter of the trees cross section. Most students worked with their partner to answer the questions on the sheet. Student- directed totally. Students were able to measure the height, circumference, age and diameter of cross section of trees with virtual ruler. Only one student worked by himself. One student was off task. One student was up to the Extension activity while other groups were up to only Activity B and some were up to Activity A. Students were allowed to work at their own pace.
7	**50 min**	**Traditional Lab-Magnets**
		Teacher said, "What is that a magnet?" Teacher had all students stand around her as she showed them how a demonstration on how to work with magnets. Students gathered around her with their lab sheets. "Did you feel that pull"?, Teacher said. Then she told 5 students to sit down and wait for her while the other five watched her do the demo. Teacher put various objects in the sand to see if the magnet would pick them up. Teacher said, "What happened when you put magnet over sand?" Student answered that the objects/ items will connect to magnet. Teacher said, "What is another name for connect. Students responded, "Attract". Teacher showed two magnets and showed how opposite poles attract while same poles repel. She gave the two magnets to other students to show that like poles, repel and opposite poles attract. Teacher spoke to the group as a whole. She said, "Which types of materials are attracted to a magnet?" She said, "Predict first. Write down in your chart. Paper clip". The lesson is very teacher directed. Students took a long time to write paper clip. Some students with group of 10 finish sooner than others and then they just wait. During whole group

		instruction students are engaged. Constant teacher feedback and constant teacher directive. Teacher said, "Do you guys remember what aluminum foil did with conducting electricity. Let's see if it attracts to the magnet." Teacher also helped students with spelling and grammar. Students wrote down there predictions. Completion took longer because students had to wait on each other. 5/10 people were not engaged. Engagement is on and off depending on whether the demonstration is whole group or with individual students. Teacher said a student was not paying attention. Teacher posed, "Did penny conduct electricity". Is everything that conducts electricity, magnetic?" Students responded, "No." Teacher was able to scaffold to facts learned during electricity lesson, 2 days ago.
7	**50 min**	**Virtual Lab-Magnets**
		Students logged into Cyber Lab Magnetism. Students with Virtual Lab worked well with each other in pairs to complete the lab questions. Students asked, "Does iron stick?, Does copper stick?" "Maybe we are using the wrong pole", a student said. Students trouble shoot on their own or with their partner. Students relied heavily on their partner for feedback from the lab. Students followed directions as they were on the lab sheets. At any given time 10 out of 10 students were engaged. One student asked, "Do you see a pattern?" Instead of asking teacher for help, students relied on themselves and their classmates for help.
8	**50 min**	**Traditional Lab-Weight and Mass**
		Students were given a scale to find the mass of various objects. Teacher followed the lab manual with the students so that they can find the mass of various objects using a balance scale. Students relied on the teacher to read the questions and review answers. The teacher showed the students how to use the balance scale and how to add weights to balance the scale. When teacher posed high order or low order questions, 5 out of 10 students raise their hand at any given time. Teacher said, "What is the best mass to use to find the weight of a 4th grader?" 5 out of 10 students raised their hands. Teacher then said, "To find the weight for average 4th grader grams is very small." Students said, "We need something bigger than grams." Teacher told students to double grams to get pounds. "1KG=2pounds, 2kg=4pounds, and 5kg= 10 pounds." Teacher said, "An average 4th grader should be a little over 30kg". Teacher said, "What is the best estimate for the weight

		of a handful of grapes. Student said, "Would it be 7000grams"?
8	**50 min**	**Virtual Lab-Weight and Mass**
		Students conducted the weight and mass lab. One of the questions on the lab was, "What is the difference between a pound and kg which one is bigger?" Students quickly found the lab, Weight and Mass and began working on it in pairs together. Students relied totally on each other to obtain answers. They even showed each other how to arrive at the answer using virtual lab equipment. The experiment that they conducted was "Look at the dog weight on Jupiter." All students were engaged for the duration of the lab and relied on each other. They showed each other how to do the experiment. Students even corrected other students' behavior. Students relied on each other for help. Virtual labs were student directed, paced and students supplied their own feedback to each other.

