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Cognitive knowledge, attitude toward science, and skill development in virtual science labratories

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COGNITIVE KNOWLEDGE, ATTITUDE TOWARD SCIENCE, AND SKILL DEVELOPMENT IN VIRTUAL SCIENCE LABORATORIES

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DEDICATION

This dissertation is dedicated to several people who encouraged me to start, continue, and finish this life long journey.

My family members’ love and support made it possible for me to reach the finish line and complete this great journey.

My lifelong partner, Hashem, who was with me every step of the way and never stopped encouraging me throughout this journey.

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EDUCATIONAL INTERESTS

- Virtual Learning Environments (VLEs)
- Virtual Science Laboratories (VSLs)
- Science education
- Inquiry learning

ABSTRACT

The purpose of this quantitative, descriptive, single group, pretest posttest design study was to explore the influence of a Virtual Science Laboratory (VSL) on middle school students' cognitive knowledge, skill development, and attitudes toward science. This study involved 2 eighth grade Physical Science classrooms at a large urban charter middle school located in Southern California. The Buoyancy and Density Test (BDT), a computer generated test, assessed students' scientific knowledge in areas of Buoyancy and Density. The Attitude Toward Science Inventory (ATSI), a multidimensional survey assessment, measured students' attitudes toward science in the areas of value of science in society, motivation in science, enjoyment of science, self-concept regarding science, and anxiety toward science. A Virtual Laboratory Packet (VLP), generated by the researcher, captured students' mathematical and scientific skills. Data collection was conducted over a period of five days. BDT and ATSI assessments were administered twice: once before the Buoyancy and Density VSL to serve as baseline data (pre) and also after the VSL (post). The findings of this study revealed that students' cognitive knowledge and attitudes toward science were positively changed as expected, however, the results from paired sample *t*-tests found no statistical significance. Analyses indicated that VSLs were effective in supporting students' scientific knowledge and attitude toward science. The attitudes most changed were value of science in society and enjoyment of science with mean differences of 1.71 and 0.88, respectively. Researchers and educational practitioners are urged to further examine VSLs, covering a variety of topics, with more middle school students to assess their learning outcomes. Additionally, it is recommended that publishers in charge of designing the VSLs communicate with science instructors and research practitioners to further improve the design and analytic components of these virtual learning environments. The results of this study contribute to the

existing body of knowledge in an effort to raise awareness about the inclusion of VSLs in secondary science classrooms. With the advancement of technological tools in secondary science classrooms, instructional practices should consider including VSLs especially if providing real science laboratories is a challenge.

Chapter 1: Introduction

The Digital Era and Science Education

In educational settings, computer technology and the Internet have opened new pathways of learning (Keengwe, Onchwari, & Wachira, 2008). With the increasing usage of computers and technology, students are becoming better and faster at using computers and the Internet. Today's students have been raised on a steady diet of technology; they are digital natives who are expected to use computers on a regular basis for a wide range of educational tasks (Robin & Sharon, 2011). The recent attention that educational technology has received has turned educators', practitioners', and researchers' focus toward the effects that these tools may have on student performance, both academically and behaviorally. Even though the use of technological tools such as educational games, online simulations, and virtual learning environments have increased in the field of education over the past few decades, educational researchers need to better understand how these technological tools can affect learning (Harasim, 2000). Changes in education policy regarding the implementation of educational technology have opened new avenues to instructional pedagogies. From Learning Management Systems (LMSs) to virtual avatars in digital games, virtual environments have found their way into educational systems. Virtual Learning Environments (VLEs) are computer-generated environments that allow participants to interact and communicate with their peers. One reason why educational communities accepted VLEs had to do with learners' and instructors' ability to communicate and interact with the objects in these environments (Kotsilieris & Dimopoulou, 2013). VLEs allow learners to visualize concepts that cannot be seen in real life. Students are able to view, interact, and experiment with certain visual effects, such as the molecular structure of compounds, that they may not see in their traditional face-to-face environment in a science classroom (Trindale, Fiolhais, & Almeida, 2002).

The word *science* refers to a body of knowledge and the process of obtaining information (Millar, 2004). Yager (1983) described science education as a discipline that fuses science and society. The sharing of discovered knowledge and knowledge that is yet to be discovered by the members of society is achieved through the process of science education. The aims of science education are as:

> (1) to help students to gain an understanding of as much of the established body of scientific knowledge as is appreciate to their needs, interests and capacities; (2) to develop students' understanding of the methods by which this knowledge has been gained, and our grounds for confidence in it. (Millar, 2004, p. 1)

Science education, with a basis in inquiry learning, could clearly benefit by using the technological capability afforded by VLEs. For instance, some of the chemistry concepts such as phases of matter require students to visualize the behaviors of water molecules that without specific materials or high-tech equipment, can be difficult for students to see and experience.

Though VLEs used in creating a graphical representation of such concepts have shown to increase student understanding, further research is necessary to determine whether the field of science education could benefit from the use of VLEs (Trindale et al., 2002). In placing emphasis on inquiry learning, educators are encouraged to follow science curricula that are composed of directed activities that are not effective in engaging students in learning (Pedersen & Irby, 2014). With the transformation in educational technology and advancement in technological tools, educators have not yet been able to benefit from this change to its fullest capacity (Cuban, Kirkpatrick & Peck, 2001). With emphasis on inquiry learning and content standards dictating what students need to know and be able to do, educators feel apprehensive about including technological tools and computers in their classrooms. One reason may be due to the emphasis placed on inquiry learning in secondary science and the process of conducting experiments in laboratories. Inquiry learning refers to various ways in which scientists study the world using scientific methods (Hofstein & Lunetta, 2004). In order for scientists to learn about the natural world, they need to observe, gather information, analyze findings, and state their conclusions, all while using the necessary tools during laboratories. According to Hofstein and Lunetta (2004), science laboratories are a crucial part of every science classroom and rich learning benefits result from participating in laboratory activities. Moreover, according to the National Science Education Standards' (NSESs') benchmarks for science literacy, students need to develop methods of inquiry as well as thinking skills that are similar to those used by scientists (Hofstein & Lunetta, 2004). These skills can be acquired via the well-planned laboratory activities that students perform in science classrooms.

Hofstein and Lunetta (2004), defined science laboratory activities as "learning experiences in which students interact with materials and/or with models to observe and understand the natural world" (p. 31). This assertion implies that in order to understand the nature of science (NoS), students ought to experience learning in laboratory settings where they can use tools and evidence to draw conclusions about the phenomena that they observe. The practice of going through a well-designed laboratory enables students to appreciate the process of gaining knowledge by navigating through a series of steps and using the available tools to complete the given tasks. The process through which every citizen undergoes in order to thrive in modern society is fundamentally based in the ability to make decisions. It is also important for every citizen to recognize the cause and effect relationship in the process of communicating opinions that makes science education a crucial part of any individual's educational experience (Marincola, 2006). In order for future generations to become independent thinkers, they need to think like scientists and understand how science functions as a part of their daily lives. The act of using available science laboratory equipment to conduct a laboratory experiment as well as make sense of what the results mean give students an opportunity to view science education as a process of learning and reflecting.

Using laboratory equipment to conduct experiments allows students to gain the 21st century skills necessary to become future problem solvers and active participants in society (National Science Teachers Association [NSTA], 2009). Moreover, science laboratories not only play a role in promoting positive attitudes toward science, but also enhance students' interest in science as well (Luketic & Dolan, 2013). Although making science laboratories part of everyday curriculum may sound appealing, many educators and practitioners face challenges when educational resources such as laboratory equipment become limited (Quigley, 2014). With the push to meet state standards and mandated testing sessions, secondary science educators have been left with only one choice when covering the mandated curriculum: eliminating laboratory experiences from their curriculum.

Aside from focusing on the science standards, increase in classroom sizes and limited classroom space have added to the obstacles educators face in instructional environments. A safety audit report conducted during academic school year of 2006-2007 in the Kansas City region indicated that more than 50% of middle and high school laboratories need more space and the majority of these science laboratories did not meet National Science Teachers Association (NSTA) safety standards (Roy, 2008). The barriers science educators face when trying to include science laboratories in their daily agenda reflect more than just monetary cost. Classroom size, safety test driven curriculum, and teachers' science background and preparation are also serious impediments to including science laboratory activities in middle and high school classrooms (Hamidu, Ibrahim, & Mohammed, 2014).

Although it is clear that laboratories are an important part of science education, increased class size, lack of necessary science laboratory equipment due to lack of funding, insufficient amount of time to prepare the laboratories, and shortage of experienced science teachers are all factors that have led to the decreasing frequency of such activities (Hamidu, Ibrahim, & Mohammed, 2014; Sun, Wang, Xie, & Boon, 2014). In spite of all of these obstacles in implementing science laboratories in secondary education, many researchers and practitioners still find that central laboratory activities play a pivotal role in students' scientific knowledge development, enhancing attitude, and providing motivating to learn science (Hofstein & Lunetta, 2004; Wong, Firestone, Luft, & Weeks, 2013).

Throughout the development period in the public education system, educational researchers have become aware of the connection science education has to other content areas and our lives outside of an educational settings. The quest to find answers to these questions requires individuals to take a series of steps that resemble methods used by scientists. However, science education is not just for scientists, but rather a way to teach critical thinking (Marincola, 2006). To help students to become scientifically literate, they must be engaged in activities that include experimentation, evaluation, and reflection. Scientific literacy refers to "one's understanding of the concepts, principles, theories, and process of science, and one's awareness of the complex relationships between science, technology, and society" (Abd-El-Khalick, Bell, & Lederman, 1998, pp. 417-418). Though activities such as science laboratories promote scientific thinking and "an appreciation of the construction of scientific assertion," (p. 1,230) their availability in most middle and high school settings is much lower than expected (Yacoubian & BouJaoude, 2010). The focus of this research will be to suggest how the use of a VLE to simulate the live laboratory experience could bridge this gap and ensure that all students have the opportunity to build critical reasoning and scientific thinking skills.

Virtual Learning Environments as Simulated Learning

Simulated learning refers to the learning that occurs in a simulated environment. In simulated environments, objects and tools are designed and represented visually to model and represent the real environment. Through their interactions with simulated environments, learners are given opportunities to make decisions, become part of an environment that is impossible to create in reality, and receive immediate feedback on their decisions (Smetana & Bell, 2012). Used in the fields of military preparation and health care education, simulations used in Virtual Learning Environments (VLEs) have subsequently found their way into the education system. Mikropoulos and Natsis (2011) defined VLEs as learning environments that are "based on a certain pedagogical model, incorporates one or more didactic objects, provide users with experiences they would otherwise not be able to experience in the physical world and redounds specific learning outcomes" (p. 770).

The inspiration behind designing VLEs emerged from the popularity of commercial gaming software that incorporated virtual environments, Virtual Reality (VR), into their designs. VR not only captured students' interests but also promoted learning among participants (Kontogeorgiou, Bellou, & Mikropoulos, 2008), which has inspired educational researchers since 1990 to design and create VLEs that promote learning. A study by Kontogeorgiou et al. (2008) concluded that participants' sense of presence played an important role in students' learning due to their ability to visualize and manipulate information in the virtual environment. With considerable attention given to the design of VLEs, educational researchers have examined different avenues by which students gain lifelong learning skills. For example, a study by Chen (2010) found that, although the presentation and interaction of materials are genuine and real in virtual laboratories, laboratory tasks are simplified for students in these environments. Concerns regarding overall learning outcomes of using VLEs have called for educational researchers' attention and clearly called into question whether or not VLEs can be as effective as real learning environments (Chou & Liu, 2005).

Virtual Science Laboratories

A computer simulation that enables essential functions of laboratory experiments to be carried out on a computer is called a Virtual Laboratory (VL); (Harms, 2000). Availability of VSLs in current science curricula and resources (e.g., McGraw-Hill's virtual laboratories at http://www.glencoe.com) offer science educators opportunities to expose students to the process of experimentation and inquiry. The visual representation of tools and equipment in VSLs resemble the artifacts students observe and utilize while conducting science experiments. In order to make students' VSL experience authentic, designers provide the tools and equipment needed to complete the experiment. From saving time and lowering expenses to minimizing ethical and safety issues, VSLs present a milestone in providing students with unlimited opportunities to experience scientific phenomena through experimentation and simulation.

Problem Statement

Unfortunately, due to the lack of time, school budget constraints, and focus on content-based standards, providing real, authentic science laboratories has become a struggle for many secondary schools. Without science laboratories, science instruction becomes purely factual and hypothetical, and the content under study becomes a series of steps that students have to memorize. The bigger problem results in students' lack of problem solving skills and interest in science-related career fields. New statistics in STEM education are very alarming. A report by Dieker, Grillo, and Ramlakhan (2012), stated that only 29% of eighth grade students performed at a proficient level in a nationwide test during the year of 2005. Due to students' low academic performance, STEM education has received a great deal of attention in regard to students' interest in STEM fields. These results will lead to bigger issues, such as losing economic status in industries that are driven by science-related fields. The decline in international test scores every decade presents an alarming wake up call for secondary science education.

With no time required for setting up, breaking down, or clearing equipment, VSL experiences can be integrated seamlessly into the instructional process without losing any time on housekeeping tasks (Jona & Adsit, 2008). With all of the advantages that VSLs have to offer, educators and practitioners still wonder about their educational outcomes and whether or not they can offer more than just a virtual world. Recent technological advancements have made VSLs highly accessible to K-12 educators. However, the effects of these tools have not yet been explored in middle school settings. Although prior research findings have demonstrated the effectiveness of VLs in higher education, little has been done to examine students' cognitive knowledge, skill development, and attitudes toward science in middle and high school science classrooms (Scalise et al., 2011). "Existing studies present conflicting and confusing findings about learning in simulated science environments" (Scalise et al., 2011, p. 1,054). Though some findings showed the improvement in students' educational performance in VSLs (Martinez-Jimenez, Pontes-Pedrajas, Polo, & Climent-Bellido, 2003), other researchers emphasize the importance of hands-on laboratories, where students interact with real laboratory equipment and acquire professional skills in order to use such equipment during experimentation (Ma &

Nickerson, 2006). Additionally, some studies also have suggested that VSLs are as effective as real science laboratories in providing students with environments that are easy to use and safe to conduct experiments in (Tatli & Ayas, 2013). Given the mixed findings about the effectiveness of VLs in secondary science classrooms, these technological tools are still not being implemented in science classrooms on a regular basis. The doubts about VSLs and their effects on students' learning have rendered these tools little more than supplemental curiosities that instructors may or may not use. More specifically, cognitive knowledge, attitude toward science, and attitude toward science with respect to VSLs have not yet been studied extensively in middle school science classrooms.

Purpose of Study

This study explored the influence of a Virtual Science Laboratory (VSL) on middle school students' cognitive knowledge, skill development, and attitudes toward science. Inspired by Bloom's domains of learning (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956), this study explored each for a selected science activity. Cognitive knowledge of specific science concepts; attitude toward science falls within the affective learning domain, and skill development such as mathematical and scientific skills signifies the psychomotor domain of learning (Kasilingam & Chinnavan, 2014).

The purpose of this descriptive, single group, pretest-posttest design study was to assess gains within each of Bloom's domains of learning outcomes following participation in a VSL for eighth grade students at Magnolia Science Academy # 6 charter middle school in Southern California. The VL focused on science content specific to principals of object mass and how mass affects whether the object will float or sink. Virtual equipment and materials within the laboratory enabled students to calculate various objects' density and predict the buoyancy of the objects. Four dependent variables were tested. First, cognitive knowledge gain was determined from pre and posttest scores. The second dependent variable, attitude toward science, was defined as a participant's behavior toward the subject of science, which was assessed prior to the activity and then again following completion of the activity. The third and fourth dependent variables were mathematics skills development and science skills development, respectively. Mathematical skills were defined as steps necessary to calculate objects' density. Scientific skills were defined as steps necessary to complete data observation and data collection. These skills were assessed by reviewing each individual student's recorded calculations and predictions during the virtual experience.

Research Hypotheses

This study attempted to demonstrate whether the amount or extent of improvement of cognitive knowledge, attitudes toward science, and skill development is stronger when today's middle school children are engaging with more technologically enhanced learning activities. Research hypotheses relate to each of Bloom's (2001) three domains of learning: cognitive knowledge, psychomotor skills, and affective domain. For knowledge and affective domain (attitudes), positive changes were anticipated from pretest to posttest and pre survey and post survey. Psychomotor skills were measured during the virtual activity. Study hypotheses include:

- H_1: Participating in Virtual Science Laboratories will improve cognitive knowledge.
- H_2: Participating in Virtual Science Laboratories will enhance students' attitude toward science.
    - H_{2a}: Participating in Virtual Science Laboratories will enhance students' enjoyment of science.

  - H_{2b}: Participating in Virtual Science Laboratories will enhance students' motivation toward science.
  - H_{2c}: Participating in Virtual Science Laboratories will enhance students' value of science in society.
  - H_{2d}: Participating in Virtual Science Laboratories will enhance students' self-concept of science.
  - H_{2e}: Participating in Virtual Science Laboratories will diminish students' anxiety toward science.
- H_3: Participating in Virtual Science Laboratories will affect mathematical skills.
- H_4: Participating in Virtual Science Laboratories will affect students' scientific skills.

Study Design

This descriptive, single group, pretest-posttest design study was conducted in a public middle school located in Southern California. The group involved two sections of an eighth grade science class purposely selected by the researcher. Each section had a common lesson plan, learning objectives, and instructor. The participants in this study were placed into sections of physical science by the administration team at the beginning of the academic school year; therefore, no randomization of students was possible. The independent variable in this study was a VL addressing the scientific concepts of buoyancy and density. The pretest-posttest design involved measurement of cognitive knowledge and attitudes prior to and after the VL experience. Skills were recorded manually by the individual student using a Virtual Laboratory Packet (VLP) during the VL activity. The researcher is a middle school science instructor and was the instructor of record for the two sections of physical science. The study was conducted at the same middle school where the researcher works.

Assumptions and Delimitations

Assumptions of the study included that participating students have a sufficient and common level of knowledge and experience with computers. This study focused on eighth grade students with similar socio-economic demographic background. The available technological tools were limited to those provided by the school in which the research study was conducted.

Student participants were enrolled in an eighth grade physical science class for the first time. The course included four units: Motion and Forces, Structure of Matter, Chemical Interaction, and Earth and Space. This study focused on the first unit of the course, Motion and Forces, and laboratory activities were conducted in a VSL.

Theoretical and Conceptual Foundation

Learning theory provides an applicable framework for studying the effects of VSLs on students' cognitive learning, skill development, and attitudes toward science. Each learning domain is essential in science education. For cognitive knowledge and skill attainment, a constructivist learning perspective is taken. The constructivist theory of learning, developed by Jean Piaget, has been used commonly in science classroom settings (Narli, 2011). The constructivist learning theory is a theoretical approach that explains how learners construct new knowledge and skills by interacting with their environment and using their prior knowledge (Lord, 1998). In a learning environment where the constructivism learning theory is practiced, individual learners construct or modify existing knowledge by initially making an interpretation of new experiences until they have constructed a personal view or understanding about the new information (Karagiorgi & Symeou, 2005). What learners experience and interact with in a learning environment shapes their understanding and beliefs about new ideas and knowledge. Developing a positive attitude toward the content of science and learning why the concepts are applicable to their lives allow the learners to become aware of the value of the content being discussed and as a result become engaged in the process of learning. When engaged and motivated, students look for ways to find answers to their questions in which they will construct their own understanding about a particular scientific concept. They do not necessarily have to rediscover scientific concepts, but in turn build and construct their own understandings about the scientific concept. "We learn through a continual process of constructing, interpreting, modifying of our own representation of reality that is based on our experiences with reality" (Harper, Hedberg, & Wright, 2000, p. 164). Through their daily experiences, scientists discover patterns that shape their own understanding about a scientific phenomenon; this teaching strategy promotes active learning. The constructivism theory of learning allows students to participate actively in activities, construct new knowledge, and gain an understanding about the content under study (Kim & Reeves, 2007). When students are actively seeking answers to the questions they might have about various concepts, they are building new knowledge in a relevant way to which they can relate. In this case, the knowledge is not constructed by the teacher, but rather by the students.

When applied to educational settings, constructivism learning theory identifies learners as individuals that construct knowledge by asking questions and proposing solutions (Yilmaz, 2008). With its popularity in science education and curriculum development, constructivism learning theory involves experiential and discovery learning as well. More specifically, knowledge comprehension through inquiry learning suggests that learners are independent thinkers that take necessary steps to find answers to their questions. The process of learning from a failed science experiment and reflection on experiences reveals the importance of learners' experiences in learning environments and how they can lead to the construction of new knowledge or the modification of existing knowledge.

One conceptual area of the study involves simulation-based learning through the use of a Virtual Learning Environment (VLE). A virtual environment is defined as one "that is based on a certain pedagogical model, incorporates or implies more didactic objectives, provides users with experiences they would not otherwise be able to experience in the physical world" (Mikropoulos & Natsis, 2011, p.770). In secondary science classrooms, it is not possible for students to fly to space and analyze atmospheric composition of planet Earth, so educators must find alternative ways to allow their students to interact with this concept. The essential piece in a VLE is learners' presence or users' "sense of being there" (Mikropoulos & Natsis, 2011, p. 770). Computers being identified as cognitive tools and as a gateway to VLEs have extended human capabilities in cognition (Kim & Reeves, 2007). These environments are simulations of reality that allow learners to complete the required tasks or activities similar to those in physical learning environments. Learners in such environments use the tools available to them in order to conduct experiments by collecting data, re-doing part of the experiments, and practicing skills such as inquiry. VLEs are considered to be meaningful environments because they are authentic, constructive, and interactive (Mundkur & Ellickson, 2012). Furthermore, a study by Morton Uhomoibhi (2011) indicated that VLEs create a student-centered space where learners are able to take ownership for their learning. Although laboratory settings have previously provided these experiences, the costs and limitations are no match for the possibilities that technology has created.

VSLs have opened new doors and created opportunities for students to conduct experiments that may be difficult to conduct in traditional science laboratories. In VLEs such as a VSL, students' interactions with the simulations may hinder facilitators' guidance and interaction (Ma & Nickerson, 2006). As a result, researchers and practitioners wonder about the effectiveness of VLEs in comparison to traditional learning environments. In VLEs, instead of interacting with a real laboratory environment, participants interact with a simulation that represents a real laboratory environment. A key question is whether a VLE can be as effective as real learning environments in promoting students' knowledge comprehension and skill development.

Inquiry, discovery, and experiential learning theories have received considerable attention from science educators and practitioners. Practicing inquiry learning in VSLs has made these technological tools an effective learning environment where students become engaged with the scientific content (Ketelhut & Nelson, 2010). What students experience and discover in a science laboratory may impact their attitude toward science and ultimately influence their performance in secondary science. In this learning process, science becomes a collection of experiences that engage students in practices that can lead to discovery learning; learners will have opportunities to become more aware of the NoS and their own thinking (Houseal & Ellsworth, 2014).

Attitudes toward a topic or instructional approach can influence the way knowledge is comprehended and constructed (Pyatt & Sims, 2012). In the secondary science classroom, students are expected to actively question, analyze, and discuss new ideas in order to make sense of them and generate their own understanding about the concept that is being discussed. Having a positive attitude toward the subject being discussed will not only enhance students' motivation, but also provide students with a sense of being connected to the topic being discussed. The Nature of Science (NoS) requires students to engage in thinking and asking meaningful questions. To master these skills, students need to stay motivated and engaged during class time. Engaged learning is generally defined as a situation in which learners are active in their learning and student activities involve active cognitive processes (Iqbal, Kankaanranta, & Neittaanmäki, 2010). When students are engaged and participating in the classroom, they are active learners and stay motivated throughout the lesson. Another study by Smith and Cardaciotto (2011) concluded that active learning leads to a variety of positive outcomes, including better student attitudes, greater motivation, improvements in students' thinking and writing, greater memory for information taught, and improved exam performance.

Motivated students are more likely to pay attention during course activity, take time to use effective learning and studying strategies, and seek help from others when needed (Jones, 2009). After reading many similar reviews, it is possible to assert that most educators look for ways to improve students' attitudes toward their subject matter; this will help students stay on task, participate in class discussions, and ultimately improve their content literacy. Engagement refers to active involvement, commitment, and concentrated attention, in contrast to superficial participation, apathy, or a lack of interest (Park, 2005).

Definitions of Terms

Constructivist learning: A method of generating and constructing knowledge as a result of interactions between what is known (prior knowledge) and the new knowledge with which one comes into contact (Richardson, 2003).

Cognitive Constructivist learning: A process of individuals' knowledge constructing at various levels of cognitive development through the stages of self-organization (Ackermann, 2001).

Cognitive knowledge: Intellectual processes that involve remembering, understanding, and recalling knowledge (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956), where knowledge is described as “organized bodies of information” (Gagne, 1972, p. 8). In this research, cognitive knowledge will be measured using the BDT multiple-choice questions that are extracted from McGraw-Hill’s TestGen®, a computerized Test Bank from Exam View.

Socio-Constructivist learning: An approach to learning in which learners construct knowledge through their interactions with peers by using languages that are mediated by culture (Kanselaar, 2002).

Constructionist learning: A method of learning in which learners build relationships between prior knowledge and new knowledge through interaction with others, creating tangible artifacts or objects (Kafai, 2006).

Inquiry learning: Involves a series of authentic activities that involve observation and the examination of phenomena through the lens used by scientists to evaluate and communicate their discoveries (Kubieck, 2005).

Discovery learning: A system of learning when learners are not provided with target information; instead, they seek the information independently with the materials provided to them (Alfieri, Brooks, Aldrich & Tenenbaum, 2011).

Experiential learning: “A process whereby knowledge is created through the transformation of experience” (Kolb, 1984, p. 41).

Simulation learning: Experiential instructional technique used in simulated learning environments that use technological tools to create significant features of a real learning environment (Rutten, van Joolingen, & van der Veen, 2012).