APPENDIX C

IRB Approval Letter

ST. JOHN'S UNIVERSITY

MEMO

Institutional Review Board
Federal Wide Assurance: FWA00009066

Date: March 27, 2018

To: Nathlye Sudlow-Naggie

CC: Dr. Seokhee Cho

Dr. Raymond DiGiuseppe
Chair, Institutional Review Board
Tel 718-990-1955
digiuser@stjohns.edu

Dr. Marie Nitopi
IRB Coordinator

Protocol # 0217-161
Protocol Title: Evaluation of Effects of Virtual Science Laboratory Activities on Science Learning for Improvement of Students' Achievement in Science

Please be advised that your human subject amendment application (dated 3/2/18) has been reviewed and approved by the Institutional Review Board (IRB). You are free to begin your project with these new revisions.

As a reminder, STJ-IRB approval of research projects is valid for one year only from the original date of approval. Beyond this period, a new proposal must be submitted.

If you have any questions, please do not hesitate to call me or Marie Nitopi, IRB Coordinator at 718-990-1440.

Best wishes for successful pursuit of this research.

****It is imperative that you keep this on file where it can easily be accessed. You will need to provide copies of this document when involved in further correspondence with the IRB. The IRB will provide you with an additional copy of this document only in the case of an emergency.****

APPENDIX D

Child Assent Form

Nathlye Naggie, M.ED.
Doctoral Student, Educational Leadership
: [redacted] Sullivan Hall 408,
St. John's University 8000 Utopia Parkway Jamaica, N.Y. 11439

Child Assent Form-Control Group
(To be read aloud to children)

My name is Ms. Sudlow-Naggie. I am a doctoral student at St. John's University, and I also work with parents and students. I do research to help children be better at science. Would you like to do better in science subjects? If you do, then we want to help you!

I would like to know how you learn and how well you can do in Science. Please do the followings.

1) Answer surveys on what you think about yourself, school, and your learning of science and technology for about 30 minutes; and
2) Participate in VISUAL-Virtual Interactive Science Universal Activities Laboratory

You may be thinking: *Will my teacher, parent, or classmates know how well I do on these tests*? Don't worry, they will NOT know how you do on any of these tests, so just do your best! You should know this study may ask you some hard or challenging questions related to new math concepts that you cannot answer, which may make you uncomfortable. If you are really worried about that, you do not have to participate. Even if you agree to join now, you may decide not to continue later, which is fine also. Your parents already gave permission for you to participate, *but* the final choice is up to you. Saying *yes* or *no* will not change your regular school grades or change whether your teacher likes you more. If you have any other questions about the project, you can always ask your teacher or me.

Remember, by participating in the project, you might be able to learn better problem solving strategies. You may even be able to find new or different ways to solve math problems! So what do you think – would you like to be in the project?

Please check one:
___ Yes, I would like to be in the project.
___ No, I will NOT participate in the project.

Is it ok for us to record your interview? ____ Yes, it's ok. ____ No, it is not ok.

Student signature: ____________________________

APPENDIX E

Parent/Guardian Consent Form

Nathlye Sudlow-Naggie M.ED
Doctoral Student, Educational Leadership
[redacted]

Parental/Guardian Consent Form-Treatment Group

Dear Parent or Guardian:

Your child has been invited to take part in You are invited to take part in a Project VISUAL - Virtual Interactive Science Universal Activity Laboratory, a research study to improve your students' science test scores. The purpose of this three month study is to find out the effects of virtual interactive science laboratory activities on your students in grade 4 Science. Specifically, the study examines the effects of VISUAL on improving students' academic achievement, students' motivation for learning and students' efficacy. This study will be conducted by me.

In this project your child will be asked to respond to survey questions on how they learn in science and technology. If you believe your child feels uncomfortable in responding to the questions or in being interviewed or feel that your child's best effort will not be put forth for this study, you may refuse to have him or her participate in the research. Your child also has the right to skip or refuse to answer any questions within the study. Please know that your decision to have your child participate or withdraw will not affect his or her academic standing in the class. Also, participation in this study will not interfere with or reduce any class time devoted to your child's regular education; rather, this study will supplement the math learning and will take place mainly during the school's designated extended period.

If you give permission for your child's participation in this study, your child will be asked to do the followings:

- Complete a survey about their demographic background and learning characteristics; and
- Participate in VISUAL-Virtual Interactive Science Universal Activities Laboratory.