Virtual Learning Environment (VLE): A computerized, 3D space that promotes interactive and meaningful opportunities to enhance learning and comprehension (Dillenbourg, Schneider, & Synteta, 2002).

Traditional science laboratory: Instructional environment equipped with science related tools and instruments to conduct science experiments.

Virtual Science Laboratories (VSLs): Computerized 3D learning environments that simulate the real science laboratory space and allow students to use scientific equipment to conduct experiments. In this study, the specific scientific content of the VSL is focusing on buoyancy and density.

Science Attitudes: An individual's behavior, emotion, and belief toward an object or a phenomenon. In this research, attitudes toward science will be measured using the ATSI, an established tool that measures five specific areas of attitudes (Weinburgh, 2000).

Mathematical skills: "Tasks involving ranking numbers, translating numbers from one representation to another, quantity discrimination, as well as more complex number skills such as arithmetic computation" (Alloway & Passolunghi, 2011, p. 134). Students in this study will record their mathematical calculations in a laboratory packet.

Science skills: Steps involving manipulation of laboratory equipment, instruments, and tools to carry out observation, data collection, and data analysis. Students in this study will record scientific predictions in a laboratory packet.

Significance of the Study

Science laboratories are an important part of science education, as they significantly influence students' learning by helping them develop scientific reasoning and ultimately enhancing students' cognitive outcomes (Luketic & Dolan, 2013). In science laboratories, students use tools and equipment in order to experience thinking and working like a scientist by conducting experiments, collecting data, and analyzing findings. Given the importance of science laboratories and their role in the world of inquiry learning, it is clear that such environments should not only be commonplace in science curriculum, but also become part of the daily agenda in secondary science classrooms. VSLs have shown positive effects on students' learning where students who participated in VSLs scored higher in their post assessment tests (Yang & Heh, 2007).

Though little is known about the potential of virtual environments in students' learning process, the results from a study by Chou and Liu (2005) concluded that students in technology-mediated VLEs scored higher on their midterms and final assessments than students in traditional classroom settings. Additionally, VLEs have transformed science education and engaged students in inquiry activities where they took ownership over their learning goals (Pedersen & Irby, 2014). VSLs could offer more than just a virtual environment. Although these technological tools have been used wildly in secondary science classrooms, their potential in enhancing cognitive knowledge, students' attitude toward science, mathematical skill development, and science skill development has not yet been studied in depth.

This research study will contribute to the pool of findings about the effects of VSLs on students' learning in secondary science classrooms. Since most of the current studies have focused on the use of VSLs in higher education, it is appropriate to shed some light on outcomes that these environments may influence in secondary science classrooms. With only a few studies having been conducted on VSLs in middle schools, the need to study the influences of VSLs on students' learning have called for present and future research to be conducted in the middle school setting. The findings from this study will help policymakers, administrators, and practitioners draw more concrete conclusions regarding the implementation of these tools in secondary science classrooms. The results from this research project will offer instructors a better understanding of VSLs and clarify any uncertainty educators may have regarding these educational tools. In other words, the results will contribute to the larger body of findings on this subject to determine whether VSLs can be effective enough to replace traditional science laboratories in regard to students' cognitive knowledge, attitudes toward science, and skill development.

Laboratory experiments have historically been a part of middle school education in subjects such as biology, chemistry, and physics. However, with the growing costs associated with education and increasing classroom sizes, many teachers and schools can no longer afford the financial, health, and legal risks associated with laboratory experiences. When laboratories are removed or not implemented sufficiently in secondary science classrooms, students may not acquire necessary skills and may lose interest in pursuing careers in science. A lack of strong science education and laboratory implementation in secondary school has been negatively affecting the U.S.'s ability to compete in the global economy. Therefore, this study will explore the potential for VLs to serve as effective, cost-efficient digital tools in facilitating inquiry-based learning for middle school science classrooms.

Chapter 2: Literature Review

With so much attention given to secondary education and the skills students need to develop in order to become active participants in 21st century society, science education has outshined other content areas in the secondary school system. As mentioned in the NSES, "learning science is something that students do, not something that is done to them" (National Research Council, 1996, p. 2). The majority of content knowledge acquired in science classrooms has to do with students' interactions with the learning environment; experiences that students gain when completing tasks using the scientific method. Science requires not only cognitive knowledge but also specific skills and positive attitudes of the learner. The educational scientist Benjamin Bloom (Forehand, 2010) established a three-domain model for learning in the mid-20th century. Although learning theories have continued to evolve, the distinctions among cognitive learning, skill attainment, and attitudes remain critical for preparing students to succeed as adults (Krathwohl, 2002; Krathwohl, Bloom & Masia, 1964; Simpson, 1971).

This literature review begins with a discussion of science literacy and expands to include a discussion of Bloom's classical model for distinguishing among domains of learning, followed by discovery learning theory (Bruner, 1961), and a pedagogical method referred to as inquiry learning (Connors & Perkins, 2009). For this research, the foundation lies in various theories of how knowledge is constructed and how learning occurs. The constructivist learning theory is branched into several components: pioneered by Jean Piaget, cognitive or individual constructivism is one the constructivist perspectives that emphasizes how a child's view about the world changes through developmental stages (Ackermann, 2001); social constructivism established by Lev Vygotsky, also referred to as the socio-cultural constructivist perspective (Kanselaar, 2002); and constructionist learning theory founded by Seymour Papert (1980), which enables the learner to create meaning by constructing a model or tangible object (Hay & Barab, 2001). Simulation-based educational practices are also explored to provide the foundation for Kolb's (1975) experiential learning model to help explain how skills are developed. This provides the connection to the concepts and principles of VLEs. Inherent in all aspects of learning is Bloom's third domain of learning: students' attitudes toward the content area. For this research, previous writings about students' attitude or affinity toward science will be explored to understand what engages and motivates them to learn within a science classroom.

Science Literacy

What is science and why should educators care about making sure our future generation is scientifically literate? "The word 'science' used in ordinary discourse in English refers to a product (a body of knowledge), to a process (a way of conducting enquiry) and to an enterprise (the institutionalized pursuit of knowledge of the material world)" (Millar, 2004, p. 1), and science literacy involves investigative skills such as making observations, reviewing analysis, and initiating communication. Historically, the term *scientific literacy* was introduced to the general public in the late 1950s in a publication titled *Science Literacy: Its Meaning for American School* (Laugksch, 2000). The period that followed this decade focused on educational policy reforms that highlighted the importance of science education and its role in society. In a society where information is obtained easily, everyone needs to find, choose, and use the information to function in a society that requires its members to think, make decisions, and solve problems (National Research Council, 1996). Science literacy is more than memorizing countless numbers of facts and different past discoveries; rather, it's more about mastering the skills that allow one to make observations, and being able to use the information that was gathered to construct meaning effectively. A century ago, acquiring scientific knowledge in secondary schools was confined to transferring a collection of facts and procedures to students (Sawyer, 2008).

The NSES define teaching science as a process where students ask questions, identify their assumptions, seek explanations, generate hypotheses, test their hypotheses, and communicate their findings (Colburn, 2000). This process allows students to construct new knowledge or modify their existing knowledge by reflecting on their prior knowledge as well as finding ways to reflect on their learning as the result of an authentic assessment. In authentic assessments, student learning is evaluated through real world problem-solving situations or laboratory experiments (Colburn, 2000).

Recently, the U.S. has faced nationwide challenges that have resulted in very poor student performance compared to other countries. According to an international performance report, in areas of mathematics, science, and reading literacy, prepared by Kelly et al. (2013), only 7% of 15-year-old students from United States scored proficient, level 5 or above. The information in this report refers to the 2012 PISA results (Program for International Assessment). The PISA scores from 3 years prior raked U.S. science literacy 13th among 33 other OECD countries (Fleischman, Hopstock, Pelczar, & Shelley, 2010). OECD, the Organization for Economic Co-operation and Development, “traces its roots to the Marshall Plan, a group of 30 member countries committed to democratic government and the market economy, which provides a forum where governments can compare and exchange policy, identify good practice, and promote recommendation” (Organisation for Economic Co-operation and Development [OECD], 2009, p. 8). While total expenditures for public elementary and secondary schools in the U.S. were estimated to be $621 billion in 2011-2012, the performance results mentioned above shows otherwise (Kena et al., 2015). These results have led to a call for action, and the

National Research Council (NRC), the National Science Teachers Association (NSTA), and American Association for the Advancement for science (AAAS) have responded to these outcomes accordingly. From the American Association for the Advancement of Science (1989) to the reform of the 1996 National Science Education Standards (NSES) and the new Next Generation Science Standards (NGSS), it is apparent that knowledge construction through inquiry learning prepares U.S. students to become future problem solvers, critical thinkers, and more importantly active members of society. Many of the skills described in the NGSS refer to tasks and activities that are conducted in science laboratories. In fact, one of the first exposures to authentic, hands-on learning is participation in a science laboratory that involves experimentation (Scalise et al., 2011). What goes beyond a memorable activity is students' knowledge and skill development in secondary science classrooms. Laboratory experiences help develop skills such as reasoning, technical expertise, negotiation skills, and practical skills that in turn will allow students to understand the NoS (Luketic & Dolan, 2013). Learning environments such as science laboratories can bridge what is discussed and taught during lectures to what they can do with the information presented to the students during the lecture.

Science laboratories offer a playground for activities that permit students to put scientific knowledge into practice. Hofstein and Lunetta (2004) defined science laboratory activities as "learning experiences in which students interact with materials and/or with models to observe and understand the natural world" (p. 31). Thinking like scientists requires more than just generating hypotheses and researching about scientific concepts. Future scientists are equipped with skills that allow them to retrieve and apply their knowledge that is applicable to specific tasks (Bransford, Brown, & Cocking, 1999). In addition to enhancing students' abilities to solve problems, gaining a sense of scientific methods, and practicing inquiry, science laboratories give students opportunities to use tools and laboratory equipment to conduct experiments related to a scientific phenomenon. Including science laboratories in secondary science classrooms creates opportunities for students to practice inquiry learning and take ownership of their science education (Domin, 1999).

The importance of science laboratory tasks in science classrooms is mentioned repeatedly in the literature as a quintessential way of teaching scientific knowledge (Hamidu et al., 2014). From inquiry learning to experiential learning, science laboratories give students an opportunity to learn skills scientists use to explore the natural world and construct explanations for scientific phenomena. Summarized by Yacoubian and BouJaoude (2010), the goal of science laboratories is to train students to develop scientific knowledge by constructing and reflecting on their own experiences, which ultimately engage students in practicing inquiry learning. Engaging students in learning science is not about earning the highest score in academia; it is more about learners' attitudes toward science that may reflect on an individual's future decision in picking careers (Ornstein, 2006). Ornstein (2006) emphasized that although many factors including home environment and past experiences may influence students' attitude toward science, science laboratory activities positively influence students' attitude toward science as the inquiry experiments became more challenging.

With so many opportunities for science laboratories provided to students and instructors, their implementation in science classrooms may be difficult and challenging. Studies in the field of science education and implementation of laboratory activities have found that meaningful laboratory experiences are a result of sufficient time for students to reflect on the conducted activities (Hofstein & Lunetta, 2004). In other words, instructors should set aside a time frame to discuss and reflect on their students' experience and address any areas of confusion or questions.

With emphasis on standardized testing and the constant pressure to teach to the content standards, instructors find it challenging to include additional time for reflection, discussion, and questions after laboratory activities.

Because scientific knowledge depends heavily on academic language and key terms to describe the phenomena, certain pedagogical strategies such as personal interaction between students during and after the laboratory activities and reflection on students' experience as well as observations to develop students' language also play a crucial role in an effective laboratory activity (Wright, 2009). In her study, which involved observing 68 hours of video that captured students' experiences in a middle school science class during laboratory activities, Wright (2009) noted that students' knowledge development in science laboratories is most effective when students use the laboratory activity to develop a meaningful language that "decontextualize[s] and recontextualize[s] knowledge for future learning situations" (p. 221). As Millar (2004) noted, the data collection that occurs during laboratory (action) and data analysis (reflection) that happens after the laboratory activity are part of a practical task and should not be separated from one another. These researchers indicate that instructors need to allow a sufficient amount of time to reflect and draw conclusions on students' experiences as well as their understanding in secondary science classrooms, particularly middle school science classrooms.

With budget shortages and increasing classroom sizes, science instructors have faced challenges that ultimately prohibit them from including practical experiences such as science laboratories in their curriculum. With the increase in the number of students, teachers are discouraged from conducting more laboratory activities and often complain about their inability to create rigorous and meaningful experiences that promote inquiry learning during class (Hamidu et al., 2014). Given the challenge of having so many students to monitor, guide, and assess, science instructors' concerns about the safety of their students prohibits them from including such activities in their curriculum. Laboratories involving hazardous chemicals and laboratory tools could pose serious safety concerns for students and the instructor. The increase in the number of accidents and injuries in science laboratories has created expenses that include not only the cost of damages on facilities, but also the cost of insurance, and lawsuits. According to a survey that conducted among teachers in Texas, 36% of teachers reported a total of 460 minor accidents during the year of 2000-2001 school year and 13% reported 85 major accidents that required medical attention over the prior 5 years (Schweingruber, Hilton & Singer, 2005).

Science laboratories are considered to be areas equipped with scientific tools that will help learners conduct their experiments and activities. Though the demand to increase science literacy nationwide is continuously growing, many school facilities' lack of science laboratory classrooms adds to the reasons why including laboratory activities have become increasingly challenging. In a survey conducted by Schneider (2003), close to 60% of teachers in Chicago and Washington reported that they either do not have any science laboratories or that the science laboratories at their facilities are somewhat or very inadequate. In a survey study of teachers in Iowa, American Lab Report found that 70% of them work in science laboratories that are not only old, but also very unlikely to be in compliance with current building codes (Schweingruber et al., 2005). As a result, many science educators opt out of using and implementing laboratories. At the same time, with so much emphasis placed on including laboratory activities in secondary science, educators hope to find other ways to keep students engaged and motivated.

How students learn, comprehend, and process information depends on the science of learning, where becoming literate is not limited to learning the facts and information, but rather includes understanding the learning process and domains of learning. In the next section, domains of learning will be discussed in detail to emphasize the importance of cognition, skill development, and attitude toward a particular content area.

Domains of Learning

With the advancement of educational technologies and the move toward a digital era, educational institutes in primary, secondary, and higher education look for instructional strategies that are tailored toward learners' needs. With this movement toward learner-centered instruction, the need to maximize students' learning has become a crucial part of the education system. When considering the science of learning across various content areas, it is essential to identify the various domains of learning. Kraiger, Ford, and Salas (1993) identified three categories of learning outcomes that are based on Bloom and Gagne's taxonomy. The three learning outcomes include: knowledge organization, skill-based outcome (which includes technical and motor skills), and affective outcome of attitude and motivation. Bloom's taxonomy, which was introduced by Benjamin Bloom during the 1950s, has divided educational objectives intro three domains: cognitive, psychomotor, and affective (Kasilingam & Chinnavan, 2014). The input from curriculum designers, instructional researchers, assessment specialists, and educational psychologists has identified and distinguished the three domains of learning as knowledge that consists of six levels, attitude consist of five levels, and skills consist of seven levels (Kasilingam & Chinnavan, 2014). In addition to Bloom's three domains of learning, Gagne proposed five major categories for learning outcomes that were listed as verbal information, intellectual skills, cognitive strategies, attitude, and motor skills (Driscoll & Driscoll, 2005). Gagne's contribution to this theory is important because he created a taxonomy of learning outcomes that included cognitive, psychomotor, and affective domains of learning. The verbal information outcomes directly related to the knowledge and comprehension segments of Bloom’s taxonomy where intellectual skill learning outcome proposed by Gagne resembled the remaining four levels of Boom’s taxonomy (Driscoll & Driscoll, 2005). The next section will describe each domain and further explain how each domain of learning operates.

The cognitive domain of learning is described as “the domain that deals with the recall or recognition of knowledge and development of understandings and intellectual abilities” (Reigeluth & Moore, 1999, p. 52). Implemented by many educational institutes, the cognitive domain of learning emphasizes comprehending, recognizing, applying, and synthesizing information (Bolin, Khramtsova, & Saarnio, 2005). The cognitive domain of learning is one of three domains introduced by Bloom that uses taxonomy to organize educational objectives. Educators all over the world respect and use the educational objective portion of Bloom’s Taxonomy. Referred to it as a “thinking domain,” (p. 28) the cognitive domain emphasizes intellectual skills that may be categorized in basic to advanced levels (Kasilingam & Chinnavan, 2014). The main levels of Bloom’s Taxonomy are knowledge, comprehension, application, analysis, synthesis, and evaluation. Knowledge is identified as a lower level objective where students recall and remember information, comprehension focuses on students’ ability to understand and translate information, application directs students to apply what they have learned to a situation or problem, analysis enables students to break down information and describe the relationship between the pieces of information, synthesis allow students to create products from their previous experiences, and evaluation empowers students to judge the value behind information or ideas (Reigeluth & Moore, 1999). As learners move up in this sequence, their level of comprehension and understanding increases.

Whether at work or home, completing a task requires a set of skills that enables the individual to complete the activity successfully. The second domain of learning is the psychomotor domain. This domain of learning addresses the need for skill development that involves operating equipment and various manual tasks (Rovai, Wighting, Baker, & Grooms, 2009). Seen in various content areas such as the laboratory in science classes, physical education, performing arts, and vocational courses, skills that learners attain allow them to complete the given task accurately and efficiently. The stages of the psychomotor domain of learning are: action, coordination, formation, and production (Kasilingam & Chinnavan, 2014). In the first stage, action, an individual takes an initial step to determine what needs to be accomplished in a task. Learners will use their senses to decide what steps should be taken. In the second stage, coordination, the learner completes the given task with the guidance and help of the instructor or expert. During the third stage, formation, the learner is able to complete the task with less assistance. In the final stage, production, the learner can independently practice and complete a specific task or activity without the support of the instructor. The ability to develop motor skills to use tools and equipment in science classrooms, for example, would allow the learner to place his or her knowledge into practice. For example, the practice of measuring and recording the mass of an object using a triple beam balance requires a specific set of sensory and motor skills. The study by Rovai et al. (2009), defined five products of learning associated with the psychomotor domain of learning:

> (a) Perception, such as detecting cues to act; (b) guided response such as being able to perform a specific act under the guidance of a teacher; (c) mechanism or the ability to perform a learned task without supervision; (d) complex overt response, or the ability to perform a complex pattern of acts; (d) adaptation, or the ability to alter an act to respond to a new situation; and (e) origination, or the ability to develop new acts. (p. 8)

Learning also happens in a third domain referred to as the affective domain, which includes attitudes, emotions, and values (Savic & Kashef, 2013). When learners recognize the value in learning something, it leads them to develop a worldview based on that value (Muehleck, Smith & Allen, 2014). The five behavioral levels of affective learning lead to learning; the primary level is called receiving. In this stage, learners notice a process or phenomenon by using their senses. The next stage is responding, where learners react to what they have seen or observed. Learners' reactions may involve asking questions where clarification of information is needed. The third stage is valuing where learners determine whether the received information is valuable enough to integrate it into their existing values. This leads to the fourth stage called organization, where learners organize and integrate information with existing information. The last stage is characterization. In this stage, values are developed into general behavior (Muehleck et al., 2014). The stages involved in the affective domain make this domain of learning a crucial one. According to Kasilingam and Chinnavan (2014), teachers in classrooms expect their students to be part of the class discussion and value the process of learning, but this is cannot be achieved solely through providing knowledge. The affective domain of learning should be considered and enhanced by relating the course knowledge to their lives and conducting discussion session where students' interests and values are shared and discussed.

When students value the information that is being discussed and learned, their level of motivation (intrinsic or extrinsic) is raised, which in turn raises their self-efficacy in order to complete a certain objective. Self-efficacy refers to "trusting one's abilities and powers for learning and performance" (Köseoglu, 2015, p. 131). Individuals' beliefs, attitudes, and values play an important role in motivation. A motivated learner creates personal goals that involve his or her emotions, values, and beliefs (D'Lima, Winsler, & Kitsantas, 2014). The role of motivation in the current educational system has received a great deal of attention. In a study by Gillet, Vallerand, and Lafreniere (2012), students' motivation, specifically intrinsic motivation, was found to decrease from third grade to ninth grade. When a learner's goal is to gain an internal reward and become engaged in activities or tasks for their own sake, his/her motivation is intrinsic. Extrinsic motivation refers to a set of behaviors that result in achieving external rewards. Areepattamannil, Freeman, and Klinger (2011) defined extrinsic motivation as "a broad array of behaviors having in common the fact that activities are engaged in not for reasons inherent in them, but for instrumental reasons" (p. 429). Even with learners who have gained the necessary skills, it is evident that motivation plays an important role in their academic success.

Inquiry learning. The National Research Council (1996) has defined scientific inquiry as "diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work" (p. 23). The work that scientists practice requires a set of skills that will enable them to observe and analyze phenomena. The ever-changing scientific concepts and knowledge call for future scientists that can solve problems and think critically. The push for inquiry learning, especially in the content area of science, has made science a discipline of study in which students can see and to whose concepts they can relate. To understand science, one has to become familiar with the nature of science (NoS). A study by Erin Peter (2006) defined NoS as follows:

> 1. Scientific knowledge is durable, yet tentative; 2. empirical evidence is used to support ideas in science; 3. social and historical factors play a role in the construction of scientific knowledge; 4. laws and theories play a central role in developing scientific knowledge, yet they have different functions; 5. accurate record keeping, peer review, and replication

> of experiments help to validate scientific ideas; 6. science is a creative endeavor; and 7. science and technology are not the same, but they impact each other. (p. 37)

When implemented effectively, inquiry learning can enable students to take ownership of and responsibility for their learning. When students use scientific methods to propose and question scientific ideas or concepts they develop critical thinking skills (minds-on) in addition to carrying out the physical portion of an experiment (hands-on); (Donnelly, O'Reilly, & McGarr, 2013). When students practice inquiry learning, they become aware of the procedures and steps scientists conduct in order to identify, evaluate, or solve problems. Students become aware of the role science plays in society and how this area of content knowledge applies to their everyday lives (Kubieck, 2005). Inquiry learning is so valuable because it can put the scientific method into practice by letting students experience the emotions, sacrifices, excitement, and challenges scientists experience in their everyday work. It allows students to practice ways to find other solutions solution to failed procedures and become engaged in the process of experimentation. Ultimately, by learning to think scientifically, students understand the relationship among evidence, a hypothesis, and a theory (Kubieck, 2005).

By practicing inquiry learning, instructors initiate opportunities that resemble those are practiced by scientists, such as opportunities to fail, opportunities to reflect, and opportunities to rethink their procedures. Unfortunately, often times, the activities practiced in non-inquiry learning environments are those in which scientists never participate. Failure to practice inquiry learning is usually blamed on the lack of resources, time, and equipment in science classrooms (Quigley, 2014). Science, by nature, is intriguing; when students are involved in activities that spark their curiosity, they ask questions and ponder about the reasons behind scientific phenomena. Science curriculum in middle schools, where students start to think about their career choices, has instead become about concepts, processes, facts, and theories that students are expected to learn and remember (Quigley, 2014) due to the push for standardized testing and sometimes the lack of teachers' preparation when implementing inquiry learning.

Though teaching science using inquiry learning strategies has received an ample amount of attention (National Research Council, 1996; National Science Teachers Association, 2004; NGSS Lead States, 2013) and has gained tremendous popularities, the effects of different types of inquiry has not yet been explored a great deal. One of the first studies in this area conducted by Bunterm et al. (2014) compared the structured and guided inquiry approaches. To compare the two types of inquiry learning, Bunterm et al. used the amount of knowledge given to students in order to distinguish the two types of inquiry learning approaches. This study used four levels, each of which was described based on the amount of information that was given to students.

> In the first level, the question, procedures, and solution are all provided to the students, the solution is not given in the second level, at the third level both the methods and the solution are not given, and at the highest level, information about the question, the procedures, and the solution are all generated by the students. (Bunterm et al., 2014, p. 1,939)

With the structured inquiry approach being closed to the second level and guided inquiry approach being closed to the third level, the authors concluded that the guided inquiry approach is the most effective type of inquiry in order to promote learning and skill development. Though this type of inquiry maybe challenging for teachers to implement in science classrooms, it promises to help learners develop of scientific skills and content knowledge.

Discovery learning. Advocates such as Bruner (1961) have found inquiry and discovery learning to be essential practices in promoting student-centered knowledge construction

(Grabinger & Dunlap, 1995). The connection between inquiry and discovery learning has been discussed extensively in recent literature. In environments where inquiry learning is practiced, most students have indicated that their interest and levels of learning in science was enhanced when they encountered an unusual, unfamiliar, or original idea or concept during the course of their class time (Jocz, Zhai, & Tan, 2014). Students' need for novelty, specifically in the science classroom, is promoted when students participate in Socratic questioning that lead to increased curiosity and helps students to practice discovery learning. In addition to novelty, the interest and value that students show in environments where they practice discovery learning allow them to acquire scientific knowledge by interacting with material and variables (Alfieri et al., 2011). Through their review of literature, Alfieri et al. (2011) suggested that discovery learning transpires when learners are not given all of the information and are encouraged to gather knowledge on their own when equipped with the necessary materials.

When approaching discovery learning as a strategy educators have used in science classes, it is recommended to keep in mind that discovery learning does not refer to "the act of finding out something that before was unknown to mankind, but rather include all forms of obtaining knowledge for oneself by the use of one's own mind" (Bruner, 1961, p. 1). As a firm believer in using discovery learning in the science classroom, Bruner (1961) stressed that because information or concepts discovered by the learners are organized in their own way of thinking, recalling them later in life is simple and effortless. Learning through discovery has received attention from cognitive constructivist such as Piaget. Buxton and Provenzo (2011) of the University of Georgia stated that practicing and promoting discovery learning in science classrooms strengthens learners' ability to solve more complex problems later in life. Presenting known concepts to students using discrepant events, for example, allows students to take steps necessary to gather known knowledge so that they can construct new knowledge.

As Piaget (1973) articulated famously, “to understand is to discover, or reconstruct by rediscovering” (p. 20), a child’s mind has to be ready to practice discovery learning. According to Alfieri et al. (2011), there are limitations of discovery learning that need to be taken into consideration. Alfieri et al. (2011) concluded that implementing discovery learning requires practice in order to be most effective; scaffolding and guidance should be part of this practice so that learners are receiving feedback and evaluation on their progress. Other studies have examined the power of prior knowledge and discovery learning. Liu and Chiang (2014), who have directed educators’ and practitioners’ attention toward collaborative discovery learning, pointed out that interaction between students and discussion about students’ prior knowledge in collaborative discovery learning environments allows learners and instructors to become aware of each other’s ideas, theories, beliefs, and new ideas.

Constructivist Learning Theory

“Constructivism is an important and driving theory of learning in modern education” (Baviskar, Hartle, & Whitney, 2009, p. 541). Constructivist learning is defined as a process of learning in which learners construct or build new knowledge based on their previous learning (Kanselaar, 2002). Constructivist learning represents a collection of learning theories such as cognitive constructivism proposed by Jean Piaget (1896-1980), social-cultural constructivism presented by Lev Vygotsky (1896-1934), and constructionism developed by Seymour Papert (1928-present); (Ackermann, 2010). Looking at the evolution of constructivist learning theory, the well known key thinkers, educators, and psychologists mentioned previously branched the constructivist theory of learning into several components, thus integrating their views of individual, social, and construction into the theory of constructivism.

It is worth mentioning that there is a difference between personal constructivism (cognitive/individual constructivism) and social constructivism (cultural/ group constructivism) (Baviskar et al., 2009). "These two different theories admired today led to the two major forms of constructivism, that have a common ground and history" (Powell & Kalina, 2009, p. 246). Whether knowledge is constructed individually or socially, constructivist learning theory can open pathways that enable learners to maximize their learning potential. The constructivist theory of learning is not a theory of teaching. Moreover, there is no one way of implementing this learning theory in a secondary classroom; however, there are criteria that, if met, make the environment a suitable place in which to construct new knowledge.

The cognitive learning theorists' approach to constructivism describes learning in terms of "internal processes such as 'insights, information, processing, perceptions, and memory'" (Kropf, 2013, p. 14). In addition to creating his developmental theory, also known as stages of development, Jean Piaget, the pioneer of cognitive or individual constructivist theory, explained that children view the world differently than adults. As they grow, children's beliefs and views are continuously evolving to move them away from everyday cognition toward scientific thinking (Ackermann, 2010). Before Jean Piaget, many researchers and practitioners believed that children could only possess less knowledge when compared to an adult. This notion was soon rejected by Piaget, who explained that children's minds could construct knowledge differently; in other words "children differ not only in the quantity of knowledge they possess; their knowledge is qualitatively different" (Sawyer, 2008, p. 52).

Socio-constructivist learning theorists such as Vygotsky (1978) noted that a child's development is independent of learning and learning is an external process. The notion of " what a child can do with assistance today she will be able to do by herself tomorrow," (p.87) has ruled the pedagogical strategies in secondary level classrooms. In an environment where the social constructivism learning theory is practiced, learners take an active role in their learning and absorb information to construct new knowledge (Huang, Rauch, & Liaw, 2010). Creating a social constructivist-learning environment allows students to acquire knowledge and new information through their own learning modalities such as collaborative question and answer sessions. As also mentioned by Powell and Kalina (2009), the interaction between the novice and expert participants will leads to the construction of knowledge in a constructivist-learning environment. A key concept mentioned in his socio-constructivist learning theory is the *zone of proximal development,* also known as ZPD. This concept refers to learning as an enzyme that activates internal development while the individual interacts and cooperates with people within his environment (Vygotsky, 1978).

Seymour Papert of the Massachusetts Institute of Technology developed constructionist learning theory. Constructionism learning is defined as "building relationships between old and new knowledge, in interactions with others, while creating artifacts of social relevance" (Kafai, 2006, p. 36). Working closely with Jean Piaget in Geneva, Papert (1980) described Piagetian learning as "learning without being taught" (p. 7) where children are referred to as builders of their own intellectual structures. Constructionism builds on constructivist learning where children construct their own knowledge by creating an object or artifact. With that being said, constructivism and constructionism are not the same. According to Piaget, children actively construct their own knowledge as they are developmentally growing from concrete thinkers at the age of 6, to formal thinkers at the age of 12. Though Papert agreed with Piaget's distinction, he asserted that the computers can personalize formal thinking by allowing learners to use objects to construct, revise, and modify old and new knowledge (Papert, 1980; Kafai, 2006).

Papert (1991) explained another key distinction between constructivism and constructionism learning theory:

> Constructionism—the N word as opposed to the V word— shares constructivism's view of learning as "building knowledge structures" through progressive internalization of actions... It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe. (p. 1)

Papert (1980) used his programing language *Logo* and an object called *the Turtle* to create an environment that allowed children to use *Turtle Talk*, language used to give commands to the turtle, as well as to model and represent their knowledge by creating geometrically-shaped objects. The complexity of using Logo grows as children become comfortable with the language of programing. Constructionists such as Papert extended the theory of constructivism by defining constructionism as construction of knowledge represented through creation of tangible objects trough the process of problem solving and higher order thinking (Chambers & Carbonaro, 2003).

In science education, learners are expected to not only gain practical knowledge and skills, but also share, communicate, and modify their ideas and findings. In other words, learning is a process that includes both social and personal construction (Yang & Heh, 2007). A rapid transformation of scientific knowledge has led to the realization that the pool of scientific knowledge keeps expanding and the only way to keep students literate is to engage them in activities in which scientists also engage that pertain to their area of discipline. Skills such as problem solving and learning different thinking strategies that students should use to answer questions are essential pieces of constructing scientific knowledge. Whether it is through social, cognitive, or construction, constructivism learning allow children to become “active builders of their own cognitive tools, as well as of their external realities” (Ackermann, 2010, p. 2).

Though there is a distinction in how learning occurs individually and in social settings, both play an essential role in students’ knowledge comprehension and learning in secondary school settings. Powell and Kalina (2009) described the necessity of using strategies that promote both cognitive and social constructivist learning theories based on the needs of their students. They emphasized the importance of providing activities that enable students to complete tasks on their own and placing them in situations that require social interactions and the instructor’s guidance. This method of learning refers to inquiry learning (Kubieck, 2005) where students use their problem solving skills to propose solutions, collect data, and state conclusions based on their results.

According to Baviskar et al. (2009), there are four elements that must be present in the structure, activity, or content of the lesson for it to be categorized as a constructivist activity: (a) eliciting prior knowledge, (b) creating cognitive dissonance, (c) application of the knowledge with feedback; and (d) reflection of learning. These principles that create a constructivist environment have been mentioned by other researchers as well (Bächtold, 2013; Colburn, 2000; Karagiorgi & Symeou, 2005; Yilmaz, 2008). The pivotal role of the constructivist theory of learning in secondary education revolves around strategies used by the instructor. “Both Piaget and Vygotsky agreed that the teacher’s role was that of a facilitator and guide, and not of a director or dictator” (Powell & Kalina, 2009, p. 247).

For constructivist learning theory to be implemented in classrooms, teachers must understand the principles behind cognitive and social constructivist learning theory and reflect on their teaching practices, specifically considering to what extent they are using a constructivist theory approach in their daily pedagogical strategies. Moreover, discussing a teacher's subject matter knowledge plays an important part in promoting a constructivist learning environment. To fully use and implement the constructivist theory of learning in secondary classrooms, teachers must be knowledgeable and create activities that help students understand, explore, and accept new knowledge presented to them in such learning environments (Richardson, 2003).

Simulation-Based Learning

With advancement in educational technology and research in learning science, simulations have found their way into educational institutes. Gaba (2007) described simulation as "a technique to replace or amplify real experiences with guided experiences, often immersive in nature, that evoke or replicate substantial aspects of the real world in a fully interactive fashion" (p. 126). This technique has incorporated various kinds of technological tools to create experiences that are impossible to achieve in real environments. The history of simulations goes back to more than a century ago. The military, aviation, and medicine have all incorporated the use of simulation to train and prepare their novice members. Simulations in the field of business have also become a central mode of instruction. Business simulation games are designed with inclusion of virtual characters that create scenarios in a community. Participants are able to meet objective in topics such as decision-making and teamwork (Faria, Hutchinson, Wellington, & Gold 2009). In addition to the business industry, the field of medicine has also benefited from the use of simulations, which started in the second half of the 20th century (Bradley, 2006). The emphasis on preparing students to become competent healthcare practitioners led to a major movement of including simulation training during the course of preparation. As Bradley (2006) mentioned, the major drive behind adapting simulations in the medical field was due to the lack of time to train students in a real environment. Moreover, students were able to cover more materials and gain necessary communication skills while practicing the skills involved in such a profession. Another study concluded that using simulation in training environments has led to self-efficacy, finding that participants who used simulation learning demonstrated a higher satisfaction and confidence (Gegenfurtner, Quesada-Pallarès, & Knogler, 2014).

As they have gained popularity in the field of training and education, simulators are organized in four categories: part-task trainers, computer-based systems, simulated patients and environments, and integrated simulators (Bradley, 2006). Part-task trainer simulators allow the participants to focus only on an area or task. For instance, students training to examine a human ear are going to use the model of an ear rather than the entire model of a human body. Computer-based systems are simulators that include audio and video. Computer-based system simulators are categorized into two systems: interactive system or VR system. Interactive systems provide the user with feedback where VR systems create more sophisticated, computer generated images that are similar to real objects or environments. Simulated patient and environment simulators allow the participants to become part of a scenario involving role-play. This type of simulator is more commonly used as an assessment tool by creating situations that involve students making decisions by taking necessary steps. Integrated simulators usually used in the medical training field "combine a manikin with computer controls that can be manipulated to provide various physiological parameter outputs that can be physical or electrical" (Bradley, 2006, p. 258).

The role of education in today's society has shifted from transferring knowledge to learners to developing skills and practices. Educational researchers aim to help students understand and implement strategies to solve problem they may come across in the real world (Sawyer, 2006). Simulations provide opportunities for students to propose solutions to a problem and take necessary steps to try out their solutions or explanations. Moreover, Bradley (2006) offered an additional rationale about why implementing simulation in educational settings could provide participants with a supportive environment where they can move toward their learning objectives at their own pace. “Students using a simulator are able to ‘stop the world, and ‘step outside’ of the simulated process to review and understand it better” (Parush, Hamm, & Shtub, 2002, p. 320). In regard to secondary education in middle and high schools, simulations have opened new doors to instruction strategies. A study by Kukkonen, Kärkkäinen, Dillon, and Keinonen (2014) concluded that simulation used in a science class to study the greenhouse effect allowed students to acquire a better understanding of the topic.

Accepted by educational researchers and practitioners, Simulation-Based Learning (SBL) has become the touchstone for primary, secondary, and higher education. The theories that could be applied as an infrastructure for environments that promote SBL are: Social and cognitive constructivist theory, pioneered by Piaget and Vygotsky, and experiential learning, introduced by Dewey and Kolb. The connection between constructivist theory and experiential learning in simulation is through a learner’s “psychomotor, affective, and cognitive learning domains, which tend to result in a deeper and more memorable experience” (Shapira-Lishchinsky, 2015, p. 975). The components involved in SBL support the constructivist theory of learning where knowledge is not provided, but rather constructed by the participants while interacting with the environment (Shapira-Lishchinsky, 2015).

The constructivist theory of learning is considered to be an important component of simulation exercises or tasks. By becoming engaged in the task, the learners are able to use information and tools in the simulated environment to generate their own understanding about the phenomena they observe. In simulations, learners explore different approaches, test diverse strategies, experience various outcomes, and build a better overall understanding of key aspects of the real world (Shapira-Lishchinsky, 2015). The advantage that SBL provides to its participants is the ability to experience outcomes that may be surprising to the learners. The surprising outcomes prepare learners for unknown situations and results.

One reason why simulations are being included in formal educational settings is how learner-centered simulation environments are. The shift to empower learners is a unique feature in learner-centered teaching. As Weimer (2013) noted, students in such an environment are engaged, motivated, and asked to reflect on their learning more often. Students are able take responsibility and make decisions based on available tools and information. The effectiveness of SBL has been utilized and explored in science education for the past 4 decades. SBL supports and promotes students' problem solving skills and higher order thinking while encouraging students to take ownership of their learning process (Smetana & Bell, 2012). Since SBL is practiced in an environment that recreates real world experiences, students are able to go through the process of decision making by collecting and organizing qualitative and quantitative data. This may not be achievable in real environments where factors involved are not being controlled or the environment is simply too dangerous or inadequate to conduct observation and data collection.

Instructors' roles in SBL environments change as students are encouraged to make independent decisions about how and where they should start in order to complete their given tasks or activities. Since SBL promotes learner-centered instruction as opposed to traditional environments that practice direct instruction, students may not be receptive to instructional strategies. For instance, a study by Foti and Ring (2008) found that when instructors switched instructional modalities while implementing SBL, some students were not able to adjust easily and continuously requested that their teacher to tell them where to find answers. Rutten, van der Veen, and van Joolingen (2015) analyzed the role of teachers in simulation learning environments and stated that practicing an inquiry teaching approach led to positive attitudes among students and teachers, but teachers were not able to incorporate both inquiry teaching strategies and have their students participate actively in class activities. Additional findings about the effectiveness of SBL concluded that students' abilities to successfully perform tasks stayed at the same level in both simulated and real environments, but more importantly, students who used computer simulation as the instructional medium were able to practice inquiry-based learning more than those who completed the same task in traditional instructional medium such as a classroom (Smetana & Bell, 2012).

Experiential learning. "Knowledge is not information, but lessons from experience" (Ackermann, 2010, p. 3). Asking questions and wondering about scientific phenomena result from students' experiences in a learning environment. Prior knowledge is modified or replaced by new knowledge when students gain insight through experience. A simple example that should be thought of in this context is learning how to ride a bike at an early age. No matter how much one reads about the process and steps necessary to master this task, without direct exposure and experience it will be challenging to complete the task. Following in Jean Piaget's footsteps, John Dewey described learning as a lifelong process that involved discovery and assimilation of knowledge through experiences (Chan, 2012). Experiential Learning Theory (ELT), described by Kolb and Kolb (2009) defines learning as a process in which "knowledge is created through the transformation of experience" (p. 298). Experience changes a student's perceptions and understanding about a particular scientific concept as well. For example, when teaching about the concept of thermal energy, students' experiences through experimentation shape their perceptions when they come in contact with a warm object. In other words, the rapid movement of molecules due to their high energy increases the thermal energy and ultimately the temperature of an object or a substance. The continuous cycle between experiencing, reflecting, thinking, and acting allows learners to not only grasp new knowledge, but also question and reflect upon their prior knowledge. For this reason, prior knowledge and experience play important roles in knowledge construction.

Dewey also mentioned the important relationship among three elements he identified in experiential learning: experience, inquiry, and refection (Chan, 2012). Because of ELT's direct connection to inquiry and constructivist learning, the field of education and learning science are not the only discipline areas that have used and implemented ELT. This learning theory has become highly applicable in other disciplines such as management, law, informational science, psychology, and accounting (Kolb & Kolb, 2009). Kurt Lewin's contribution to the world of experiential learning is described as a "four stage cycle of action research with reflection, planning, and action observation," (p. 406) which lead to the work of Kolb's ELT proposed by David A. Kolb (Chan, 2012). In addition to Dewey and Lewin's contribution to experiential learning, Kolb's experiential learning model (Figure 1) explains that *Concrete Experience* (new experience), leads to *Reflective Observation* (reflecting on what was observed from the new experience and modify one's current understanding), continues to *Abstract Conceptualization* (new understanding is shaped based on reflection), which promotes *Active Experimentation* (applying what was learned to other situations); (Chan, 2012).

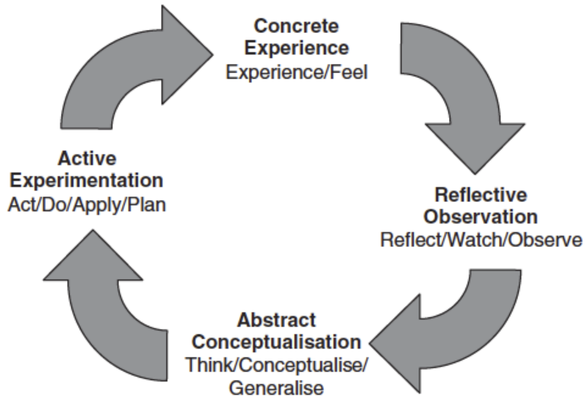

Figure 1. Theory model of Kolb's model of experiential learning. Reprinted from "Exploring an Experiential Learning Project through Kolb's Learning Theory Using a Qualitative Research Method," by C. K. Y. Chan, 2012, *European Journal of Engineering Education*, *37*(4), 405-415. Copyright 2012 by the author. Reprinted with permission.

Applying this model to a science classroom's curriculum enables instructors to use experiential learning to further emphasize the importance of transforming students' prior knowledge into new knowledge and implement this practice as a pedagogical strategy that could develop students' reflective skills. For students to benefit fully from such learning practices, they must be guided by their instructors in order to look back on what they observed during the experiment and how that experience will shape their understanding of scientific phenomena. Further studies on experiential learning in educational settings suggest that students' attitudes are enhanced. Since students come to class with their own way of perceiving and interpreting scientific knowledge, reflecting back on their own experiences outside of school can ignite their interest in regard to topics discussed in science (Mejia & Wilson-Lopez, 2015). In addition to past experiences, experiences that learners encounter during instruction shape their views about the essential role science plays in their community and society.

The general purpose of internships, travel, and service learning is to familiarize novice participants with the general concepts and procedures expert participants use to be successful members of the community. Novice participants need to gain the necessary experience to be able to function and grow. This idea, presented by Liebmann (2008), the author of *Living It! The Rise of Experiential Education in the 21st Century,* highlights the importance of practicing experiential learning in an educational setting. Liebmann provided several examples of ways to transform a traditional learning environment in order to bridge basic foundations of knowledge to valuing the experience of practice; students move from knowing the theory to practicing it out in the real world.

The essential outcomes of practicing experiential learning have been studied internationally as well. A study by Zhang and Campbell (2012) examined the effectiveness of experiential learning in China using an *Integrated Experiential Learning Curriculum* (IELC) to measure students' attitudes toward and interest in science. The results suggested that using IELC led to more positive attitudes toward the subject of science. Though this curriculum is newly developed and little research has been conducted in this field, the research from this study showed promise that experiential learning curriculum that incorporates science inquiry could enhance students' attitudes.

Virtual learning environments. "Virtual environments are three-dimensional representation of a space in which users can move around, interact with objects within the environments" (Pedersen & Irby, 2014, p. 34). The success of virtual environments in the pilot training industry has opened new doors in the world of education (Jelfs & Whitelock, 2000). With recent changes in implementation of technology and the emergence of VLEs, educational institutes have begun investing VLEs to capture a body of students that are incapable of physically attending the learning environments. The history of virtual worlds dates back to 1980s when single-player games were designed (Kotsilieris & Dimopoulou, 2013). One example of virtual environments is VR, which is a collection of technological hardware that allows users to interact and communicate with three-dimensional realities (Steuer, 1992). Participants' interest and creativity in such environments have piqued researchers' and practitioners' interest in designing virtual environments that not only resemble the learning environments, but also promote learning. Constructivist learning theory has been an important component of VLEs (Kotsilieris & Dimopoulou, 2013; Mikropoulos & Natsis, 2011; Mundkur & Ellickson, 2012). When considering other characteristics of VLEs besides theoretical models, presence or "sense of being there" (p. 770) is another key attribute (Mikropoulos & Natsis, 2011). Although presence contributes to positive learning experiences, it may be affected by an individual's age, gender, learning style, and computer experiences. Depending on a participant's learning style and computer experiences, learning experience may be maximized for those individuals who have the skills to navigate through the virtual environments and be aware of their surroundings. To complete a task in virtual environments participants need to navigate through the environment easily and use its features effectively. A study by Kontogeorgiou et al. (2008) concluded that sense of presence, visual design, and free navigation in virtual environments play essential roles in participants' learning outcomes.

When looking at the literature in regard to the features of VLEs, it is clear that meaningful learning happens in an environment that is authentic, interactive, and constructive (Mundkur & Ellickson, 2012). VLEs are designed with features that enable participants to use information and tools to construct knowledge by interacting with virtual instruments. In a study by Pedersen and Irby (2014), a VLE was developed using seven key elements: the core task, the virtual environment, information resources, virtual instruments, scaffolds for data collection and analysis, expert modeling video, and help for tool functionality. These components were used to create a VLE that allowed the participants to meet the learning objectives and become engaged in the process of learning. Although VLEs provide educators and students with opportunities that are not available in real learning environments, designing the most effective VLEs requires a careful planning, designing, and implementation period. This study provided a model of VLE and described the steps required to successfully design a VLE that promotes inquiry learning in secondary science classrooms. A study by Dillenbourg et al. (2002) identified seven features of VLEs:

1. A VLE is a designed information space.
2. A VLE is a social space: educational interactions occur in the environment, turning spaces into places.
3. The virtual space is explicitly represented: the representation of this information/social space can very from text to 3D immersive worlds.
4. Students are not only active, but also actors: they co-construct the virtual space.
5. VLEs are not restricted to distance education: they also enrich classroom activities.
6. VLEs integrate heterogeneous technologies and multiple pedagogical approaches.
7. Most virtual environments overlap with physical environments. (pp. 3-4)

Although the design and implementation of VLEs may be “labor-intensive” (Pedersen & Irby, 2014, p. 41), it has found its way in secondary science classrooms. Designers have used the interactive features of such environments to create virtual environments that resemble science laboratories. VLs simulate the real science laboratory and are defined as VLEs that allow students to use the tools and equipment to conduct experiments (Tatli & Ayas, 2013).

When looking at the literature in regard to the effectiveness of VLEs in educational settings, findings suggest that VLEs not only improve learners’ computer self-efficacy, but also improve their willingness to participate in class activities (Chou & Liu, 2005). Another study by

Mikropoulos and Natsis (2011) indicated that VLEs provided a nurturing environment for students to succeed academically. Additionally, Pretorius (2010) identified constructivism as an effective teaching approach in VLEs. In addition to constructivism, discovery learning was also found to be another important tool that, if practiced in VLEs, could enhance students' learning (Pretorius, 2010). Though most students' interactions and assignment completion are conducted on VLEs, VLEs could be as effective as traditional learning environments in enhancing students' knowledge. A report from the North America Council for Online Learning indicated that students in VLEs outscored the national average on AP exams (Watson, 2007). Furthermore, the impacts of VLEs on science education lead to interesting findings in regard to students' understanding of and perception about the NoS. For example, a study by Machet, Lowe, and Gütl (2012) showed that science laboratories and information presented in such an activity may become more effective if remote science laboratories are designed and organized in virtual worlds. The reason why virtual worlds could dramatically transform laboratories has to do with the importance of models and representation of scientific concepts. Laboratories that are designed in virtual environments improve a student's ability "to understand the purpose of the model and its relationship to real world" (p. 538).

Virtual science laboratory. The increased use of VLs amongst schools and educators is a strong indicator that this method could help many students reach their maximum learning capacity in a science classroom. The result of a research project done by Yang and Hen (2007) indicated that VLs have a significant impact on students' academic achievement in secondary science. Yang and Hen investigated and compared the impacts of virtual physics laboratories to those of traditional instruction. The results suggested that virtual physics laboratories promoted students' academic achievement and science processing skills. The following sections will look at some of the findings about VLs and discuss why the use of this type of technology is beneficial in secondary science classrooms, as well as strengths and weaknesses in VSLs.

With every passing year, new technology and computer software are introduced to the world of education and science. VLs are accessible at any time and students are able to redo the lab as many times as they want. In the online environment, Lahoud and Krichen (2010) concluded that accessibility was the key concern, followed by fidelity and then usability; in this environment, being able to readily access the labs appears to be more important than how accurately they mimic the real environment. Moreover, the findings from this study suggested that, although traditional laboratories may have high fidelity, fidelity seems less important than being able to access the labs and complete the assignments.

Another issue that has arisen in science labs is that most of the regular labs that are done without the use of computers aren't always available to students who missed lab days. Most of the time, if students were not present in the classroom to do the lab, they would have few opportunities to make up the lab. Availability and different varieties of VLs have made the implementation of science content easier for teachers, which has allowed them to dedicate more of their time to delivering content knowledge rather than preparing physical laboratories.

In addition to accessibility, cost of VLs and physical labs are other areas worth assessing. When comparing physical labs and VLs together, Vaidyanath, Williams, Hilliard, and Wiesner (2007) noted that even though theoretical and practical knowledge are equally important, they come at different costs; the practical component, which requires a laboratory setup, comes more expensively; costs incurred include procurement of equipment, setup, maintenance, operation, and training. Moreover, they mentioned that the laboratory equipment is typically available only for limited periods of time. Another study by Campbell et al. (2004) concluded that low-cost simulations could replace some expensive physical equipment, decrease the amount and costs of the equipment, and increase access to up-to-date electronic laboratory experiences. However, one of the major drawbacks is that students are not given the opportunity to experience hands-on learning. Based on these studies, the use of VLs can offer most of the same content and at the same time eliminate additional costs.

One of the challenges that science educators might face throughout their career is students' objection to dissecting animals in their science classrooms. Dissection became part of school curricula in the 1920s, and has since become the traditional way for students to learn about and be exposed to animal structures in science education. There would be few occasions in which students are not able to perform the hands-on activity of an anatomy dissection of animals in science classrooms. It is estimated that in a typical class, 3-5% of students will verbally object to a dissection activity (Oakley, 2009). The possibilities that VLs can offer to those who oppose hands-on dissection are endless. For example, students can virtually dissect an animal without physically touching an animal through the use of the computer; they are able to see and understand the anatomy within the animal body. This issue leads to the next topic, which explains student safety issues in hands-on science labs.