I will request New York City Department of Education to provide your child's scores Science tested by the New York State. I will administer a survey at the school <u>during the available non-instructional time</u>. I will keep all research records, that can identify your child confidential as required by law. Such data will be accessible only by an authorized research team member (me). Any publication of research findings will maintain confidentiality of children's identities.

For questions about the Project VISUAL, your child's participation, or to report a research-related problem, [redacted]

For questions about your child's rights as a research participant, you may contact the Human Subjects Review Board, St. John's University, at 718-990-1440.

Thank you for your time and consideration.

Sincerely,

Nathlye Naggie, M.ED.

Please fill out below and tear off at the dotted line. Return the bottom portion to the teacher and retain the top portion for your record.

Parental/Guardian Consent Form

Please check one:

____ I give permission for my child to participate in the program.
____ I DO NOT give permission for my child to participate in the program.

Name of child	*Parent's signature*	*Date*

APPENDIX F

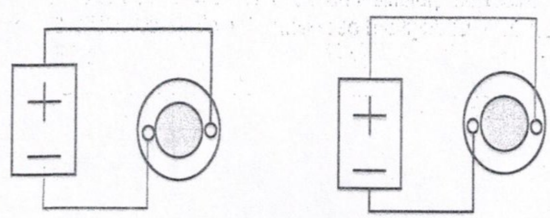
Sample Traditional Lab

Team Name: TRADITIONAL Date: ______________

Completing the Circuit Worksheet Answers

1. In the space below, draw two ~~ways to~~ light the bulb. Use the symbols below.

There are four different ways to set it up to light the bulb. Switch the wires for two of the ways to light the bulb, switch the battery around for the other two.

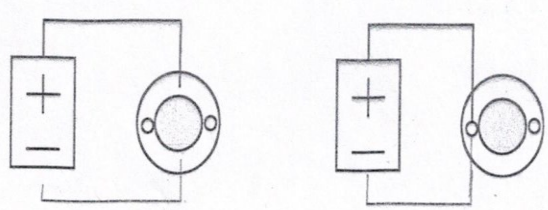


2. What do you have to do to get the bulb to light up?

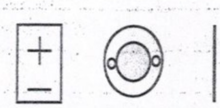
To get the bulb to light, the circuit must be closed; connect the battery + side to one side of the bulb holder and the battery – side to the other side of the bulb holder.

3. Draw two ways to connect the bulb, battery and wire so the bulb does not light. Use the symbols below.

There are *many* different ways to set it up so the light the bulb does <u>not</u> light up. See two examples below.



4. Choose the right answer to complete the sentence:
There will be an electric current in ___*a closed*___ circuit.
   A. an open
   B. a closed
   C. a big
   D. a long