From chemistry to biology classrooms, science labs are filled with equipment and chemicals to which students are exposed every day. Many studies have pinpointed the importance of student safety in physical labs. Some researchers such as Oakely (2009) have mentioned that formaldehyde, a solution to preserve animals' bodies, is classified as a toxic and hazardous substance by the United States Occupational Safety and Health Administration and has been linked to respiratory tract injuries, vision impairment, and skin damage upon contact.

With all they can offer, VLs do have a few disadvantages. One of the disadvantages of VLs, according to Scheckler (2003), is that students are removed from the reality of the lab, which may already be removed from the reality of biology processes of fixing, staining and thin sectioning. Some students would like to experience the handling of the specimens as it might help them have a better understanding of scientific concepts. David Heise (2006) from Columbia College demonstrated this through his study; he concluded that interacting directly with the physical world provided an orientation-free knowledge representation that could then be utilized more flexibly in later judgments. Students are not fully capable of developing skills to understand the content knowledge if VLs replace physical labs. Another disadvantage of VLs is the lack of instructor supervision. A study by Scheckler (2003) indicated that since VLs lack the immediacy of supervision and contact with an experienced teacher, only self-motivated learners do well in virtual environments. VLs can be very powerful only when they are planned carefully. Students' goals and outcomes must be reviewed and analyzed by an instructor in order to meet all their needs.

Attitude Toward Science

To understand how attitude is influenced in learning environments, one must first define it. Raved and Assaraf (2011) defined attitude as "students' orientation, or relation towards a particular object or event" (p. 1,221). The term is further broken down into three subcategories of cognitive, behavior, and affective. Raved and Assaraf defined the cognitive element of attitude as a person's attitude toward an object or event based on what he/she knows. Furthermore, the behavior element of attitude is described as the way individuals behave toward the object or event. Finally, the third subcategory of attitude, the affective element, refers to the emotion an individual has toward an object or event. Educational researchers and practitioners find the drop in attitude of toward particular subjects alarming, particularly, when there is direct correlation between students' attitude and learning outcomes (Odom, Marszalek, Stoddard, & Wrobel, 2011). Positive learning outcomes in science have not only led to students showing a positive attitude toward the subject, but also increased their level of engagement. For example, if students develop a positive attitude toward a chemical reaction experiment because it relates to what they have seen during fireworks displays, they tend to stay engaged and motivated to ask questions, further analyzing the properties of elements and their reactions in order to fully understand why fireworks generate various colors.

Engaged learning is generally defined as a situation in which learners are active in their learning and student activities involve active cognitive processes (Iqbal et al., 2010). When students are engaged and participating in the classroom, they are active learners that stay motivated throughout the lesson. When students are engaged and motivated to participate, learning takes place much more efficiently. According to Jones (2009), academic motivation is important because motivated students tend to engage in activities that help them learn and achieve at a faster rate in an academic setting. Students start thinking and using their ability to connect with the topic being discussed in the class. Another study by Smith and Cardaciotto (2011) concluded that active learning leads to a variety of positive outcomes for students, including better attitudes, greater motivation, improvement in thinking and writing, enhanced memory for information taught, and improved exam performance.

> In an active learning model, the learner takes more responsibility for his/her own learning under the guidance of a teacher. Characteristics that are included in active learning include: (1) Relevance to real-world applications. (2) Authentic solving of real-world problems. (3) Application of prior knowledge and/or experiences to solve new problems.

(4) Collaboration with others. (5) Integration of subject matter. (6) Self-directed learning. (Christensen, Knezek & Tyler-Wood, 2015, p. 900)

Another study by Rukavina, Zuvic-Butorac, Ledic, Milotic, and Jurdana-Sepic (2012) examined the influence of active learning on positive attitude development in mathematics and science. The results showed that the majority of students developed a positive attitude toward both subjects when they participated in workshops that were designed to actively engage students in topics that were relevant to everyday life.

Additionally, Chen and Howard (2010) found a correlation between students' attitudes and their participation in advanced science classes. As students' attitude toward advanced science classes improved, their participation in these classes increased. Students enjoy activities when they are under the impression that they have control over the outcome (Jones, 2009). Consequently, the activity becomes authentic and students develop a sense of self-efficacy. Jocz et al. (2014) described self-efficacy as a major contributing factor to students' interest in science. Four factors that may influence self-efficacy are: *mastery experience* or interpretation of previous experience, *vicarious experience* or observing another individual performing a task, *social persuasion* or judgment and feedback students received from others, and *physiological states* or level of stress and anxiety (Britner & Pajares, 2006).

As students progress in their academic career from elementary to secondary schools, their interest and attitude decrease (Christensen et al., 2015). Students' attitudes in a learning environment are influenced by multiple factors. Factors that influence students' attitude specifically toward science are: recognition of science as important, importance of the teacher's role in class, positive experience during class, and level of enthusiasm toward conducting scientific experiments (Agranovich & Assaraf, 2013). Findings by Agranovich and Assaraf

(2013) directly correlated with other studies in this field in which attitude toward science was found to be enhanced if students find the information discussed during class relevant to their lives outside of school. It is important to note that the perceptions of and attitudes toward science were different in boys and girls. Girls related science to the world around them where boys referred to science as a necessity in human society. The authors believed that these findings might be due to different social expectations from boys and girls, where boys are expected to be more successful in the field of science careers. Other factors that influence student' attitudes toward and interest in STEM driven subjects include: teacher's role, parents' role, and students' motivation. Additionally, as mentioned by Jarvis and Pell (2005), the relationship between attitude and academic performance is strong among girls; girls with a positive attitude toward science tend to outperform others academically.

The availability of technological tools in science education and the inclusion of computers in secondary science classrooms have sparked questions regarding whether the presence of these tools influence students' attitude toward science. Though computers and technological tools started to become popular and effective in higher education, the inclusion of such digital tools in secondary science classrooms has resulted in positive outcomes. This is evident in findings by Odom et al. (2011), who noted that computers enhance students' attitudes when used in environments that implement constructivist, student-centered methods model of teaching. It is worth noting that students' attitudes toward science influence their academic performance. This relationship is explained by Odom et al. (2011) as a *task value*, which they defined as "a motivational factor that refer to how much a student considers something to be important or relevant" (p. 2353). Particularly in a science class, the scientific topic under study should be introduced to students in a way that is relevant to their everyday lives. Students should be able to recall examples that they have encountered outside of classroom to the concept covered during class to be able to make the topic relevant to themselves. When students find the topic valuable to learn and can connect the concepts to their personal experience and interest, they become engaged and motivated (Ateh & Charpentier, 2014). When they are engaged, students have opportunities to become involved in the process of collecting and analyzing data, which ultimately enhances their overall performance in the classroom.

Educational researchers and practitioners have been paying close attention to measuring students' attitude and overall performance in secondary science classrooms that are equipped with technological tools such as computers. In the science classroom, being able to independently collect and evaluate evidence in solving a problem is identified as an important area of mastery (Scalise et al., 2011). The skills that enable students to gather and communicate their knowledge ultimately allow them to become aware of their misconceptions about specific scientific topics. The question of whether students are able to practice and develop these skills in a virtual environment has led to some promising findings. Students improved marginally in their ability to communicate and organize their ideas effectively when they used technology in their secondary science classroom (Siegle & Foster, 2000). When students are communicating and sharing their ideas with one another, they are increasing their higher order thinking and ultimately understanding the content better. Moreover, the finding from Iqbal et al.'s (2010) study revealed that learning through virtual worlds can be engaging for learners and can enhance their overall performance as well as their attitude and motivation.

Capturing students' attention span as well as keeping them on task is one of the challenges educators face in secondary science classrooms. Academic learning time is related to the time during which students are productively engaged in learning and is closely associated with learning outcomes (O'Leary, 2011). After reading many similar reviews, it may be possible to say that most educators look for ways to increase students' affinity toward their subject matter; doing so will help students stay on task, participate in class discussion, and ultimately improve their content literacy. Engagement was represented by their active involvement in, commitment to, and concentration on the tasks included in the activity, in contrast to lack of participation, apathy, or inconsistent effort and performance (Park, 2005). The motivation and engagement of students in class is closely related to their academic success and achievement. Moreover, in his studies, Park (2005) asserted that students' engagement during class encouraged them to work harder and participate more. He also mentioned that the greater the increase in participation level, the higher the achievement scores in science, reading, mathematics, and social studies. Motivated students tend to stay on task and achieve more in an academic setting. This is especially important in secondary science classrooms where students need to learn the concepts by observing, hearing, and demonstrating. Motivated students are more likely to pay attention during course activity, take time to use effective learning and study strategies, as well as seek out help from others when needed (Jones, 2009). The NoS requires students to continually think and ask meaningful questions; to master this, students need to stay motivated and engaged during class time.

Living in an era of technology, many students prefer to use computers and believe using computers during class can help them stay motivated and engaged. In a study by Mouza (2008), students' motivation and engagement increased dramatically when they started to implement the use of laptops during class instruction. Increased motivation, as noted earlier, is closely linked to higher academic achievement. In her study, Mouza mentioned that an important outcome of using laptops was increased student motivation and persistence in completing schoolwork. Use of technological tools such as laptops in class encouraged students' motivation and interaction, which ultimately increased content literacy.

VLs can play an important role in motivating students in secondary science classrooms. A study by Iqbal et al. (2010) stated that learning through virtual worlds can be engaging for students and can affect their test scores as well as their attitude and motivation toward them. When students are motivated during class, they participate in class discussions in learning environments that are student-centered and engages students academically. Another research study by Chu and Leung (2003) concluded that most students showed a positive attitude toward the virtual systems and found that such systems encouraged and motivated them to learn effectively. VLs can offer more than just simulations of science concepts; they are useful educational tools that allow educators to transfer their content knowledge to their students in a more effective way. VLs have opened a new door to the world of educational technology and enabled students to learn more effectively by visualizing certain scientific concepts. VLs can be used as educational tool and allow instructors improve their diverse students' learning. Since their appearance in secondary science classrooms, many studies have been done about the relationship between VLs and students' learning. However, few studies have examined the effects of VLs on students' achievement and attitude in middle school science classrooms. The aim of this study is to contribute to the pool of knowledge about the use of VLs in middle school science classrooms and shine light on the effectiveness of such educational tools in students' academic achievement, skill development, and attitudes toward science.

Summary

Looking at the current literature in science education and literacy, a great deal of attention is given to how science is taught and learned in the 21st learning environment. To examine students' cognitive knowledge, attitude toward science, and skill development, Benjamin Bloom's domains of learning were investigated and studied. Bloom's domains of learning categorized learning into three domains: cognitive, psychomotor, and affective. The methods and strategies that are used in science education focus on inquiry and discovery learning. Using these strategies in science classrooms has allowed students to think like scientists by identifying a problem and proposing solutions.

Learning theories such as constructivism and constructionism allowed the researcher to analyze and examine the process of knowledge construction in formal learning environments. The major learning theory encompassing the theoretical foundation for this study is constructivism (Kanselaar, 2002). Whether it is done individually or socially, constructivism theory allows learners to construct knowledge through their prior knowledge of or interaction with their environment or other individuals. In addition to constructivism, Papert's constructionism, presenting knowledge through construction of a tangible object, was analyzed. Though these three forms of constructivist learning theory share the same root, constructivism theory, each defines the process of knowledge construction in relation to individual experience through cognitive development, construction of tangible objects, and social interaction.

SBL, VLEs, and attitude toward science formed the conceptual framework of this study. The interaction between the participants and learning environment becomes meaningful when the learning environment is constructive and interactive. Though VLEs have only been around for a few decades, they have shown promising outcomes in students' performance. Students' participation and experience in VLEs have not only positively impacted their academic performance, but also increased students' participation during the given task (Chou & Liu, 2005). In the area of science education, VSLs have made it possible for students and instructors to conduct experiments that may not be possible to perform in real science laboratories. Current advancements of technology in the area of secondary education, particularly middle and high schools, have not yet been studied fully. The results from analyzing VSLs' affects on students' academic achievement, skill development, and attitude toward science may add more evidence to the current pool of literature that may ultimately make these learning environments as effective as physical or real learning environments.

With significant advancement in computer technology and considerable amount of attention given to science education over the past decade, educators, practitioners, administrators, and policymakers have changed their mindset about the need to provide educational resources to secondary science classrooms to improve future generations' skills in solving problems and critical thinking. Teaching students to think like scientists and appreciate the NoS requires careful planning and availability of resources such as science laboratories. Opportunities to include science laboratories in every science classroom dwindling as educational budgets continue to shrink. The idea of using technological tools such as VSLs has generated a reasonable amount of positive outcome in secondary science classrooms, particularly in high schools. Little has been done to measure students' academic achievement, skill development, and attitude toward science in middle school while using VSLs. Could VLs be considered as effective as real laboratories, improving students' academic achievement, enhancing their skills, and improving their attitude toward science? Though many research studies have claimed that VLs can be as effective as real (hands-on) science laboratories, and VLs have shown promising results in enhancing students' attitude toward science, few studies have focus their attention on middle school students. To overcome uncertainty regarding whether or not VLs could be as effective as real laboratories, additional research is needed, especially in middle school learning environments. The goal of this research study is to contribute to the body of literature that focuses on middle school students' academic achievement and attitudes toward science while using VSLs. This research study will contribute to the growing evidence that may help educators and practitioners include VLs in their daily practices as early as middle school. The next chapter will describe the proposed methods for this study.

Chapter 3: Methods

This chapter describes the research design, sources of data, data collection strategies and procedures, instruments, tools, and human subject considerations for this research study. The purpose of this study was to determine how a VSL impacts students' cognitive knowledge, attitudes toward science, mathematical skill development, and scientific skill development in eighth grade science classrooms. According to Bloom et al. (1956), cognitive refers to intellectual processes that involve remembering, understanding, and recalling knowledge, where knowledge is described as "organized bodies of information" (Gagne, 1972, p. 8). For this study, cognitive knowledge referred to participants' earned scores from pre and posttests covering the concepts of buoyancy and density. Attitude is described as "the feeling that a person has about an object, based on their belief about that object" (Kind, Jones, & Barmby, 2007, p. 4). Attitude toward science, in this study, referred to students' attitudinal changes toward the subject of science measured through a pre and post survey called the Attitude Toward Science Inventory (ATSI). Developed by Dr. Molly Weinburgh (2000), ATSI measured students' attitudes toward science in key areas of motivation, enjoyment, self-concept, anxiety, and values. The concept of scientific skill in this context referred to students' ability to observe and collect data. Mathematical skill referred to the calculation of numerical data collected during a scientific experiment.

Research Design

This descriptive, single group, pretest-posttest research study, examined the relationship between VSLs and students' learning outcomes. Descriptive research design, one of three main categories of applied research design, summarizes the relationship between two or more variables (Bickman & Rog, 2008). The independent variable involved the use of a VSL with middle school students, while the dependent variable involved measurement of students' cognitive knowledge, attitude toward science, and skill development when participating in a VSL. To determine the effectiveness of VSLs, this study used a single group pretest-posttest design. The single group pretest-posttest design involves a group that is pretested, participates in an intervention, and is tested again (Gay, Mills & Airasian, 2011).

Two classes of students taking a physical science course during the academic school year of 2016-2017 were the participants in this study. The physical science course is offered in two sections: 8A and 8B. The involved instructor taught both sections of physical science using a curriculum map, teaching strategies, and methods that are state-standard driven. The sequence of units was the same for both classes: motion and forces, structure of matter, chemical interactions, and earth in space. This study was conducted during the first unit of the physical science course, motion and forces. Both sections of students participated in a VSL.

Variables

The independent variable is the VSL, which focused on the topics of buoyancy and density. The dependent variables were cognitive knowledge, attitude toward science, mathematical skill development, and scientific skill development. The influence of the independent variable (VSL) on students' cognitive knowledge was assessed by comparing baseline knowledge (pretest) to a posttest measure. Attitudes toward science were measured with a survey tool (ATSI) and pre and post scores were analyzed. Students' math and science skills were recorded manually by each student in a VLP and evaluated following the VSL activity.

Hypotheses

Four main research hypotheses were tested. The first hypothesis was concerned with cognitive knowledge, and the second hypothesis was focused on attitudes toward science and involved five sub-hypotheses, one for each of the subscales of the tool: students' anxiety toward science, enjoyment of science, self-concept of science, value of science in society, and motivation in science. The third hypothesis placed emphasis on mathematical skills, and the fourth hypothesis was centered on scientific skill development.

- H_1: Participating in Virtual Science Laboratories will improve cognitive knowledge.
  - H_0: There is no difference in cognitive knowledge from pretest to posttest.
- H_2: Participating in Virtual Science Laboratories will enhance students' attitude toward science.
  - H_0: There is no change in students' attitudes toward science.
    - H_{2a}: Participating in Virtual Science Laboratories will enhance students' enjoyment of science.
      - H_{0a}: There is no change in students' enjoyment of science.
    - H_{2b}: Participating in Virtual Science Laboratories will enhance students' motivation toward science.
      - H_{0a}: There is no change in students' motivation of science.
    - H_{2c}: Participating in Virtual Science Laboratories will enhance students' value of science in society.
      - H_{0a}: There is no change in students' value of science in society.
    - H_{2d}: Participating in Virtual Science Laboratories will enhance students' self-concept of science.
      - H_{0a}: There is no change in students' self-concept in science.
    - H_{2e}: Participating in Virtual Science Laboratories will diminish students' anxiety toward science.

- H_{0a}: There is no change in students' anxiety toward science.
- H_3: Participating in Virtual Science Laboratories will affect students' mathematical skills.
    - H_0: There is no change in students' mathematical skills.
- H_4: Participating in Virtual Science Laboratories will affect students' scientific skills.
    - H_0: There is no change in students' scientific skills.

The Buoyancy and Density VSL

The Buoyancy and Density VSL is an online educational tool provided by McGraw-Hill Education. McGraw-Hill Education, one of the top three science textbook publishers nationwide, has changed their strategy in an effort to provide their users with innovative digital materials to meet the needs of the current generation of learners (Davis, 2013). With VSLs designed to meet state content standards, McGraw-Hill Education has recognized the effect that its tools may have on students' scientific knowledge comprehension and skill development. The components included in McGraw-Hills's VSLs included: objectives and procedures, journals, data tables, graphing features, and a virtual environment that houses tools and instruments used to conduct the experiment (See Figure 2). Students and instructors were able to access McGraw-Hills's VSLs from the website that houses all the science textbooks for various grade levels. The VSLs are aligned with the California state content standards. The content covered in this VSL was part of state standards 8.8.a-8.8.d, 8.9.a, and 8.9.b. The instructional activities that were practiced in these VSLs were part of the classroom's normal activities. The activity involved students measuring the mass and volume of several objects, which allowed them to calculate the different objects' density and make predictions on whether or not they will float or sink if placed in a container filled with water. The instructor was required to cover the content listed in California's state standards and designed her lesson plan to meet these standards accordingly. Magnolia

Science Academy #6 charter middle school has purchased and used McGraw-Hill's Science textbooks for grades sixth through eighth. The chosen VSL for this study focused on the scientific concepts of buoyancy and density.

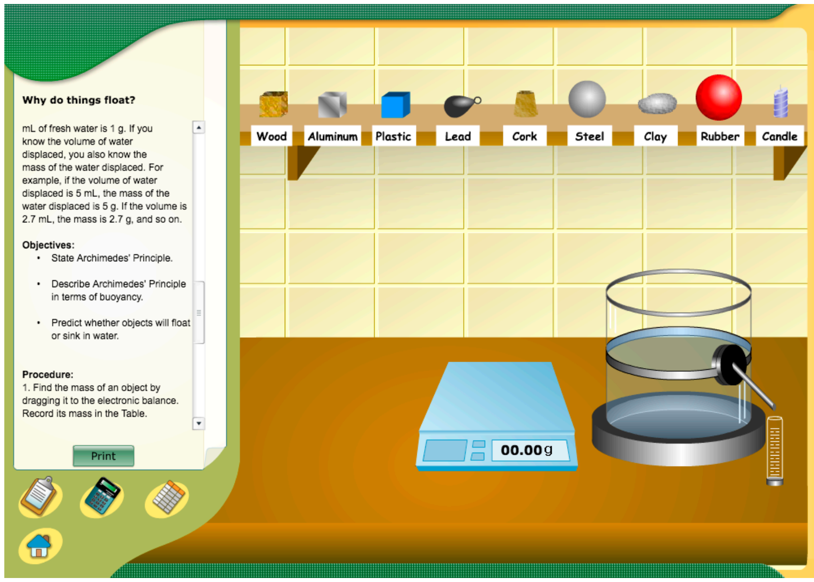

Figure 2. McGraw-Hill's density and buoyancy virtual laboratory (Why do things float?). Reprinted from *Why Do Things Float?* by McGraw-Hill Education, n.d., retrieved from (http://www.glencoe.com/sites/common_assets/science/virtual_labs/CT01/CT01.html). Copyright 2016 by the author. Reprinted with permission.

Objectives for the VSL. Three specific learning objectives were identified for the VSL. To ensure validity, researcher sought consultation and collaboration with another science instructor who is familiar with teaching concepts of density and buoyancy. Following participation in the VSL, Students will be able to:

1. State Archimedes' Principle.
2. Describe Archimedes' Principle in terms of buoyancy.
3. Predict whether objects will float or sink in water using mathematics and science skills.

Setting

Located in Southern California, Magnolia Science Academy # 6 (MSA 6) charter middle school provides educational programs that place emphasis on STEM (Science, Technology, Engineering, and Math) career fields and enable students to become active learners in their communities. MSA 6 charter middle school is an inclusive STEM-focused school, established in fall 2009. This school provides an academically rigorous and enriching standards-based curriculum for all students in grades six through eight. In addition to enriching STEM-focused curriculum, MSA 6 charter middle school provides a unique set of courses and programs such as: life skills, advanced math programs, enrichment classes, and sustained silent reading classes. This charter school serves 175 students in grades six through eight with an average class size of 29. Twelve percent of students are English Language Learners (ELLs) and 15% are identified as needing special education accommodations. Teachers use a curriculum that focuses on critical thinking, effective communication, and social and collaborative skills. Students have access to computer laptops in each of their classrooms. Female students make up 46% of the student body and male students make up 54%. The demographic population is mostly composed of students from low socioeconomic status, backgrounds, and 79% of the students qualify for reduced or free lunches. Student ethnicities include 74% Hispanic/Latino, 11% African American, 8% White, 3% Filipino, 3% Two or more races, 1% Asian, and 1% Pacific Islander (Greatschools.org).

Study Group

The target participants of this research study included two class periods (8A and 8B) of eighth grade students at MSA 6 charter middle school. Fifty-six students were enrolled in the two sections. In this research study, a section referred to a class period, which lasted for 50 minutes of instruction. Students had one period/course per day for a total of seven periods. In eighth grade science, students cover scientific concepts in physics, chemistry, and astronomy. Students were placed in each section randomly by the administrative office. Students in both sections possessed similar academic abilities and met similar placement requirements. The ratio of male to female in each class was different for each section. Each student was given access to a laptop computer to conduct the VSL individually.

Procedures and Data Collection

The parental consent information form was sent to participants' parents by mail prior to the start of study procedures. The student assent information sheet was distributed to students prior to the start of the experiment. The participants in this study in both sections of physical science classes received the same direct instruction and class activity in the same order for the same duration of time. This allowed the researcher to keep all other factors and variables consistent for both sections of physical science.

Data collection was extended over a period of 5 days. Figure 3 shows the activities over the five days including when data were being gathered. Key activities included the VL experience that involved individual student completion of a packet where they recorded their activities and completion of paper-based tools measuring cognitive knowledge (test) and attitudes (survey). Both the cognitive test and attitude survey were administered twice: once before the VSL to serve as baseline data (pre) and again following the activity (post).

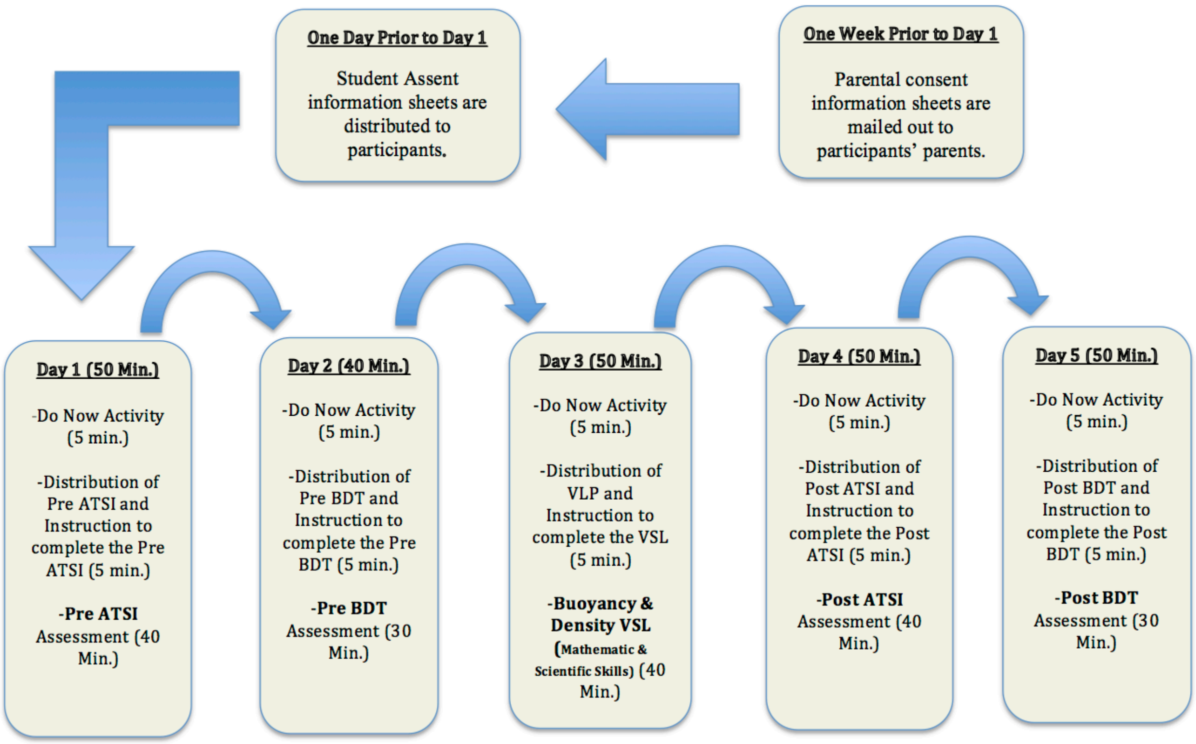

Figure 3. Procedures and data collection process.

Instructional activities. The activities completed during each day were designed to ensure that students' knowledge, skills, and attitudes are not changed due to any instructions. The researcher has designed this procedure carefully to minimize any variables that may alter the outcomes of this research study. Each day during the data collection process, students started the class by completing a *Do Now* activity, which was a brief writing activity students were expected to complete upon their arrival to the class. The *Do Now* activity lasted up to 5 minutes. After completion the *Do Now* activity students were given instructions for the pre and post assessments. The instruction and distribution of the assessments took 5 minutes to complete. Students were directed to start their assessments after the instructions were completed. Students who completed their assessment early were advised to turn their assessment in to their instructor. Direct instruction, class discussion, and any other activities were not part of this 5-day procedure. The researcher's decision to eliminate the related instruction and activities had to do with the design of this study in which all the other variables were held constant to ensure the accuracy of data. Since students' learning was assessed through the use of a VSL, related instructions or class activities were removed. The questions in the *Do Now* activities were not discussed among students and the instructor. The reason for this has to do with the effect that discussion of *Do Now* activities may have on students' attitudes. The topics of the *Do Now* activities were not related to the scientific concepts that are covered in the VSL. The time for each activity segment, including instruction and distribution of instruments, were organized in Figure 3.

Virtual Science Laboratory (VSL). Students completed the buoyancy and density VL on day 3. Students in each group were given a VLP that described the procedures of completing the buoyancy and density VL (Appendix C). The distribution and explanation of the VLP took approximately 5 minutes. Expectation and objectives were communicated to students before the start of the buoyancy and density VL. The directions needed to find the buoyancy and density VL was listed on the VLP. The required time to complete the VL was expected to be 40 minutes. Soon after the directions were read and the distribution of the VLP was completed, students were directed to start their VL individually on their laptop computers.

Students recorded their qualitative and quantitative data in directed sections of the VLP. The observation and recordings of data made by students in the data table of the VLP was used to evaluate students' scientific skills. Mathematical skills were captured through the density calculation page. On this page students were expected to use the density formula and unit to calculate density and make predictions regarding whether an object will sink or float.

Knowledge and attitude measurements. Two measurement tools were involved. Cognitive knowledge was measured using a Buoyancy and Density Test (BDT). Attitudes toward science were measured using the ATSI survey (Weinburgh, 2000). Pre and post collection of each occurred over the course of the experiment. Students completed the pre-ATSI survey on day 1, during the class period. A printed version of pre-ATSI (Appendix D) was distributed in both classes where students marked their responses using a pen or pencil. After completion of the *Do Now* activity, the instructor read the directions to complete the pre-ATSI survey. The time needed to complete the pre-ATSI was 40 minutes. Once all students have completed the pre-ATSI survey, the instructor collected response sheets and stored them in a safe designated area. Since class time was limited to 50 minutes, no further activity occurred after the pre-ATSI survey.

The pre-Buoyancy and Density Test (BDT) included 11 multiple-choice questions and were distributed to students on Day 2 (Appendix A). The time given to students to complete this pretest was 30 minutes. After the completion of *Do Now* activity, the instructor read the directions to students after distributing the pretest and collected the pretest when all students have completed it. Due to the length of both instruments and the potential effect each could have on the other, the researcher decided to plan on administering the pre-ATSI survey, post-ATSI survey, pre-BDT, and post-BDT on separate days.

The instructor administered the post-ATSI survey (Appendix E) on day 4. After the *Do Now* activity, the instructor read the instruction to complete the survey and students were given 40 minutes of class time to complete the survey. The questions asked in the post-ATSI were identical to the pre-ATSI. The instructor collected and saved the responses in a locked cabinet along with other data collected during this study. On day 5, after the *Do Now* activity, the instructor distributed the post-BDT (Appendix B) with identical questions to that of the pretest, but different in order. The time given to students to complete this posttest was 30 minutes. Questions were in multiple-choice format and students were expected to mark their answers on the test with a pen or pencil. After all participating students have completed the questions on post-BDT, the instructor collected and saved the posttests for analysis.

Tools and Instruments

The instruments used in this pre and post design study were the ATSI and BDT, a cognitive measure of buoyancy and density knowledge. The VLP was used to capture students' mathematical and scientific skills.

Attitude toward science inventory (ATSI). The ATSI, a multidimensional assessment, contained 40 items organized in five subscales that measured students' attitudes in areas of motivation in science, enjoyment of science, anxiety toward science, self-concept regarding science, and value of science in society (Weinburgh, 2000). Each subscale contained eight questions. Originally, the ATSI measured an additional subscale involving students' perceptions of teachers. This subsection was removed from ATSI because it was not related to the scope of the designed study. The subscale scores were based on a 6-point Likert scale ranging from 6, Strongly Disagree, to 1, Strongly Agree.

ATSI validity and reliability. Content validity of ATSI has been reported by Sandman (1973) who performed the factor analysis on a mathematic version of this inventory. The construct validity of ATSI was reported by Gogolin and Swartz (1992), who noted, "The construct validity was determined in the form of nonspurious item-to-scale correlation. The mean correlations were above the minimum acceptance level of 0.30 and were supportive of internal consistency within each set of items" (p. 491). The calculated alpha reliability coefficients for all the subscales were reported “within the range of acceptability” (Weinburgh, 2000, p.5). Permission to use the survey was obtained from the author via email.

Buoyancy and density test (BDT). Questions for the pre- and post-BDTs were assembled in Exam View test Generator 7.5. The questions were extracted from McGraw-Hill’s TestGen®, a computerized Test Bank from Exam View. The BDT measured students’ cognitive knowledge by calculating students’ scores in both pretests and posttests. Questions used in the pre-BDT and post-BDT targeted important scientific concepts and ideas about density and buoyancy.

BDT validity and reliability. The questions on the BDT, generated by McGraw-Hill’s TestGen®, allow educators to access a bank of questions designed and based upon their state’s standards. These questions are aligned with chapters, lessons, and activities based on scientific concepts covered in each grade level. Items on the BDT were parallel to California State Standards and objectives mentioned in the VLP.

The BDT has been used by several other science teachers in other schools with students similar in age and group demographic population. Additionally, consistent usage of this test for the past few years by the science departments at sister schools of MSA 6 charter middle school and the consistent scores collected from Exam View tests have increased the reliability of the test. Sister schools refer to other schools operated by the Magnolia Public School foundation. The Magnolia Public School foundation charter school foundation operates and oversees 10 charter schools ranging from K-12.

Virtual laboratory packet (VLP). The VLP was designed to collect students’ data and calculation during the buoyancy and density VL. The VLP included direction to complete the buoyancy and density VL and complete each step while recording their observations. The purpose of designing this document was to prohibit students from testing their hypothesis before calculating object's density. The procedure of the VL was modified slightly to allow students the opportunity to generate a hypothesis through observation and calculation and test their hypothesis by dropping the object inside a container filled with water. The VLP allowed the researcher to access and collect students' data and mathematical calculations. The analysis of students' artifacts allowed the researcher to determine whether students have gained mathematical and scientific skills. Mathematical skills were measured through students' density calculations, whereas scientific skills were measured through students' data collection and recording.

Human Subjects Considerations

This descriptive study involved minors at a charter school. Since the participants in this study are minors, communication with students' parents and guardians were a pivotal part of this research. To make sure this study "does not infringe any equal opportunities or human right legislation," (p. 329) the researcher provided parents or guardians with information about the research study and its intention (Gray, 2009). To ensure participants' confidentiality, students' names were coded numerically to ensure that their identities were protected. The collected pre and post-ATSI surveys, VLPs, and pre and post-BDTs were in the form of hard copies where students' names were replaced by numerical codes to ensure participants' confidentiality. All the necessary steps in meeting IRB requirements and ethical standards were followed to minimize risks. Processes such as consulting with colleagues, minimizing the duration of risks, and monitoring subjects during the data collection procedure were followed in order to minimize harmful risks to participants. Potential risks to subjects may include the invasion of privacy by identifying students' names on artifacts collected during data collection. It is the researcher's responsibility to assure that participants' confidentiality is secured and protected. The researcher was aware that a breach of confidentiality might have resulted in stress, guilt, social harm, and embarrassment.

The researcher obtained site approval from the charter school's central office. Since this particular charter school is an independent charter school (not affiliated with any school districts), necessary steps were taken to receive approval from the charter's central office. Additionally, since the study was conducted in the researcher's classroom, administrative approval was obtained. This process ensures that the proper permission was gained before accessing the school, parents, teachers, and students. The school administrative team, parents, and students were notified about the expectations and processes related to the research study. The school's central office required the distribution of parental consent information sheets prior to data collection. Therefore, a consent information letter, a descriptive letter explaining the purpose of the study, was mailed to participants' parents. This information sheet informed parents about the nature of the research study and the overall benefits of participating in this study. The students' assent information sheet was distributed to participants in order to be certain that they felt comfortable with the study and were informed about the purpose and procedure of this research project. Though, participants were not required to sign the assent information sheet, they were asked to read/review the information sheet to become familiar with the purpose and procedure of the research study. Since the activities involved in this research study were part of normal curriculum activities, their participation allowed them to meet curriculum standards for Physical science. All students from both classes agreed to participate in this research study.

Approval was gained from Pepperdine University's Institutional Review Board (IRB) under exempt category 1.

Proposed Analysis

The cognitive BDT pretest and posttest resulted in a single test score pre and post. ATSI survey data were scored as designed by the author of the survey to provide five sub-score values for each student. Both pre and post sub-scores were calculated.

Students' scientific and mathematical skills were assessed through review of the calculations and predictions recorded within the VLP journal. Accuracy of students' calculations of density for each object and prediction of whether it would float or sink were rated for each participant.

All test and survey data were entered into a Microsoft Excel spreadsheet and uploaded into SPSS for analysis. Descriptive statistics including frequency distributions were used to analyze all data. Findings were also presented in graphics to aid presentation. To test the hypotheses, paired sample *t*-tests were performed to compare students' learning and attitudes pre and post the VSL experience. An alpha of .05 was used to determine statistical significance.

Means to Ensure Study Validity

This study was designed to ensure all students would have the same experiences during the procedure and data collection time frame. Necessary steps have been taken to minimize variables that may have changed the results. For instance, direct content instruction between the post and pre assessments was eliminated to ensure students' attitude, knowledge, and skill were not affected by another variable. The chosen independent variable for this study was the buoyancy and density VSL. The researcher has carefully designed each day of the study to assure that discussions and instructions that may have altered the outcomes were removed and all conditions were kept constant. The researcher's decision to choose valid and reliable instruments ensured the study's validity. Measures to assess cognitive knowledge were derived from the

McGraw-Hill's TestGen®, a well-known science textbook publisher. Measures to assess attitudes toward science were derived from the ATSI. The evaluation and use of this instrument by previous studies and the analysis of content and construct validity made this instrument a valid instrument to include in this study (Weinburgh, 2000). A VLP was used to record students' mathematical and scientific skills, ensuring that students' observations, data collection, and data calculation were recorded in one designated area. Finally, to ensure accuracy of analysis, the researcher used SPSS, a statistical analysis software tool.

Chapter 4: Results

The purpose of this descriptive, single group, pretest-posttest design study was to assess gains within each of Bloom's domains of learning following participation in a VSL for eighth grade students at a middle school in Southern California. The student participants ($N = 56$) were placed in two sections of physical science classes by the administration in the beginning of the academic school year and both sections were exposed to the same VSL that focused on the concepts of buoyancy and density. The content covered in this VSL were part of state standards 8.8.a-8.8.d, 8.9.a, and 8.9.b. The activity involved students measuring the mass and volume of several objects, which allowed them to describe Archimedes' Principle in terms of buoyancy, calculate the objects' density, and make predictions on whether they will float or sink if placed in a container filled with water.

To measure cognitive knowledge of math and science, a Buoyancy and Density Test (BDT) was used both pre and post participation in the VSL. To measure attitudes toward science, the ATSI provided assessment of students' value of science in society, enjoyment of science, motivation in science, self-concept of science, and anxiety toward science. The VLP was used to record students' scientific and mathematical skills. Students' mathematical and scientific skills were measured through an analysis of recorded data in the VLP. Both mathematical and scientific skill sections were scored for completion and accuracy.

The collected data were analyzed to test hypotheses concerning cognitive knowledge, attitudes toward science, mathematical skill development, and scientific skill development. The first hypothesis was concerned with cognitive knowledge. The second hypothesis was focused on attitudes towards science and included five sub-hypotheses, one for each of the subscales of the tool: students' anxiety toward science, enjoyment of science, self-concept of science, value of science in society, and motivation in science. The third hypothesis placed an emphasis on mathematical skills, and the fourth hypothesis was centered on scientific skill development.

- H_1: Participating in Virtual Science Laboratories will improve cognitive knowledge.
    - H_0: There is no difference in cognitive knowledge from pretest to posttest.
- H_2: Participating in Virtual Science Laboratories will enhance students' attitude toward science.
    - H_0: There is no change in students' attitudes toward science.
        - H_{2a}: Participating in Virtual Science Laboratories will enhance students' enjoyment of science.
            - H_{0a}: There is no change in students' enjoyment of science.
        - H_{2b}: Participating in Virtual Science Laboratories will enhance students' motivation toward science.
            - H_{0a}: There is no change in students' motivation of science.
        - H_{2c}: Participating in Virtual Science Laboratories will enhance students' value of science in society.
            - H_{0a}: There is no change in students' value of science in society.
        - H_{2d}: Participating in Virtual Science Laboratories will enhance students' self-concept of science.
            - H_{0a}: There is no change in students' self-concept in science.
        - H_{2e}: Participating in Virtual Science Laboratories will diminish students' anxiety toward science.
            - H_{0a}: There is no change in students' anxiety toward science.
- H_3: Participating in Virtual Science Laboratories will affect students' mathematical skills.

- H_0: There is no change in students' mathematical skills.

- H_4: Participating in Virtual Science Laboratories will affect students' scientific skills.
  - H_0: There is no change in students' scientific skills.

Descriptive findings and results of the hypotheses testing are presented below following a description of the student participants. Findings are organized and grouped into the three domains of the Bloom model.

Description of Participants

The target participants of this research study included two class periods (8A and 8B) of eighth grade students enrolled at MSA 6 charter middle school during the 2016-2017 academic year. A total of 56 students (*N* = 56) participated in the study. Of the 56 student participants, 20 (35.7%) were female and 36 (64.3%) were male (Figure 4).

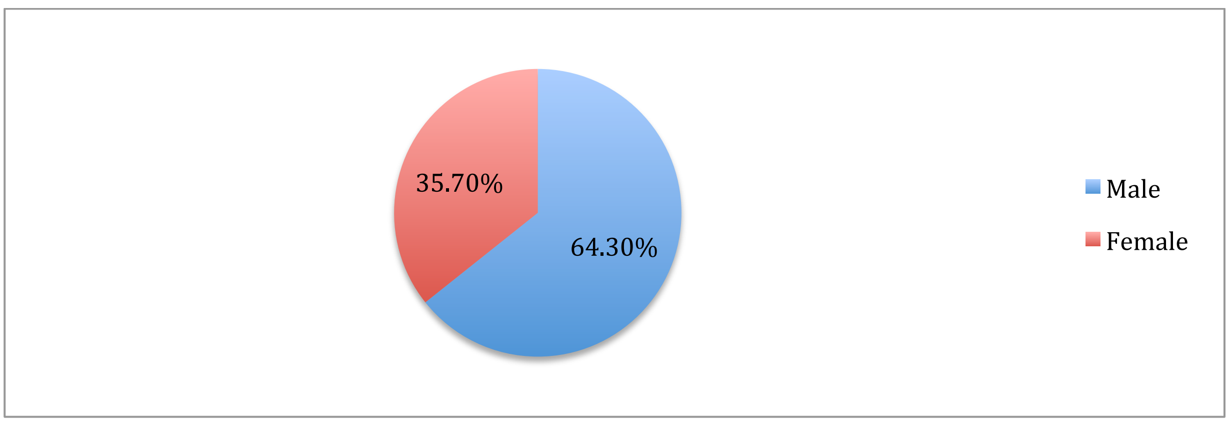

Figure 4. Frequency distribution of gender for student participants (*N* = 56).

All students from both classes were able to fully participate and complete all activities within the 5 days set aside for the experiment. Each day during this experiment, students started the class by completing a *Do Now* activity, which includes a brief writing activity that students were expected to complete upon their arrival to the class. The *Do Now* activity lasted up to 5 minutes. After completion of the *Do Now* activity, students were given instructions for the pre and post assessments. The instruction and distribution of the assessments took 5 minutes to complete. Students were then directed to start their assessments after the instructions were completed. Students who completed their assessment early were advised to turn their assessment in to their instructor. Direct instruction, class discussion, and any other activities were not part of this 5-day procedure.

Cognitive Knowledge Findings

Students' cognitive knowledge of buoyancy and density were measured pre and post participation in the VSL by the Buoyancy and Density Test (BDT). The 11 questions on the pre BDT and post BDT were extracted from McGraw-Hill's TestGen®, a computerized Test Bank from Exam View. The questions in BDT targeted important scientific concepts and standards about density and buoyancy. The Pre BDT and Post BDT were scored using the answer key generated by the Exam View. Each question was worth one point for a total of 11 points. All students were able to participate in both pre and post BDT test.

Descriptive results. The statistical analysis of the pre BDT indicates that participants achieved a mean score of 6.41 with standard deviation of 2.32 and a standard error of 0.31. Eleven students (19.6%) scored 9 points or higher out of a possible 11 points. Thirty-five students (62.5%) scored in the range of 5 to 8 out of a possible 11 points, and 10 participants (17.9%) scored in the range of 0 to 4 out of a possible 11 points on pre BDT. Furthermore, the frequency distribution analysis suggested the mode of 7.0 and range of 11.0 for pre BDT (Table 1).

The statistical analysis of post BDT showed that participants achieved a mean score of 6.84 with standard deviation of 2.10 and a standard error of 0.28. The frequency distribution analysis concluded that 13 students (23.2%) scored 9 points or higher, 35 students (62.5%) scored in the range of 5 to 8, and eight students (14.3%) scored in the range of 0 to 4 out of possible 11 points. The range for this set of data was 8.0 and mode was calculated to be 8.0 (Table 1). The mean difference between pre BDT and post BDT was calculated as 0.43 (Table 3).

Table 1

Descriptive Statistics for Pre and Post BDT

	Pre-BDT	Post-BDT
Valid	56	56
Missing	0	0
Mean	6.411	6.839
Std. Deviation	2.3181	2.0957
Std. Error of Mean	0.3098	0.28
Median	7	7
Mode	7	8
Range	11	8
Minimum	0	2
Maximum	11	10

Note. N = 56

Comparison between the frequency distributions for both pre BDT and post BDT is summarized in Table 2 and Figure 5.

Table 2

Frequency Distribution of Pre and Post BDT

Pre BDT			Post BDT		
Score	Frequency	Percent	Score	Frequency	Percent
0-4	10	17.9	0-4	8	14.3
5-8	35	62.5	5-8	35	62.5
9+	11	19.6	9+	13	23.2
Total	56	100	Total	56	100

Note. N = 56

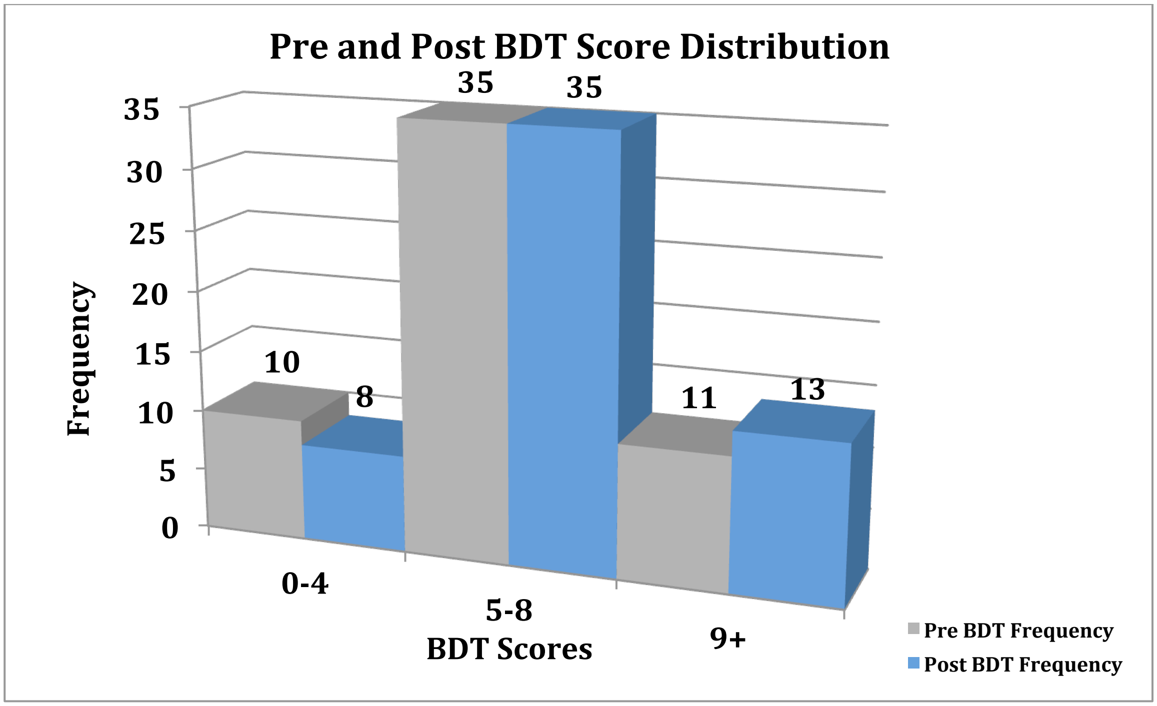

Figure 5. Frequency distribution of pre and post BDT (*N* = 56).

The analysis of pre and post BDT showed an increased mean value for post BDT. The mean differences between pre BDT and post BDT was calculated as 0.43 (Figure 6).

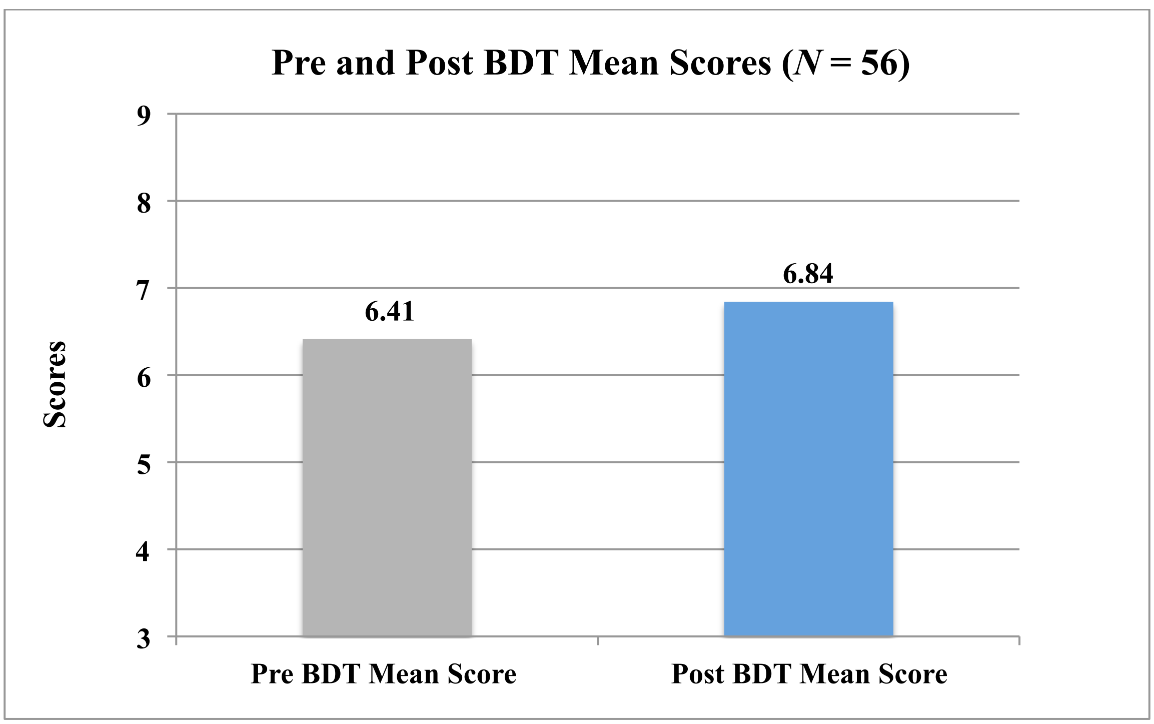

Figure 6. Mean scores for pre and post BDT (*N* = 56).

Hypothesis testing results. To test the hypothesis that participating in VSLs will improve cognitive knowledge, a dependent sample *t*-test was performed. Although, statistical analysis on the BDT suggests that the mean score from post BDT (M = 6.84, SD = 2.10, N = 56) is higher than the mean score from pre BDT (M = 6.41, SD = 2.32, N = 56), the significant (two-tailed) value is higher than .05 meaning that the results are not significantly different (t (55) = -1.66, $p \geq .05$). The null hypothesis cannot be rejected as the results of these findings. Therefore, there was no significant difference between the mean scores of pre and post BDT.