Team Name: ______________________ Date: __________

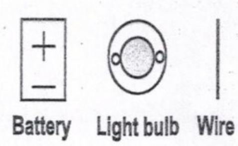
Completing the Circuit Worksheet

1. In the space below, draw two ways to light the bulb. Use the symbols below.

2. What do you have to do to get the bulb to light up?

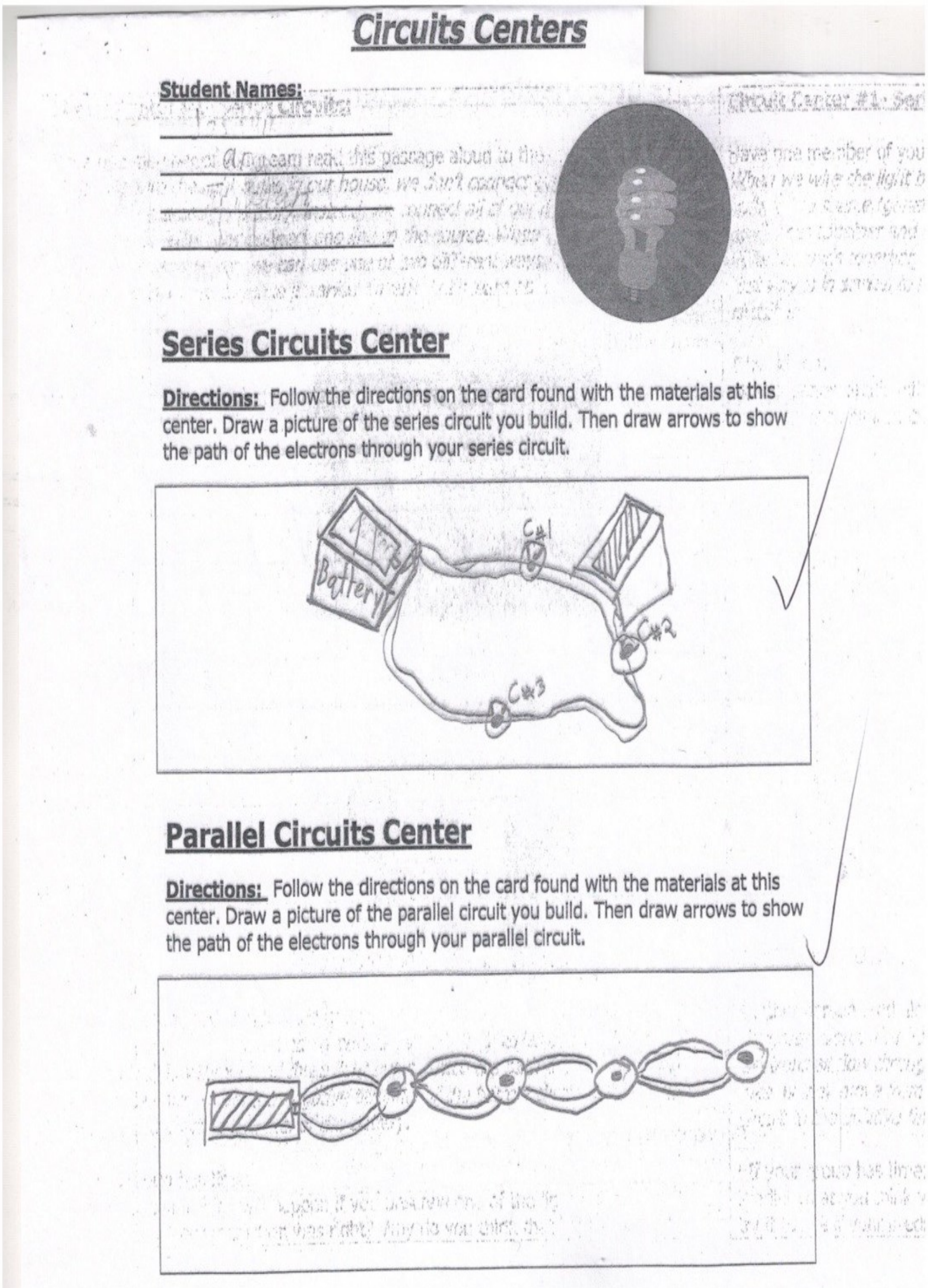
3. Draw two ways to connect the bulb, battery and wire ~~so~~ the bulb does not light. Use the symbols below.

4. Choose the right answer to complete the sentence:
   There will be an electric current in ____________ circuit.
   A. an open
   B. a closed
   C. a big
   D. a long



APPENDIX G

Sample Student Work (Traditional Lab)



Circuits Centers

Student Names:

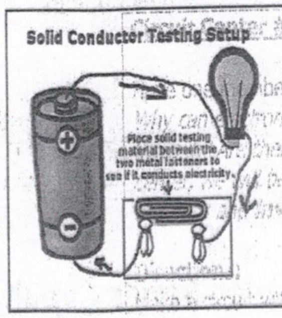
Series Circuits Center

Directions: Follow the directions on the card found with the materials at this center. Draw a picture of the series circuit you build. Then draw arrows to show the path of the electrons through your series circuit.

Parallel Circuits Center

Directions: Follow the directions on the card found with the materials at this center. Draw a picture of the parallel circuit you build. Then draw arrows to show the path of the electrons through your parallel circuit.

Conductors and Insulators Center:



Directions: Follow the directions on the card found with the materials at this center. Predict which objects will conduct electricity. Then place the object between the fasteners and record which objects lit up the light bulb. HINT: Remember that if the object is a conductor, electricity CAN easily flow through it so the light bulb will light. If an object is an insulator, electricity CANNOT easily flow through it so the light bulb will not light.