Table 3

Paired Sample t-Test for BDT

Outcome	Paired Differences							
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Differences		*t*	*df*	*Sig. (2-tailed)*∗
				Lower	Upper			
Pre BDT-Post-BDT	-0.4286	1.9246	0.2572	-0.944	0.0868	-1.666	55	0.101

Note. *df* = degree of freedom, *t* = *t* value.
$p \leq .05$

Attitudes Toward Science Findings

Students' attitudes toward science were measured through the use of a multidimensional survey assessment tool that contained 40 items. The items in the ATSI survey were organized in five subscale categories that measured students' motivation in science, enjoyment of science, anxiety toward science, self-concept regarding science, and value of science in society. Each subscale comprised of 8 items. The subscale scores are based on a 6-point Likert scale ranging from 1, Strongly Agree (most favorable) to 6, Strongly Disagree (least favorable). The ATSI information sheet provided in Appendix F summarized the possible range of scores for each subscale in ATSI survey. The possible range of scores is from 8 (most favorable) to 48 (least favorable). The scores for statements that were worded negatively were reverse coded so that the lower score would always reflect more positive attitudes.

The reliability of the ATSI instrument and level of internal consistency have been reported to be sufficient by other researchers (Weinburgh, 2000). The researcher ran the Chronbach's alpha reliability for each subscale in ATSI survey and the results are summarized in Table 4. The alpha reliability coefficients were in alignment with previous studies and were within the range of acceptability (Weinburgh, 2000). The alpha coefficient values were consistent from pre to post in subscales anxiety toward science and enjoyment of science. The alpha coefficient values for motivation in science, self-concept regarding science, and value of science were not consistent. The most reliable scales were anxiety toward science, enjoyment of science, and self-concept regarding science.

Table 4

Chronbach's Alpha Coefficient Values

Subscales	PreATSI (α)	PostATSI (α)
Motivation in science	0.62	0.72
Enjoyment of science	0.79	0.75
Anxiety toward science	0.91	0.91
Self-concept regarding science	0.74	0.84
Value of science in society	0.69	0.60

Note. α = Chronbach's Alpha. α ranges from 0 to 1.0. Coefficients closer to 1.0 indicate higher intercorrelation of items.
$\alpha > .70$ are reliable.

Descriptive results. The statistical analysis for each subscale is shown in Table 5. The overall statistical analysis showed the mean score of 121.39 (*SD* = 32.04) for pre ATSI and mean score of 117.20 (*SD* = 31.47).

Table 5

Descriptive statistics for Overall Pre ATSI and Post ATSI

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Std. Error
Pre-ATSI (overall)	56	142.0	69.0	211.0	121.393	32.0396	4.2815
Post-ATSI (Overall)	56	148.0	63.0	211.0	117.196	31.4709	4.2055

The results from this descriptive analysis reveal that the overall attitudes of students were positively changed by a mean difference of 4.19 (Table 5).

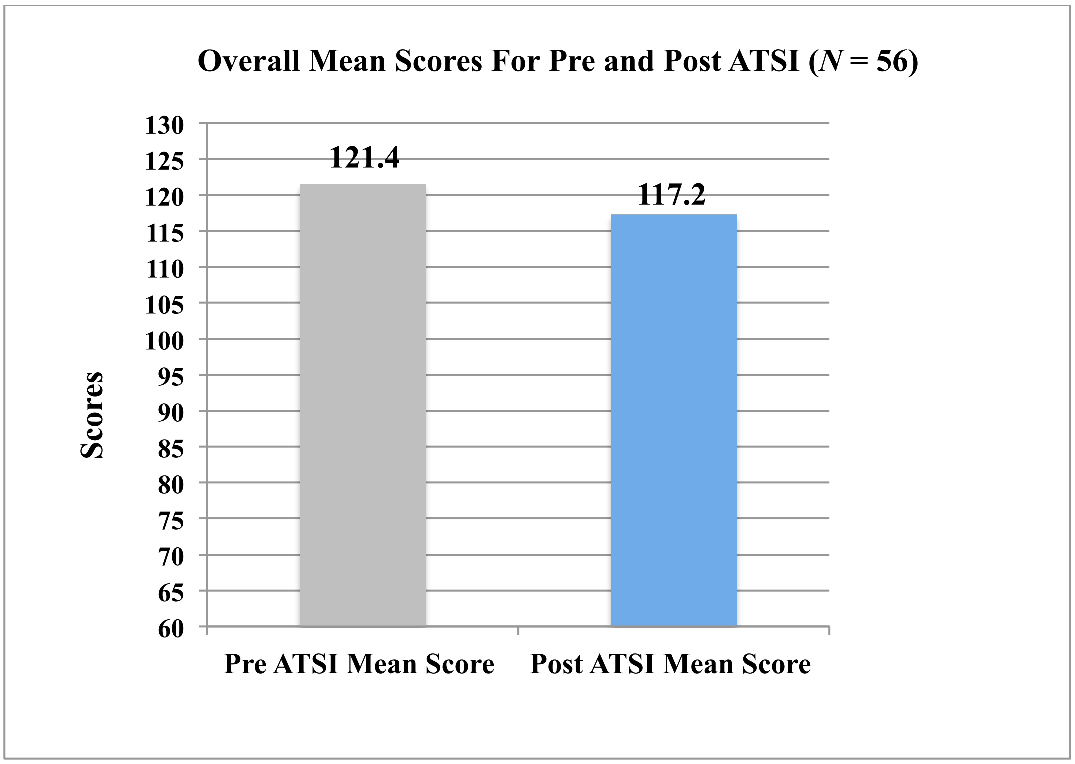

Figure 7. Mean scores for pre and post ATSI ($N = 56$). Lower post-mean score reflects a positive change.

Hypothesis testing results. To test the hypothesis that participating in VSLs will enhance students' attitude toward science, a dependent sample *t*-test was performed. This hypothesis was further broken down into 5 subscales. The dependent sample *t*-test was performed for each of the subscales. The overall paired sample *t*-test results concluded that the significant (two-tailed) value is higher than .05, which means the results are not statistically significant t (55) = 1.12, $p \geq .05$. Thus, the null hypothesis cannot be rejected. The researcher could not assume that the differences in mean scores were significant. Further descriptive analyses on each subscales of ATSI survey indicate a favorable change from pre assessment to post assessment (Table 6).

Table 6

Descriptive Statistics for ATSI Survey Subscales

	Pre Value	Post Value	Pre Enjoy	Post Enjoy	Pre Motivation	Post Motivation	Pre Self	Post Self	Pre Anxiety	Post Anxiety
Mean	23.82	22.11	24.41	23.54	27.11	26.45	24.3	23.9	21.75	21.21
Std. Deviation	6.7	5.87	7.79	7.54	6.59	6.94	7.01	7.78	9.66	9.5
Median	23	22	24	22.5	28	26.5	24	23	20.5	20.5
Mode	18.00[a]	25	24	21.00[a]	28	27	19.00[a]	15.00[a]	24	13.00[a]
Range	32	28	36	33	29	36	27	32	40	39
Minimum	12	13	9	10	15	12	12	12	8	8
Maximum	44	41	45	43	44	48	39	44	48	47

Note. $N = 56$
a. Multiple modes exist. The smallest value is shown.

Descriptive results for value of science in society. The item analysis for each statement of this subscale suggested that students' attitudes were positively changed after using the VSL except for item # 33. The statistical analysis of items for pre and post value of science in society revealed that the mean score decreased from (M = 23.82, SD = 6.70) to (M = 22.11, SD = 5.87).

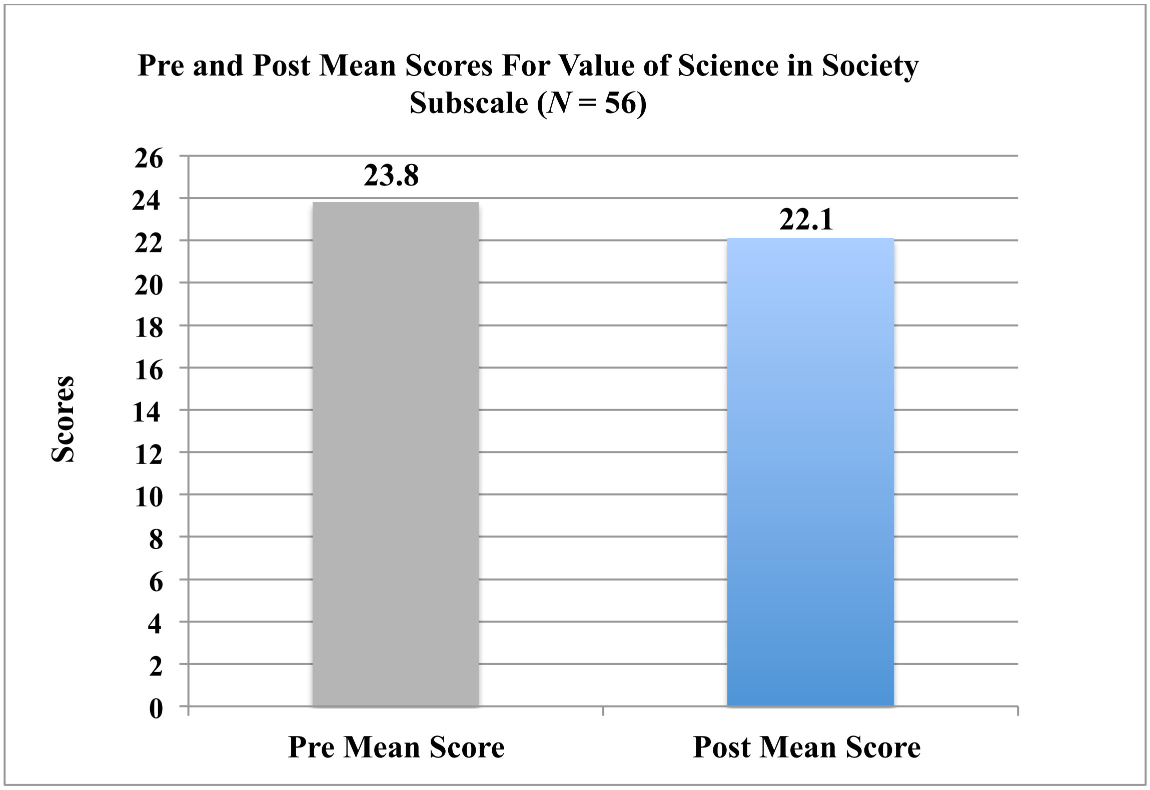

Figure 8. Mean scores for pre and post value of science in society subscale ($N = 56$). Lower post-mean score reflects a positive change.

The value of science in society subscale was the subscale that reflected the most attitudinal change. Students' attitudes were positively changed by a mean difference of 1.71 (Figure 8).

Table 7

Frequency Distribution of Pre Value of Science in Society

Score	Frequency	Percent
12.0-16.0	5	8.9
17.0-20.0	14	25.0
21.0-25.0	18	32.1
26.0-29.0	9	16.1
30.0+	10	17.9
Total	56	100.0

Note. $N = 56$

The frequency distribution analysis of scores on pre value of science in society suggested that the data were distributed closer to the mean score of 23.82 (Table 6). Thirty-two respondents (57.1%) scored in the range of 17.0 to 25.00 (Table 7).

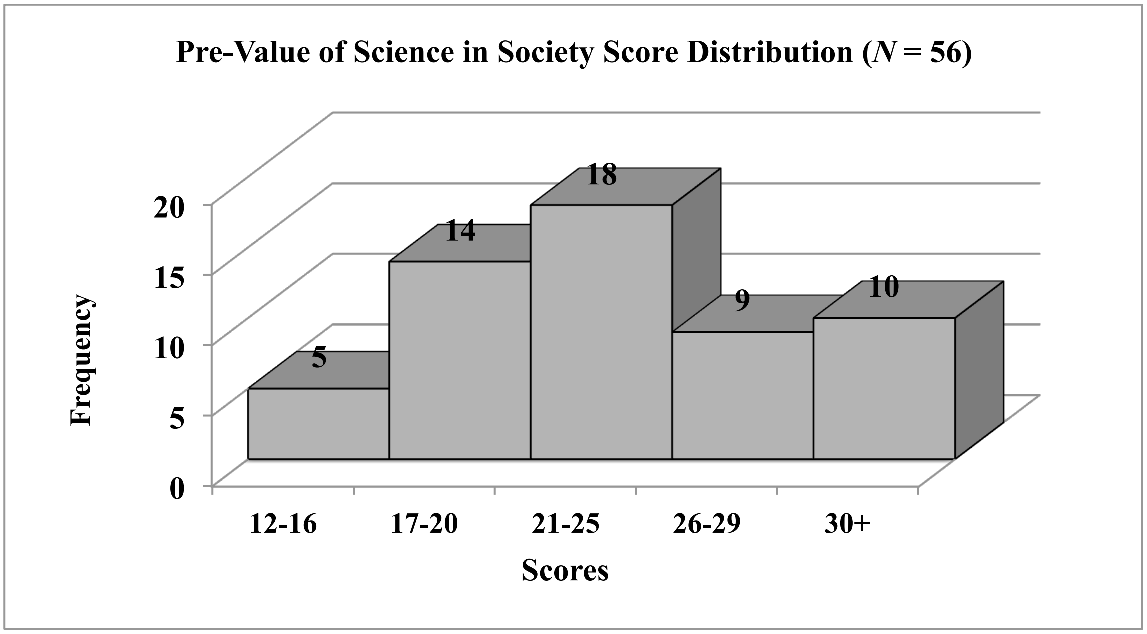

Figure 9. Frequency distribution of pre value of science in society (*N* = 56).

The frequency distribution analysis scores on post value of science in society showed that data are skewed right and mass of the distribution is concentrated on the left (Figure 8).

Table 8

Frequency Distribution of Post Value of Science in Society

Score	Frequency	Percent
13.0-16.0	8	14.3
17.0-20.0	16	28.6
21.0-24.0	15	26.8
25.0-31.0	13	23.2
32.0+	4	7.1
Total	56	100.0

Note. *N* = 56

These findings suggest a favorable change in subscale value of science in society. Close to fourteen percent of participants scored in the range of 13.0-16.0 and nearly 29 percent of participants scored in the range of 17.0 to 20.0 on items pertaining to post value of science in society (Table 8).

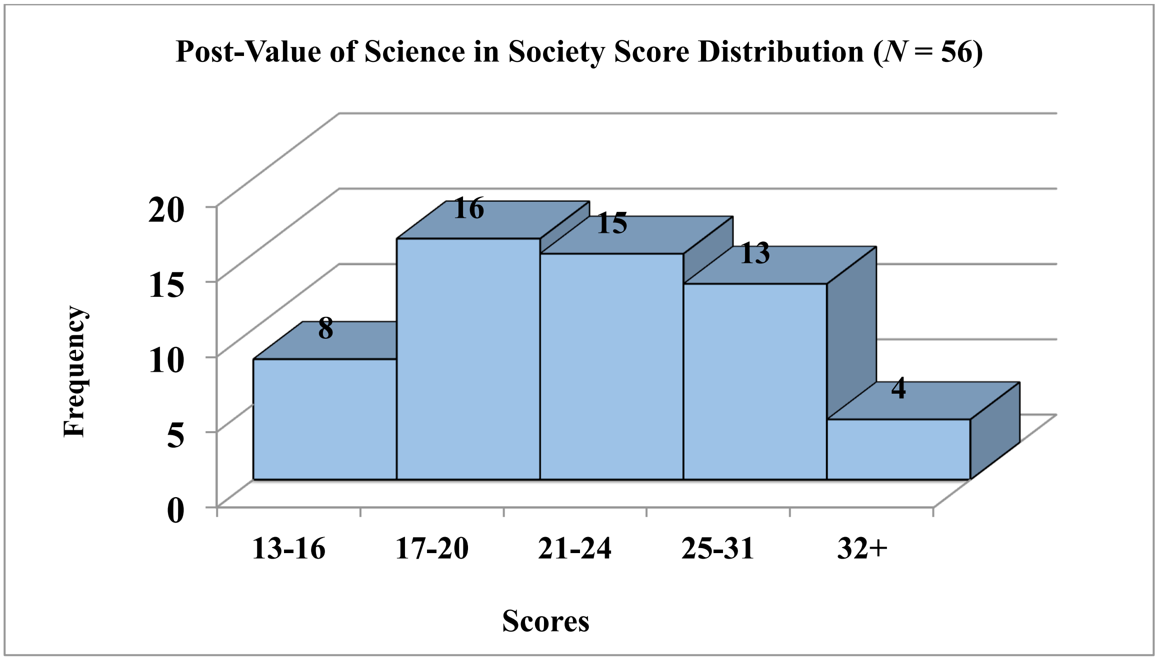

Figure 10. Frequency distribution of post value of science in society ($N = 56$).

Hypothesis testing results for value of science in society. To test the hypothesis that participating in VSLs will enhance students' value of science in society, a dependent sample *t*-test was performed. The mean difference between for pre value of science in society and post value of science in society is ($M = 1.7143$, $SD = 7.093$). The paired sample *t*-test suggests that the significant (two-tailed) value is higher than .05. The results are not statistically significant $t(55) = 1.81$, $p \geq .05$ (Table 9). The null hypothesis is retained.

Descriptive results for enjoyment of science. The statistical analysis of items for pre and post enjoyment of science indicated that the mean score decreased from ($M = 24.41$, $SD = 7.79$) to ($M = 23.54$, $SD = 7.54$). The frequency distribution analysis of scores on pre enjoyment of science suggested that the data was distributed closer to the mean score of 24.41 (Table 6). The enjoyment of science subscale was the subscale with the second most attitudinal change. Students' attitudes were positively changed by a mean difference of 0.88 (Figure 11). Thirtyfour percent of respondents scored in the range of 14.00 to 23.00 in pre enjoyment of science (Table 10).

Table 9

Paired Samples t-Test for Pre and Post Value of Science in Society

Outcome	Paired Differences							
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Differences				
				Lower	Upper	*t*	*df*	*Sig. (2-tailed)*∗
Pre Value-Post-Value	1.7143	7.0934	0.9479	-0.1853	3.6139	1.809	55	0.076

Note. *df* = degree of freedom, *t* = *t* value.
∗$p \leq .05$

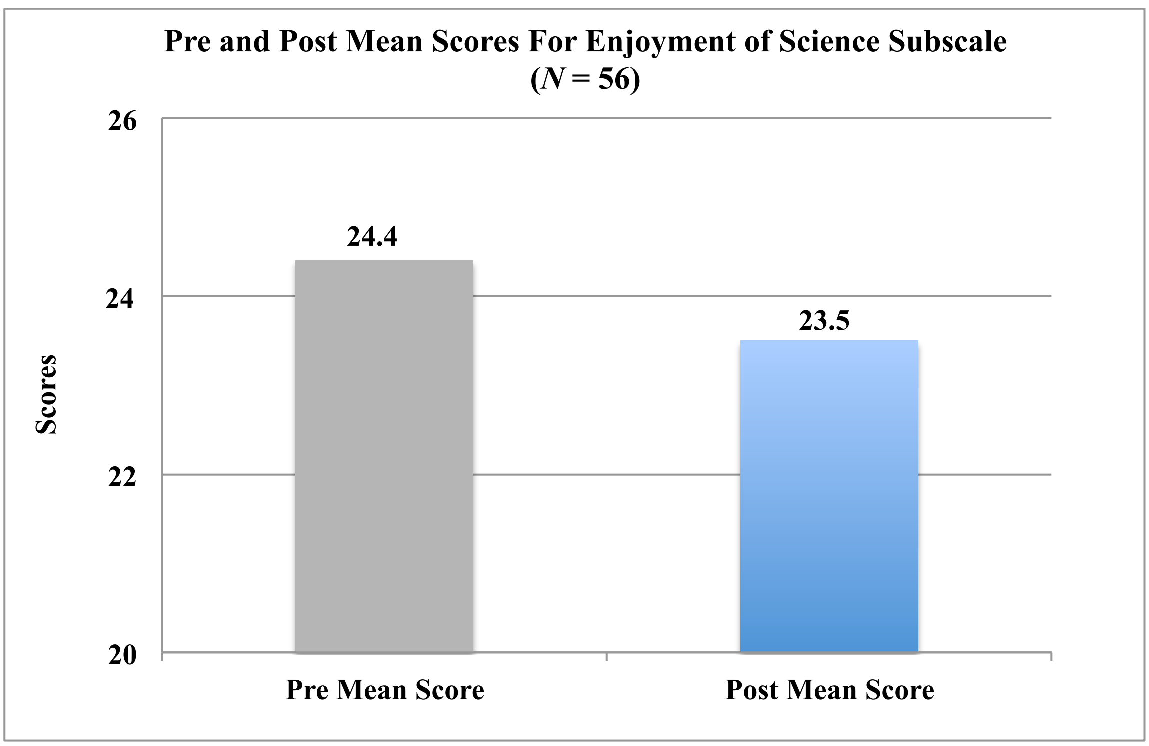

Figure 11. Mean scores for pre and post enjoyment of science subscale (*N* = 56). Lower post-mean score reflects a positive change.

Table 10

Frequency Distribution of Pre Enjoyment of Science

Score	Frequency	Percent
9.0-13.0	5	8.9
14.0-19.0	9	16.1
20.0-23.0	10	17.9
24.0-27.0	16	28.6
28.0-32.0	8	14.3
33.0+	8	14.3
Total	56	100.0

Note. N = 56

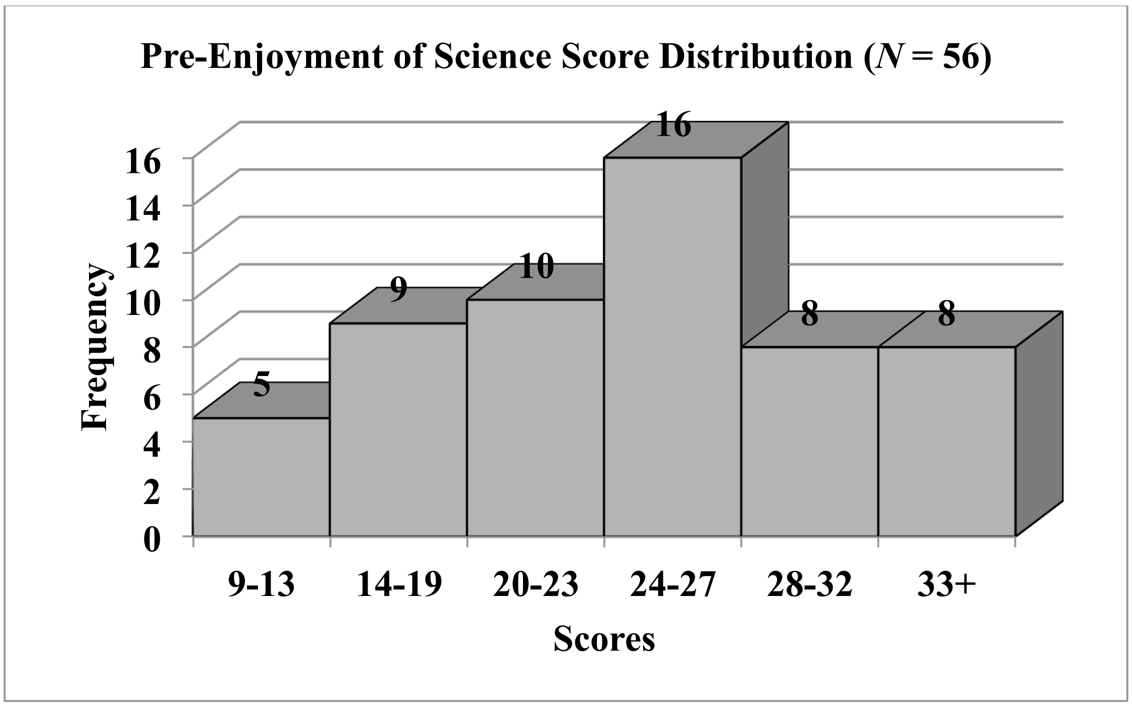

Figure 12. Frequency distribution of pre enjoyment of science ($N = 56$).

The frequency distribution analyses of post enjoyment of science revealed that close to forty three percent of respondents scored in the range of 16.00 to 23.00 in post enjoyment of science (Table 11).

Table 11

Frequency Distribution of Post Enjoyment of Science

Score	Frequency	Percent
10.0-15.0	7	12.5
16.0-19.0	10	17.9
20.0-23.0	14	25.0
24.0-27.0	12	21.4
28.0-32.0	6	10.7
33.0+	7	12.5
Total	56	100.0

Note. $N = 56$

The item analysis for each statement of this subscale suggested that students' enjoyment for science were positively changed after using the VSL except for item # 5, 12, and 23. Students' enjoyment for science was negatively changed for these items.

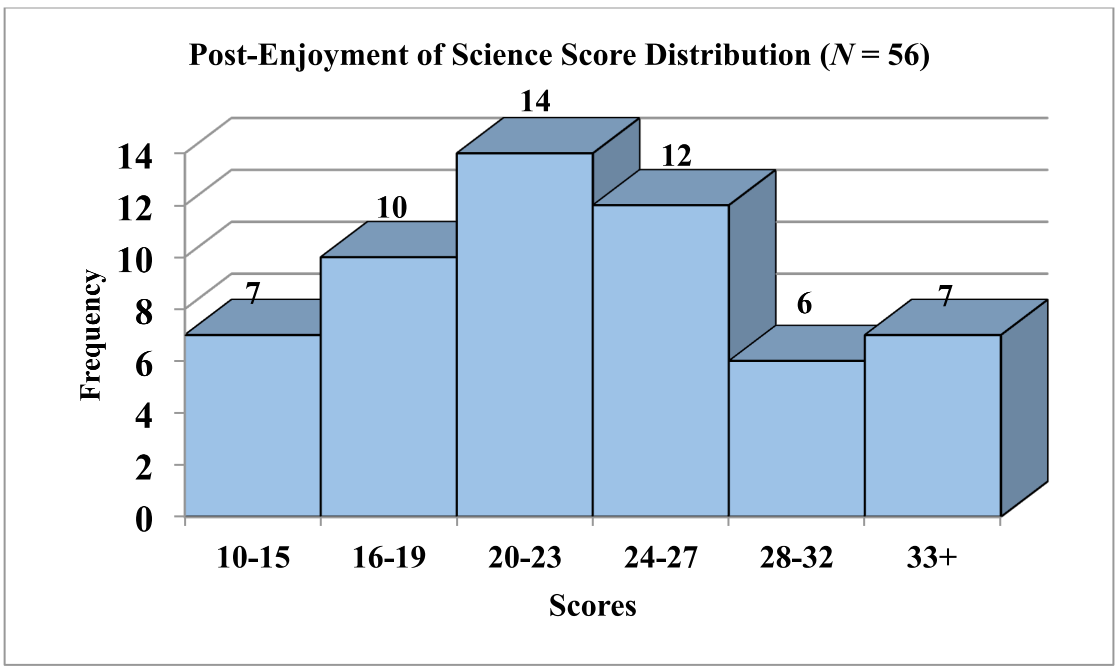

Figure 13. Frequency distribution of post enjoyment of science ($N = 56$).

Hypothesis testing results for enjoyment of science. To test the hypothesis that participating in VSLs will enhance students' enjoyment of science, a dependent sample t-test was performed. The paired sample *t*-test suggests that the significant (two-tailed) value is higher than

.05. The results are not statistically significant, t (55) = 1.01, $p \geq .05$ (Table 12). The researcher could not assume that the differences in mean score is significant.

Table 12

Paired Samples t-Test for Pre and Post Enjoyment of Science

Outcome	Paired Differences					*t*	*df*	*Sig. (2-tailed)*∗
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Differences				
				Lower	Upper			
Pre Enjoy-Post-Enjoy	.8750	6.4725	.8649	-.8583	2.6083	1.012	55	.316

Note. *df* = degree of freedom, *t* = *t* value.
∗$p \leq .05$

Descriptive results for motivation in science. The third subscale of ATSI survey measured students' motivation in science. The statistical analysis of items for pre and post enjoyment of science indicated that the mean score decreased from (M = 27.11, SD = 6.59) to (M = 26.45, SD = 6.94). The frequency distribution analysis shows that 6 participants (10.7%) scored in the range of 15.00 to 18.00 and 10 participants (17.9%) scored in the range of 19.0 to 22.0 on pre motivation subscale of ATSI survey (Table 13). Additionally, The item analysis for each eight statements of this subscale suggested that student' attitudes were positively changed after using the VSL except for item # 3, 13, 32, and 35. The motivation in science subscale was the subscale with the third most attitudinal change. Students' attitudes were positively changed by a mean difference of 0.66 (Figure 14). Figure 15 summarizes the frequency distribution of scores for pre motivation in science.

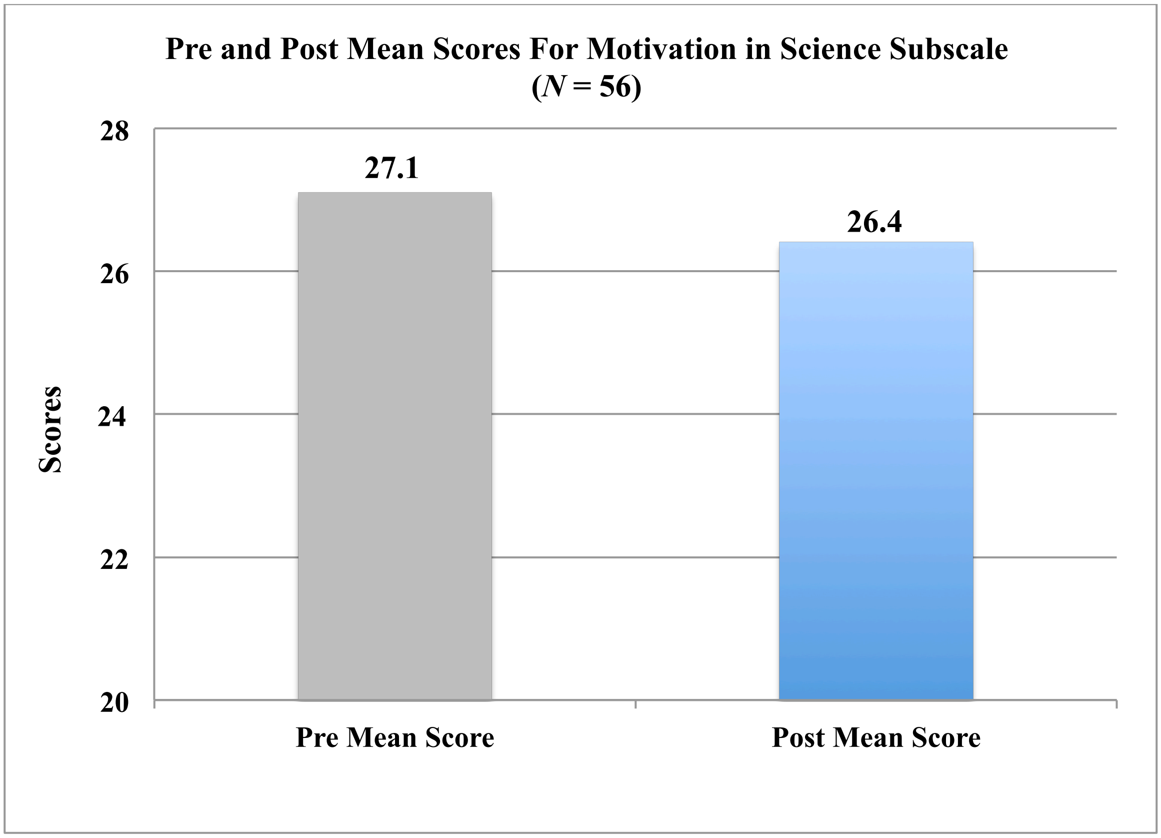

Figure 14. Mean scores for pre and post motivation in science subscale ($N = 56$). Lower post-mean score reflects a positive change.

Table 13

Frequency Distribution of Pre Motivation in Science

Score	Frequency	Percent
15.0-18.0	6	10.7
19.0-22.0	10	17.9
23.0-26.0	9	16.1
27.0-30.0	12	21.4
31.0-34.0	12	21.4
35.0+	7	12.5
Total	56	100.0

Note. $N = 56$

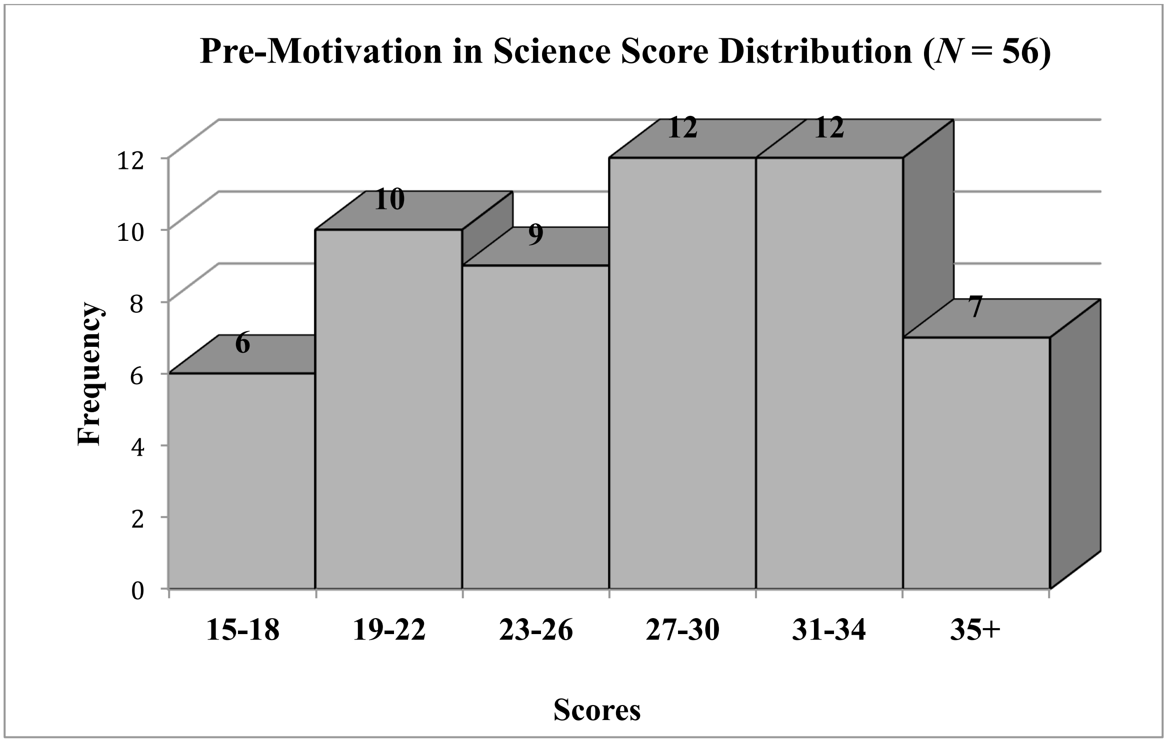

Figure 15. Frequency distribution of pre motivation in science (*N* = 56).

The frequency analyses of post motivation with (*M* = 26.45, *SD* = 6.94) indicate that data was distributed near the mean score. Thirteen participants (23.2%) scored in the range of 23.0 to 26.0 and 33.9% of participants scored in the range of 27.0 to 31.0 (Table 14). Figure 16 summarizes the score distribution for post motivation in science subscale.

Table 14

Frequency Distribution of Post Motivation in Science

Score	Frequency	Percent
12.0-18.0	6	10.7
19.0-22.0	9	16.1
23.0-26.0	13	23.2
27.0-31.0	19	33.9
32.0-40.0	6	10.7
41.0+	3	5.4
Total	56	100.0

Note. *N* = 56

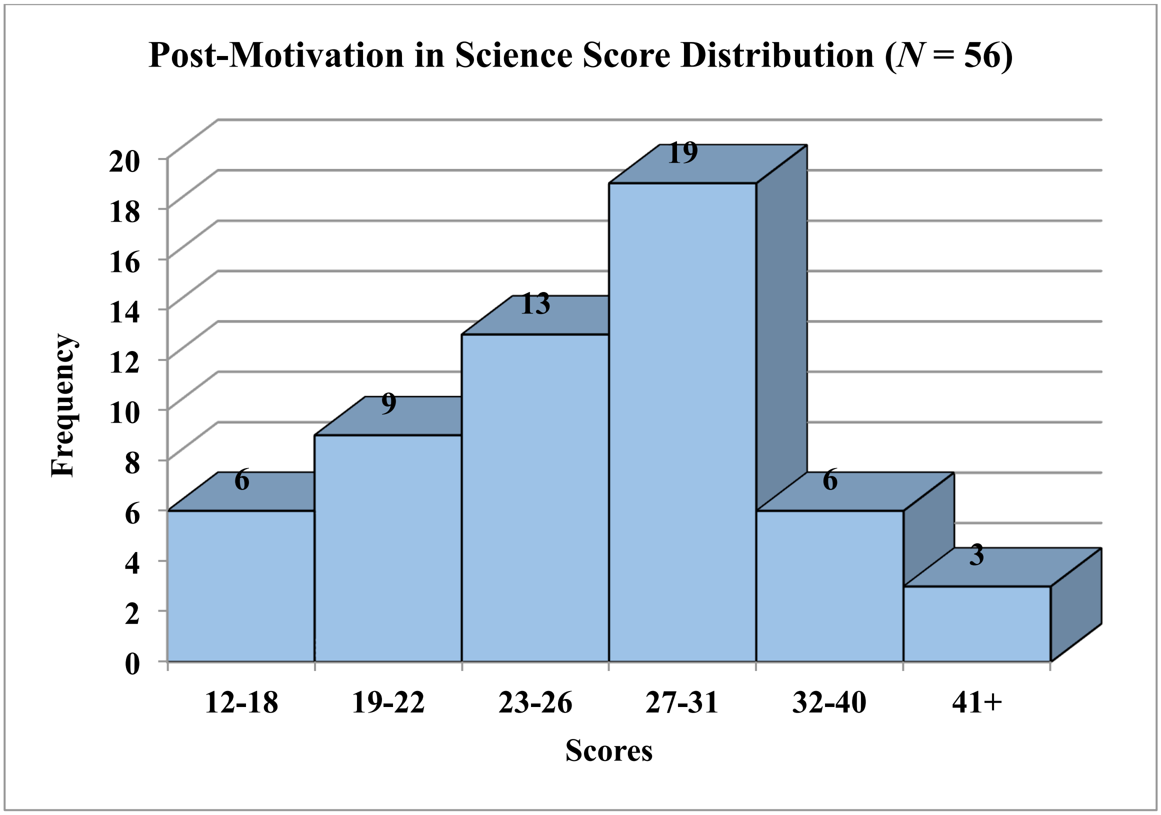

Figure 16. Frequency distribution of post motivation in science ($N = 56$).

Hypothesis testing results for motivation toward science. To test the hypothesis that participating in VSLs will enhance students' motivation toward science, a dependent sample *t*-test was performed. The paired sample *t*-test suggests that the significant (two-tailed) value is higher than .05. The results are not statistically significant, t (55) = 0.85, $p \geq .05$ (Table 15). The null hypothesis cannot be rejected.

Descriptive results for anxiety toward science. The forth subscale in ATSI survey measured students' anxiety toward science before and after using the VSL. The statistical analysis of items for pre and post anxiety toward science indicated that the mean score decreased from (M = 21.80, SD = 9.66) to (M = 21.21, SD = 9.49). The high standard deviation on both pre and post anxiety toward science scores suggest that the values are dispersed largely across the range of possible score. The item analysis for each statement of this subscale suggested that students' anxiety toward science were positively changed after using the VSL except for item # 6, 18, and 34. The anxiety toward science subscale was the subscale with the fourth most attitudinal change. Students' attitudes were positively changed by a mean difference of 0.54 (Figure 17).

Table 15

Paired Samples t-Test for Pre and Post Motivation Toward Science

Outcome	Paired Differences							
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Differences				
				Lower	Upper	*t*	*df*	*Sig. (2-tailed)*∗
Pre Motivation-Post Motivation	.6607	5.7880	.7735	-.8893	2.2108	.854	55	.397

Note. *df* = degree of freedom, *t* = *t* value.
∗$p \leq .05$

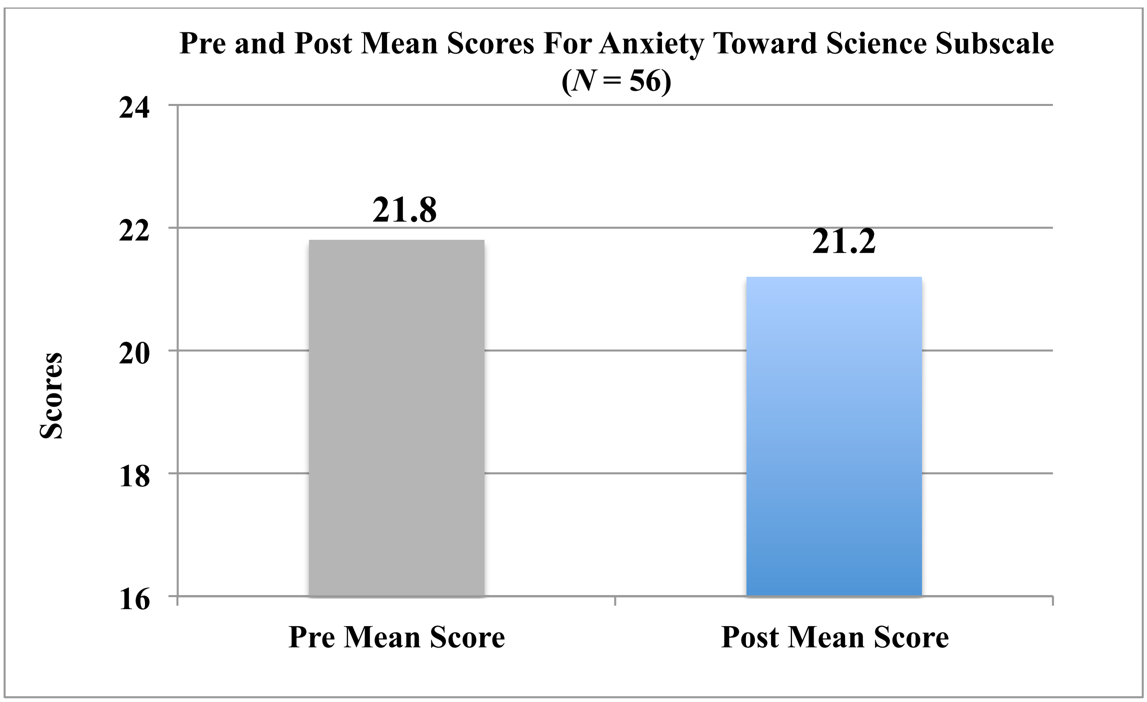

Figure 17. Mean scores for pre and post anxiety toward science subscale (N = 56). Lower post-mean score reflects a positive change.

Frequency distribution analysis for pre anxiety toward science suggested that 21 participants (37.5%) scored in the range of 8.0 to 17.0.

Table 16

Frequency Distribution for Pre Anxiety Toward Science

Score	Frequency	Percent
8.0-11.0	11	19.6
12.0-17.0	10	17.9
18.0-21.0	8	14.3
23.0-27.0	12	21.4
28.0-32.0	8	14.3
33.0+	7	12.5
Total	56	100.0

Note. $N = 56$

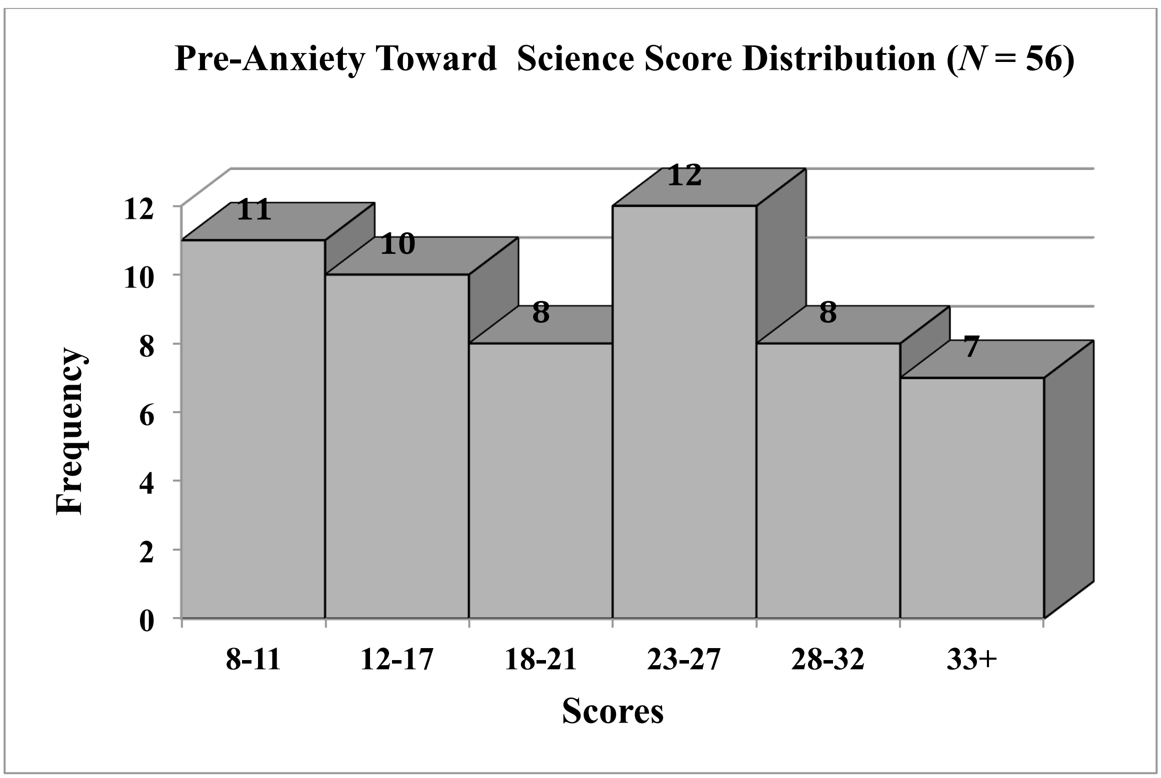

Figure 18. Frequency distribution of pre anxiety toward science ($N = 56$).

Although the change in mean scores was positive (decreased), frequency distribution analysis indicated that the range of scores and frequency distribution of scores changed drastically from pre to post anxiety toward science. Frequency was distributed in a larger range of value in post anxiety toward science compared to pre anxiety toward science. Twenty-six participants (46.5%) scored in the range of 8.0 to 19.0 (Table 17).

Table 17

Frequency Distribution for Post Anxiety Toward Science

Score	Frequency	Percent
8.0-11.0	8	14.3
12.0-15.0	10	17.9
16.0-19.0	8	14.3
20.0-23.0	11	19.6
24.0-29.0	8	14.3
30.0+	11	19.6
Total	56	100.0

Note. $N = 56$

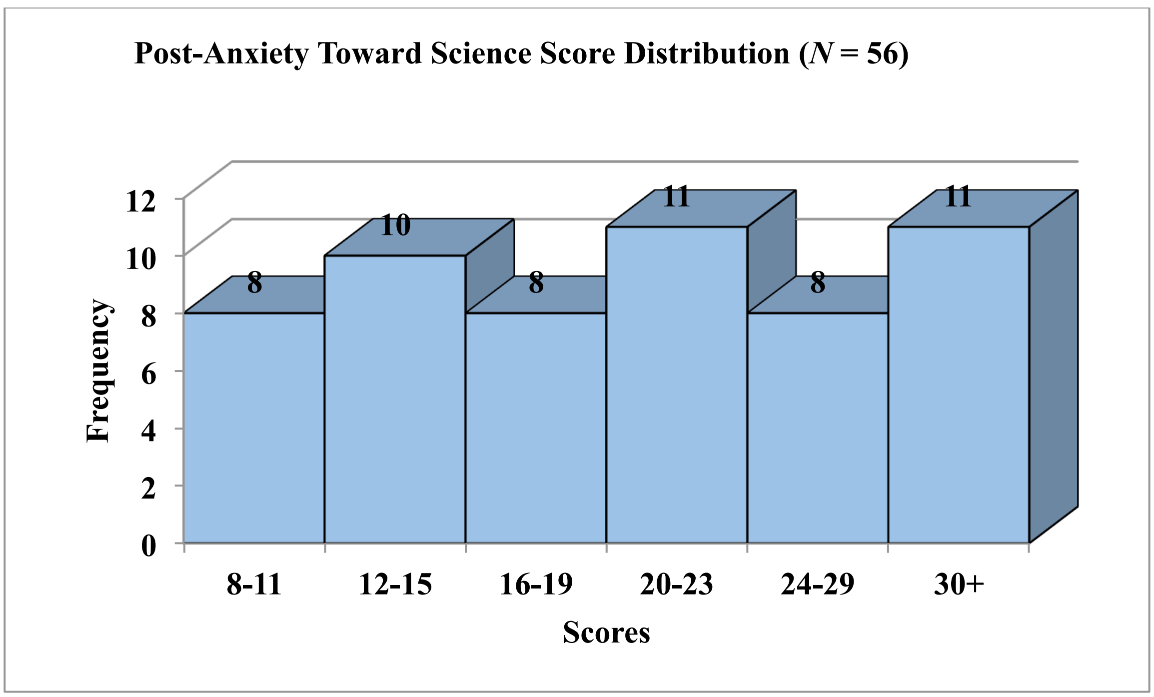

Figure 19. Frequency distribution of post anxiety toward science ($N = 56$).

Hypothesis testing results for anxiety toward science. To test the hypothesis that participating in VSLs will diminish students' anxiety toward science, a dependent sample *t*-test was performed. The paired sample *t*-test suggests that the significant (two-tailed) value is higher than .05. The results are not statistically significant, t (55) = 0.47, $p \geq .05$ (Table 18). The null hypothesis cannot be rejected due to the significant value.

Table 18

Paired Samples t-Test for Pre and Post Anxiety Toward Science

Outcome	Paired Differences					*t*	*df*	*Sig. (2-tailed)*∗
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Differences				
				Lower	Upper			
Pre Anxiety-Post Anxiety	.5357	8.4659	1.1313	-1.7315	2.8029	.474	55	.638

Note. *df* = degree of freedom, *t* = *t* value.
∗$p \leq .05$

Descriptive results for self-concept regarding science. The statistical analysis of items for pre and post self-concept regarding science showed the mean score for pre self-concept regarding science (M = 24.30, SD = 7.01). The mean score for post self-concept regarding science (M = 23.89, SD = 7.78) decrease suggesting a favorable attitudinal change (Figure 17). The frequency distribution analysis on pre self-concept regarding science indicated higher dispersion across the range of scores (Table 19). The item analysis for each eighth statements of this subscale suggested that students' self-concepts regarding science were positively changed after using the VSL except for items # 17 and 40 showed no change in attitude from pre to post assessment. The self-concept regarding science subscale was the subscale with the fifth most attitudinal change. Students' attitudes were positively changed by a mean difference of 0.41 (Figure 20).