Name of Object	Material of Object	Prediction:		Actual:	
		Conductor	Insulator	Conductor	Insulator
Paper clip	Metal	✓		✓	
Penny	Copper	✓		✓	
Icy Spoon/pick	wood		✓		✓
Magnet	metal		✓		✓
Spoon	plastic		✓		✓
rubber band	rubber		✓		✓
foil	alluminum	✓		✓	
Nickel	metal	✓		✓	
nail	metal		✓	✓	

What did this investigation tell you about conductors?

This investigation tells use that only some objects work as conductors like paper clips, pennys, Magnets, foil, nickels, and nails they all work because they are all metal.

APPENDIX H

Sample of Student Work (Virtual Lab)

ExploreLearning **Gizmos**

Name: [redacted] Date: [redacted]

[redacted]

Student Exploration: Weight and Mass

Vocabulary: balance, force, gravity, mass, newton, spring scale, weight

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)

1. Your **weight** is the pull of **gravity** on your body. Suppose you step on a bathroom scale on the Moon. How would your weight on the Moon compare to your weight on Earth?

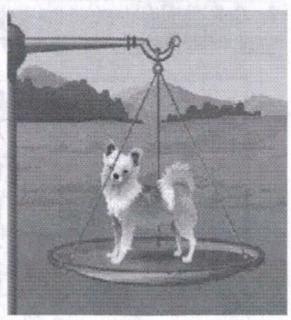
   A. greater on the Moon (B.) less on the Moon C. same on Earth and the Moon

2. Your **mass** is the amount of matter, or "stuff," in your body. How would your mass on the Moon compare to your mass on Earth?

   A. greater on the Moon (B.) less on the Moon (C.) same on Earth and the Moon

Gizmo Warm-up

On the *Weight and Mass* Gizmo™, you can use a **balance** to compare the masses of objects.



1. Place the **dog** on the right pan of the balance. What happens? the left side goes up

2. Place the **5-kilogram (kg) mass** on the other pan. Which has more mass, the dog or the 5-kg mass? The 5-kg mas

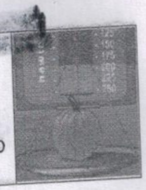
3. The 5-kg mass is heavier than the dog, so take it off the pan and place a 1-kg mass on the pan. Add 1-kg masses to the left pan until it goes down. Then take one of the 1-kg masses off the pan so that the masses are above the dog.

4. Use this process of adding and subtracting other masses from the left pan until the two pans are balanced. Add up all the masses on the left pan. This is equal to the mass of the dog.

   What is the mass of the dog? 2 kg and 360 gm

   You can check your answer by clicking the center of the cross beam of the balance.

[redacted]

Activity A: Weight on different planets	Get the Gizmo ready: • Click [redacted]ear scales [redacted]emove all objects from the spring scale and the balance. • Click the center of the cross beam of the balance to turn off the mass display.	

Introduction: A **spring scale** is used to measure **force**. Since weight is a type of force, a spring scale can measure weight. The metric unit of force is the **newton** (N).

Question: Will an object's weight change on different planets?

1. Measure: Place the **pumpkin** on the spring scale. Click the red line on the scale to see the weight measured to the nearest newton.

   What is the weight of the pumpkin? 30.0

2. Predict: If you take an object to a different planet, do you think its weight will stay the same or be different? (Circle your answer.)

   Same   (Different)

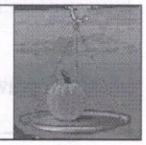
3. Collect data: Measure the weights of the following objects on Earth, the Moon, Mars, and Jupiter. Record your measurements in the data table below.

	Pumpkin	Dog	Watermelon
Weight on Earth	30.0N	23.2N	96.5N
Weight on Moon	5.0N	3.8N	16.0N
Weight on Mars	11.4N	8.8N	36.5N
Weight on Jupiter	75.9N	58.8N	244.2N

4. Analyze: Does the weight of an object change when it is moved to a different planet?

   Yes it does depending on gravitational pul

5. Extend your thinking: Which celestial body had the strongest gravity, Earth, the Moon, Mars, or Jupiter? Explain how you know. Jupiter because the weights of the object on Jupiter are the heaviest meaning it has the strongest gravity

Activity B: Mass on different planets	Get the Gizmo ready: • Click **Clear scales.**	

Question: How do weight and mass change on different planets?

1. Predict: If you take an object to a different planet, do you think its mass will stay the same or be different? (Circle your answer.)

   (Same) Different

2. Collect data: Use the balance to measure the masses of the following objects on Earth, the Moon, Mars, and Jupiter. Record your measurements in the data table below.

	Pumpkin	Dog	Watermelon
Mass on Earth	3060g	2370g	9850
Mass on Moon	3060g	2370g	9850
Mass on Mars	3060g	2370g	9850
Mass on Jupiter	3060g	2370g	9850

3. Analyze: Does the mass of an object change when it is moved to a different planet?

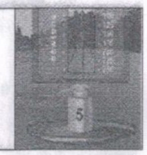
   No it doesn't

4. Draw conclusions: Based on what you have learned about mass and weight, why do you think the mass did *not* change but the weight did? Mass didn't change because when you measure mass it already goes down, weights change with gravity.

5. Extend your thinking: First, using the balance, find the *mass* of a pumpkin on Jupiter. Then place the pumpkin on the spring scale and record its *weight*. Finally remove the pumpkin and weigh the masses from the balance on the spring scale. How do the weights compare?

   The weights compare by on being smaller

Extension: Force of gravity	Get the Gizmo ready: • Click **Clear scales.**



Question: How strong is gravity on Mars, Jupiter, Earth, and the Moon?

1. Observe: Using the spring scale, measure the weights of objects on different planets. List the three planets and the Moon from strongest gravity to weakest.

   Strongest jupiter, earth, mars, moon Weakest

2. Predict: On which planet or moon do you think the 5-kg mass will weigh the most? Least?

   The most on Jupiter and the least on the moon

3. Collect data: Find the weight of the 5-kg mass at each location.

	Earth	Moon	Mars	Jupiter
Weight of 5-kg mass (N)	49.0N	8.1N	18.6N	123.9N

   Was your prediction correct? yes

4. Calculate: Weight depends on mass and the strength of gravity. Estimate the strength of gravity on each location by dividing the weight of the 5-kg mass by 5.

	Earth	Moon	Mars	Jupiter
Strength of gravity (weight of 5-kg object ÷ 5)	9.4	16.1	37.1	24.74

5. Calculate: First measure the mass of the flowerpot in the Gizmo. Then predict the weight of the flowerpot on each planet (multiply the mass by that planet's strength of gravity). Finally check your predictions by actually weighing the flowerpot on each planet, using the Gizmo.

	Earth	Moon	Mars	Jupiter
Flowerpot mass (kg or g)	4270	4270	4270	4270
Predicted flowerpot weight (N)	40.0N	10.9N	18.8N	126.7N
Measured flowerpot weight (N)	41.8N	6.9N	15.8N	107.9N

APPENDIX I

Approval Letter from Principal

March 20, 2018

Dear IRB Committee:

This letter is to inform you of my approval of Nathlye Sudlow-Naggie to conduct her study at the [redacted] Her study, the Evaluation of Effects of Virtual Science Laboratory Activities on Science Learning for Improvement of Student's Achievement in Science, will examine the effects of virtual science laboratory on improving students' academic achievement, students' motivation for learning and students' efficacy.

If I have any more questions about her project I will contact her or her mentor, at [redacted]8 or Dr. Seokhee Cho at chos1@stjohns.edu, 718 990 1303 respectfully. I look forward to having Nathlye conduct her study with [redacted]

[redacted]

Principal

[redacted]

APPENDIX J

Students Motivation Towards Science Learning Questionnaire

Appendix 1: the SMTSL questionnaire

Directions for students

This questionnaire contains statements about your willingness in participating in this science class. You will be asked to express your agreement on each statement. There are no "right " or "wrong" answers. Your opinion is what is wanted. Think about how well each statement describes your willingness in participating in this class.

Draw a circle around

1. if the statement you strong disagree
2. if the statement you disagree
3. if the statement you have no opinion
4. if the statement you agree
5. if the statement you strong agree

Be sure to give an answer for all questions. If you change your mind about an answer, just cross it out and circle another.

Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements.

Your Name___________; Teacher's Name___________
School___________; Grade___________ ;Male_____ Female_____
Science Class; Biology_____ Physical Science_____

A. Self efficacy	Strongly disagree	Disagree	No opinion	Agree	Strongly agree
1. Whether the science content is difficult or easy, I am sure that I can understand it.	1	2	3	4	5
2. I am not confident about understanding difficult science concepts.(–)	1	2	3	4	5
3. I am sure that I can do well on science tests.	1	2	3	4	5
4. No matter how much effort I put in, I cannot learn science.(–)	1	2	3	4	5
5. When science activities are too difficult, I give up or only do the easy parts.(–)	1	2	3	4	5
6. During science activities, I prefer to ask other people for the answer rather than think for myself. (–)	1	2	3	4	5
7. When I find the science content difficult, I do not try to learn it (–)	1	2	3	4	5

23. I participate in science courses so that other students think that I'm smart.(–)	1	2	3	4	5
24. I participate in science courses so that the teacher pays attention to me.(–)	1	2	3	4	5
E. Achievement Goal	**Strong disagree**	**Disagree**	**No opinion**	**Agree**	**Strong agree**
25. During a science course, I feel most fulfilled when I attain a good score in a test.	1	2	3	4	5
26. I feel most fulfilled when I feel confident about the content in a science course.	1	2	3	4	5
27. During a science course, I feel most fulfilled when I am able to solve a difficult problem.	1	2	3	4	5
28. During a science course, I feel most fulfilled when the teacher accepts my ideas.	1	2	3	4	5
29. During a science course, I feel most fulfilled when other students accept my ideas.	1	2	3	4	5
F. Learning Environment Stimulation	**Strong disagree**	**Disagree**	**No opinion**	**Agree**	**Strong agree**
30. I am willing to participate in this science course because the content is exciting and changeable.	1	2	3	4	5
31. I am willing to participate in this science course because the teacher uses a variety of teaching methods.	1	2	3	4	5
32. I am willing to participate in this science course because the teacher does not put a lot of pressure on me.	1	2	3	4	5
33. I am willing to participate in this science course because the teacher pays attention to me.	1	2	3	4	5
34. I am willing to participate in this science course because it is challenging.	1	2	3	4	5
35. I am willing to participate in this science course because the students are involved in discussions.	1	2	3	4	5

Note: (–) represent reverse items.

B. Active learning strategies	Strong disagree	Disagree	No opinion	Agree	Strong agree
8. When learning new science concepts, I attempt to understand them.	1	2	3	4	5
9. When learning new science concepts, I connect them to my previous experiences.	1	2	3	4	5
10. When I do not understand a science concept, I find relevant resources that will help me.	1	2	3	4	5
11. When I do not understand a science concept, I would discuss with the teacher or other students to clarify my understanding.	1	2	3	4	5
12. During the learning processes, I attempt to make connections between the concepts that I learn.	1	2	3	4	5
13. When I make a mistake, I try to find out why.	1	2	3	4	5
14. When I meet science concepts that I do not understand, I still try to learn them.	1	2	3	4	5
15. When new science concepts that I have learned conflict with my previous understanding, I try to understand why.	1	2	3	4	5
C. Science Learning Value	**Strong disagree**	**Disagree**	**No opinion**	**Agree**	**Strong agree**
16. I think that learning science is important because I can use it in my daily life.	1	2	3	4	5
17. I think that learning science is important because it stimulates my thinking.	1	2	3	4	5
18. In science, I think that it is important to learn to solve problems.	1	2	3	4	5
19. In science, I think it is important to participate in inquiry activities.	1	2	3	4	5
20. It is important to have the opportunity to satisfy my own curiosity when learning science.	1	2	3	4	5
D. Performance Goal	**Strong disagree**	**Disagree**	**No opinion**	**Agree**	**Strong agree**
21. I participate in science courses to get a good grade. (–)	1	2	3	4	5
22. I participate in science courses to perform better than other students. (–)	1	2	3	4	5

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VITA

Name	*Nathlye Sudlow-Naggie*
Baccalaureate Degree	*Bachelor of Arts*, *Hunter College, CUNY, NY*
	Major: Chemistry
Date Graduated	*December, 1995*
Master's Degree	*Master of Science, Adelphi University, Garden City NY,*
	Major: Biology and Secondary Education 7-12 grades
Date Graduated	*August, 1999*
Certificates	*Professional Diploma, Queens College, CUNY, NY*
	Major: Administration and Supervision
Date Graduated	*February, 2002*