Table 19

Frequency Distribution for Pre Self-Concept Regarding Science

Score	Frequency	Percent
12.0-15.0	7	12.5
16.0-19.0	10	17.9
20.0-23.0	10	17.9
24.0-27.0	12	21.4
28.0-32.0	8	14.3
33.0+	9	16.1
Total	56	100.0

Note. $N = 56$

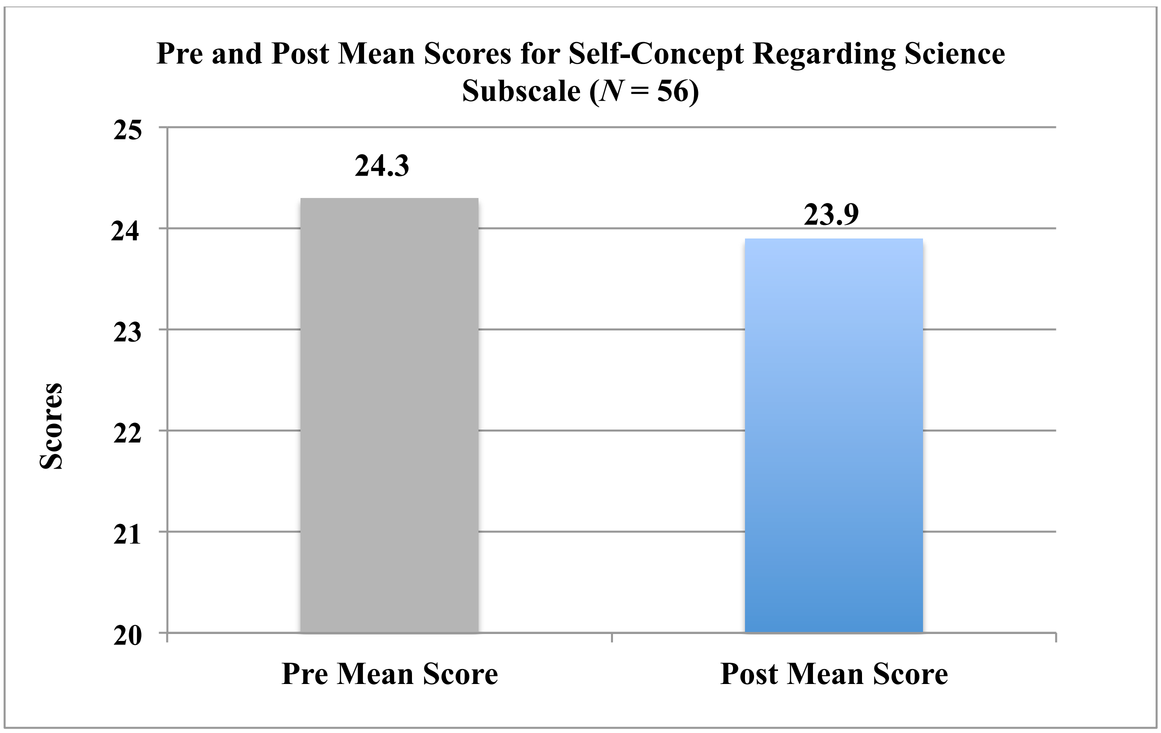

Figure 20. Mean scores for pre and post self-concept regarding science subscale ($N = 56$). Lower post-mean score reflects a positive change.

The pre self-concept regarding science frequency distribution analyses suggested that seventeen participants scores in the range of 12.0-19.0 (Table 19). Figure 21 summarizes the frequency distribution of pre self-concept regarding science.

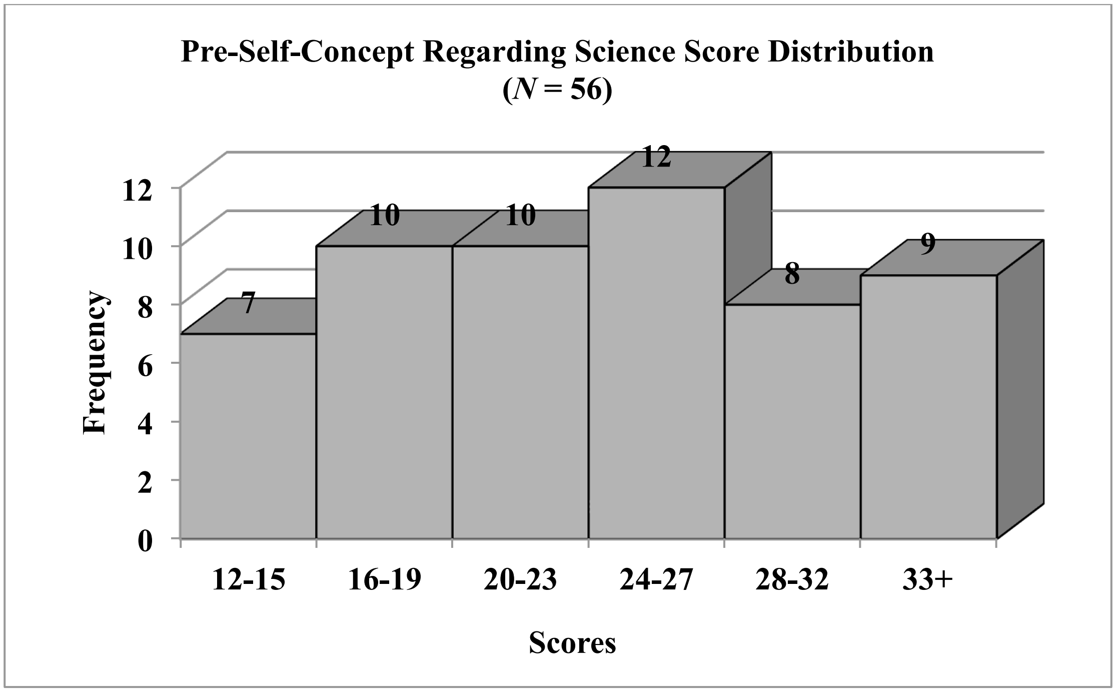

Figure 21. Frequency distribution of pre self-concept regarding science (*N* = 56).

The post self-concept regarding science frequency analyses suggested that even though the frequency of scores were somewhat equally distributed across the possible range of scores, participants' average scores decreased by 0.41 points (Table 20).

Table 20

Frequency Distribution for Post Self-Concept Regarding Science

Score	Frequency	Percent
12.0-15.0	9	16.1
16.0-19.0	9	16.1
20.0-23.0	13	23.2
24.0-27.0	9	16.1
28.0-33.0	10	17.9
34.0+	6	10.7
Total	56	100.0

Note. *N* = 56

The frequency distribution figures for both pre and post self-concept regarding science indicate a shift toward the left resulting in a more favorable attitude in this subscale.

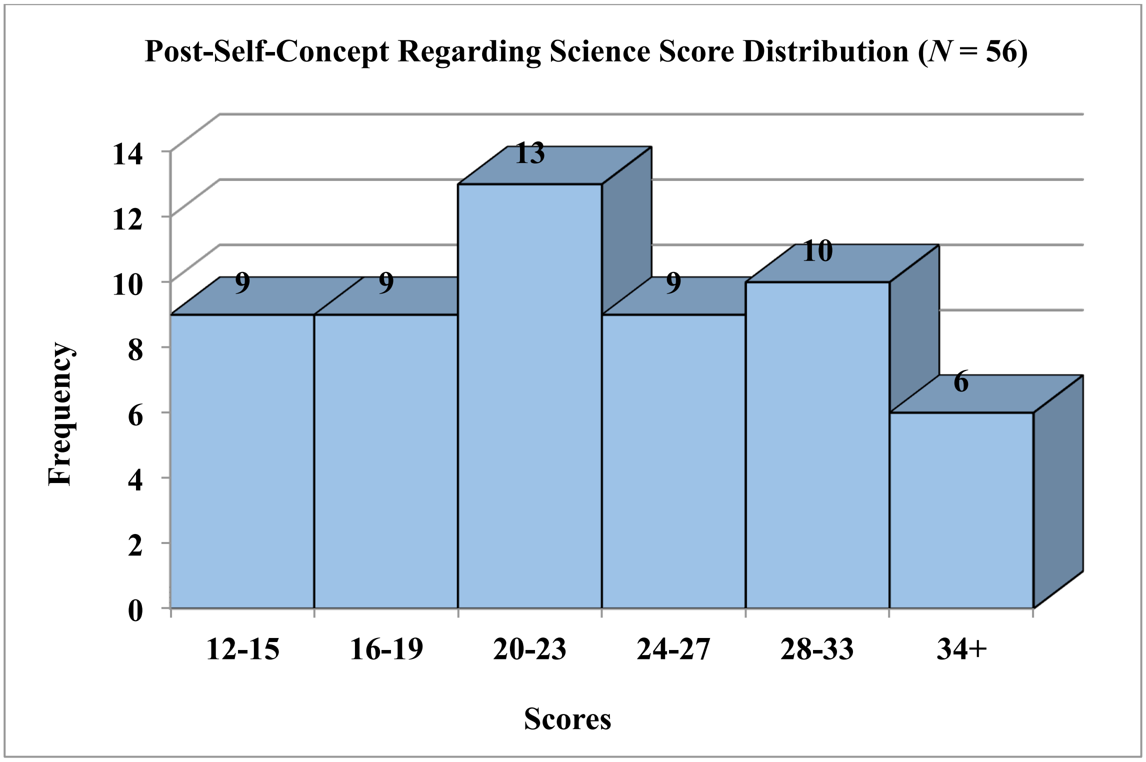

Figure 22. Frequency distribution of post self-concept regarding science (*N* = 56).

Hypothesis testing results for self-concept regarding science. To test the hypothesis that participating in VSLs will enhance students' self-concept of science, a dependent sample *t*-test was performed. The paired sample *t*-test suggests that the significant (two-tailed) value is higher than .05. The results are not statistically significant, $t\ (55) = 0.43$, $p \geq .05$ (Table 21). The researcher could not assume that the differences in mean score is significant. The null hypothesis is retained.

Table 21

Paired Samples t-Test for Pre and Post Self-Concept Regarding Science

Outcome	Paired Differences							
				95% Confidence Interval of the Differences				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	*t*	*df*	*Sig. (2-tailed)**
Pre Self-Post Self	.4107	7.1038	.9493	-1.4917	2.3131	.433	55	.667

Note. *df* = degree of freedom, *t* = *t* value.
**p* ≤ .05

Skill Development Findings

Descriptive results for hypothesis 3. To test the hypothesis that participating in VSLs will affect students' mathematical skills, descriptive and frequency analysis were performed. Students' mathematical skills were recorded on the mathematical skill page on the VLP. Students' use of density formula, mathematical calculations, and appropriate usage of units were assessed.

The total score for this section was 9 points. The statistical analysis indicates a mean score of 2.87 with standard deviation of 1.54. The high number of standard deviation suggested the wide dispersion of data around the mean score (Table 22). The findings suggest that the Buoyancy and Density VSL did not have an effect on students' mathematical skills.

Table 22

Statistical Analysis for Mathematical Skills

Mean	2.87
Std. Deviation	1.54
Std. Error of Mean	.21
Median	3.00
Mode	3.00
Skewness	-.01
Std. Error of Skewness	.32
Kurtosis	.16
Std. Error of Kurtosis	.63
Range	6.75
Minimum	.00
Maximum	6.75

Note. N = 56

None of the students could fully incorporate the appropriate units and complete the mathematical calculations for the entire objects provided in the VSL. Fifteen participants (26.8%) scored in the range of 0.0 to 2.0 out of the possible nine points in mathematical skill section (Table 22). Frequency distribution analyses for mathematical skills suggest that scores are normally distribution around the mean score of 2.87. The maximum score obtained by the participants was 6.75 (Table 23). Figure 23 summarizes the score distribution for participants' mathematical skills.

Table 23

Frequency Distribution for Mathematical Skills

Score	Frequency	Percent
.0-2.0	15	26.8
2.25-3.50	25	44.6
3.75-5.25	14	25
5.50+	2	3.6
Total	56	100.0

Note. *N* = 56

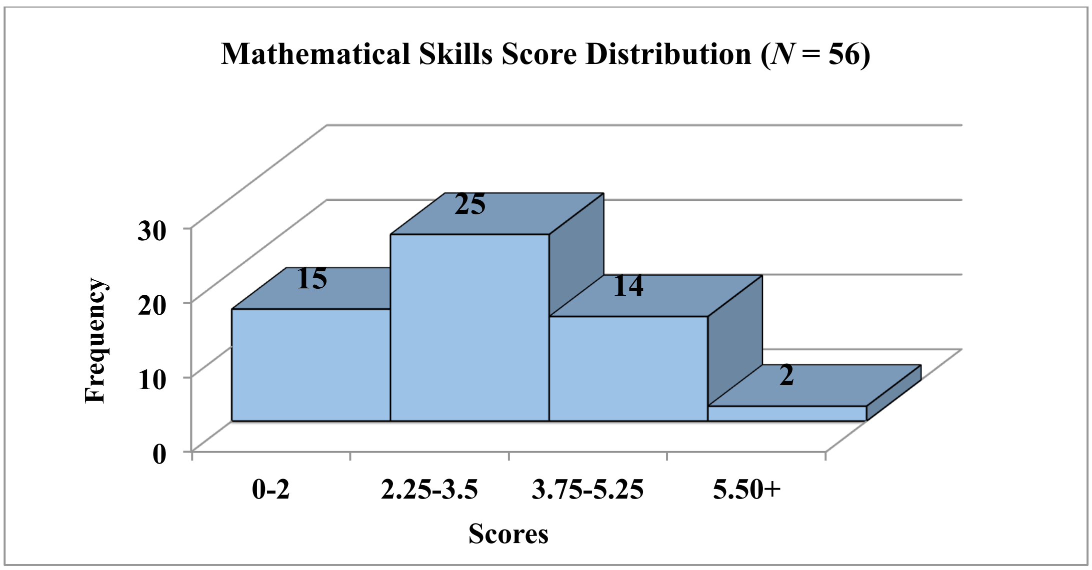

Figure 23. Frequency distribution of mathematical skills (*N* = 56).

Hypothesis 4. To test the hypothesis that participating in VSLs will affect students' scientific skills, descriptive and frequency analysis were performed. Students' scientific skills were measured by scores students earned from completing the data table on page 4 of the VLP. The total score for the data table was 36 points. The process of observation, data collection, generation of hypotheses, data analysis, and drawing conclusion were the scientific skills students had to practice in order to complete the data table. After selecting an object from the shelf in the VSL, students measured objects mass and volume using the available scientific equipment. The name, mass, and volume of each object were recorded in the data table. Forty-seven (83.9%) participants selected the objects in the order that they were organized in on the shelf from left to right. However, only nine participants (16.1%) randomly selected the objects from the shelf in the VSL. The objects that were arranged on the shelf were: wood, aluminum, plastic, lead, cork, steel, clay, rubber, and a candle (Figure 2). The findings suggest that the Buoyancy and Density VSL did have an effect on students' scientific skills.

Table 24

Statistical Analyses for Scientific Skills

Mean	28.88
Std. Deviation	4.52
Std. Error of Mean	.60
Median	30.25
Mode	32.00
Skewness	-.61
Std. Error of Skewness	.32
Kurtosis	-.33
Std. Error of Kurtosis	.63
Range	18.50
Minimum	17.00
Maximum	35.50

Note. $N = 56$

The statistical and frequency analyses were performed and the results suggested that 15 participants (26.8 %) scored in the range of 30.5 to 32.0 out of possible 36 points. It should be noted that thirteen participants were able to score 32.5 or higher in data table section of the VLP. Figure 24 summarizes the score distribution participant's scientific skills.

Table 25

Frequency Distribution for Scientific Skills

Score	Frequency	Percent
17.0-22.5	4	7.1
23.0-24.5	7	12.5
25.0-27.5	11	19.6
28.0-30.0	6	10.7
30.5-32.0	15	26.8
32.5+	13	23.2
Total	56	100.0

Note. $N = 56$

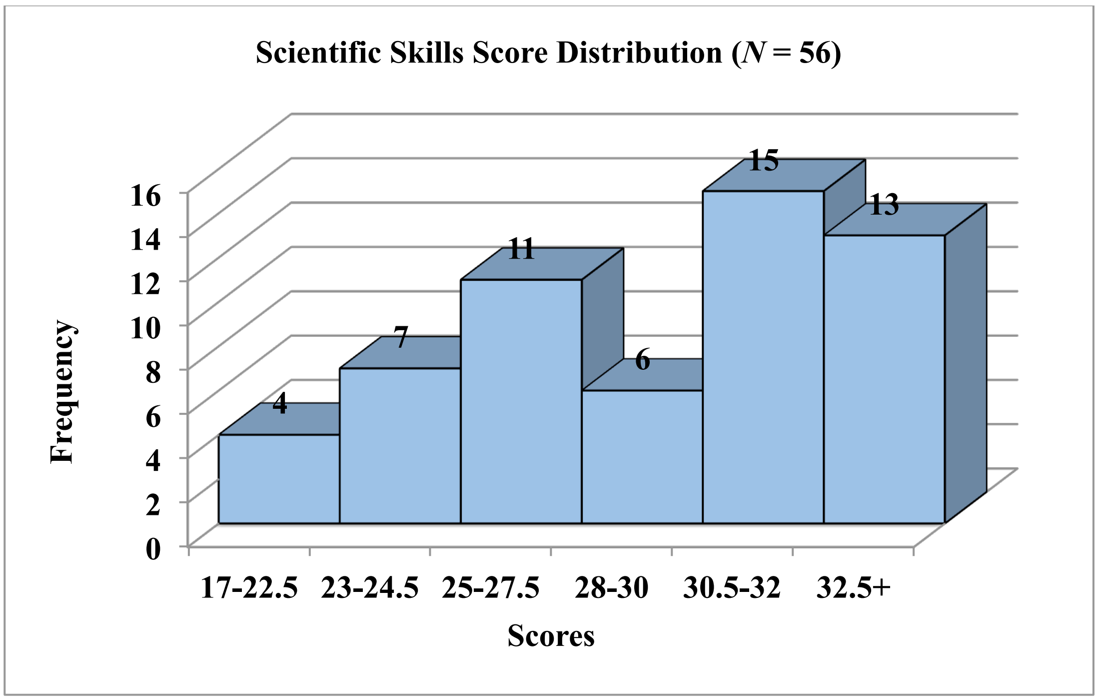

Figure 24. Frequency distribution of scientific skills ($N = 56$).

In the last segment of the VLP (pp. 8-9), participants were asked to answer five journal questions. Three of these journal questions were scored for the total of three points (1 point for each question). These questions further measured students' comprehension and understanding about the concepts of buoyancy and density. The descriptive findings show the mean score of ($M = 1.13$, $SD = 0.79$).

Table 26

Statistical Analysis on Journal Questions

Mean	1.13
Std. Deviation	.79
Std. Error of Mean	.11
Median	1.00
Mode	.50 [a]
Skewness	.27
Std. Error of Skewness	.32
Kurtosis	-.59
Std. Error of Kurtosis	.63
Range	3.00
Minimum	.00
Maximum	3.00

Note. $N = 56$
a. Multiple modes exist. The smallest value is shown.

Two participants (3.6%) scored 3.0 and nine participants (16.1%) scored 0.0 (Table 26). Majority of participants (78.4%) scored within the range of 0.5 to 2.0 out of a possible three points suggesting that their responses were partially correct. Students were able to grasp some but not all the concepts related to buoyancy and density (Table 27).

Table 27

Frequency Distribution for Journal Questions

Score	Frequency	Percent
.0	9	16.1
.5	11	19.6
1.0	11	19.6
1.5	11	19.6
2.0	11	19.6
2.5	1	1.8
3.0	2	3.6
Total	56	100.0

Note. $N = 56$

Summary of Key Findings

This chapter reported the findings of a single group pretest-posttest design study that assessed students' cognitive knowledge, attitude toward science, science skill development, and mathematical skill development following participation in a VSL. Based on the results of both statistical and inferential statistics, although students' average means changed positively from pre and post assessment, the statistical significance was not evident from paired sample *t*-tests.

Fifty-six eighth grade students at a charter middle school in southern California participated in this study. To assess students' cognitive knowledge, the BDT was used. The questions on BDT were extracted and assembled from McGraw-Hill's TestGen® Test Bank. The analysis of pre and post BDT showed increase mean value for post BDT, but results from paired sample *t*-test revealed that the increase in mean scores were not statistically significant.

Students' attitude toward science was measured by ATSI survey, which was organized in five subscales that measures students' attitudes in areas of motivation in science, enjoyment of science, anxiety toward science, self-concept regarding science, and value of science in society. The mean score for all five subscale decreased, which resulted in a favorable attritional change. The results from paired sample *t*-tests, however, suggested that the change in the mean scores were not statistically significant enough due to significant value (*p* value) being higher than .05.

Participation in the VSL did not have a drastic impact on student's mathematical skills. The frequency and statistical analysis of scientific skills suggested that majority of participants were able to use the skills such as observation, data collection, and data observation to practice these scientific skills. Nineteen participants (37.6%) were able to score 32.0 or higher by completing the data table provided in the VLP. Though few students were able to fully understand and comprehend the concept of buoyancy and density, majority of students were only able to demonstrate their understand about this scientific concept partially.

The results of this study can be additional evidence that deals with the affects of virtual learning environments on student's cognitive learning, attitude toward science, and skill development. Further discussions, conclusions, and recommendations for scholarship and practice will be discussed in the following chapter.

Chapter 5: Discussion

The Issue and Significance

With so much attention given to academic content standards, particularly in the field of science, providing students with authentic science laboratories has become a challenging task for many secondary science educators. As a result of this issue, budget constraints, and lack of time, students lose the opportunity to participate in science laboratories that promote scientific thinking, problem solving skills, and interest towards science related career fields. School budget constraints and larger class sizes have made science laboratories a task that may be impossible to do during one's daily routine. As a result, science instruction becomes nothing more than listing facts and theories, discovered by former scientists, to be memorized. Subsequently, students' academic performances nationally and internationally have decreased at an alarming rate. The U.S. performance in PISA (Program for International Student Assessment) 2012, revealed that only "7% of students scored at proficient level 5 or above" (p.9) compared to Shanghai-China's performance which was 27% (Kelly et al., 2013). With such a low performance, these problems may lead to a bigger issue of lowering economical statues in the growing field of STEM education, particularly science.

In a science laboratory, students are able to use scientific tools and equipment to conduct experiments. The process of conducting experiments requires students to think like scientists by observing, collecting, and analyzing data and findings. Additionally, science laboratories help students develop scientific reasoning and improve their cognitive outcomes (Luketic & Dolan, 2013). With its important role in science education and inquiry learning, it is clear that science laboratory experiments should be part of science instruction across the nation or internationally.

VSLs have gained acceptance among educational practitioners in demonstrating positive effects in students' learning outcomes (Yang & Heh, 2007).

With the increase in popularity of online education, VSLs have allowed science educators to integrate these educational tools into their daily lesson plans. With no time needed to prepare these laboratories, their inclusion in secondary science classrooms is just one click away. Though VSLs provide instructors with a safe, non-hazardous environment, the educational outcomes and their effect on students' learning outcomes have not yet been explored, particularly in middle school settings. The question whose answer remains unknown to educational researchers and practitioners is whether VSLs are as effective as real science laboratories.

This single group pretest-posttest study sought to explore the impact of VSLs on students' cognitive knowledge, attitude toward science, and skill development.

Theoretical and Conceptual Foundations

Introduced by Benjamin Bloom during the 1950's, Bloom's taxonomy organized educational objectives into three learning domains of cognitive, psychomotor, and affective. The cognitive domain of learning is described as the domain that allows the learner to recall knowledge and develop understanding about a particular topic (Reigeluth & Moore, 1999). The psychomotor domain of learning involves a set of skills that will aid the learner to operate equipment or complete various types of tasks (Rovai et al., 2009). In science education, the process of observing, collecting, and analyzing data is considered to be scientific skills that learners gain through experimentation. The process of analyzing data and calculation requires mathematical skills that scientists need to complete a particular task during experimentation. The third domain of learning is the affective domain, which includes attitude, emotion, and values (Savic & Kashef, 2013). Educational researchers and practitioners have measured learning outcomes using these three domains of learning because learning something new involves more than understanding the concept; it involves a set of skills and series of emotions.

The field of science and nature of science (NoS) enable learners to practice inquiry learning by becoming aware of the procedure, applying the skills, and taking steps to solve a problem (Erin Peter, 2006). Inquiry learning, similar to the process of scientific method, allows learners to experience the excitement and challenges that scientists face during their daily activities. Moreover, inquiry learning puts the scientific method into practice, which will allow students to use experimentation strategies to find solutions or evidence (Kubieck, 2005). As a result of this practice, learning a new scientific concept is achieved through a series of steps. In addition to inquiry learning, discovery learning, developed by Bruner (1961), has been discussed quite extensively in the recent literature. Bruner stressed that because information or concepts discovered by learners are organized in their own way of thinking, recalling them later in life is simple and effortless. Learning through discovery has received attention from cognitive constructivists such as Piaget (1973).

Referred to as an important learning theory in modern education (Baviskar et al., 2009), constructivist learning theory plays a critical role in individual knowledge construction. Constructivist learning is branched into three learning theories. Cognitive or individual constructivism proposed by Jean Piaget (1896-1980) defines learning as a process that involves a series of internal steps in which knowledge is constructed. Another strand of constructivist learning is socio-constructivist learning theory. Lev Vygotsky (1978), a well-known socio-constructivist theorist noted that the collaboration and interaction among participants allow them to complete a task with assistance and allow children to take on an active role in their learning (Huang et al., 2010). The third strand of constructivist learning is the constructionist learning theory. Introduced by Seymour Papert (1980), constructionist learning theory involves building or constructing knowledge by creating an artifact. His work at Massachusetts Institute of Technology signifies a fundamental relationship between human thinking and computers. Computers allow children to model and represent their knowledge by allowing them to create objects that are product of thinking and solving problems. This mode of instruction has led computer software and digital tools to drive instruction in various levels of education.

One type of digital tool that allows learners to experience situations that may not be possible to experience in real life is simulation. Simulations in the field of business, medicine, military, and aviation have benefited leaners in areas of teamwork and decision making skills (Faria et al., 2009). Teamwork and decision-making skills allow learners to practice collaboration and create opportunity to practice negotiation and problem solving skills.

With its success in primary, secondary, and higher education, simulation-Based Learning (SBL) has allowed participants to construct knowledge while interacting with the environment (Shapira-Lishchinsky, 2015). What students experience in such environments would prepare them for situations that will present them with unknown factors they may face in the future. It is through an experience where participants are able to learn new knowledge or transform their current knowledge to new ones. As Kolb and Kolb (2009) state, experiential learning allows learners to reflect on their experiences as they continue to transform their prior knowledge, which deepens students' reflective skills. John Dewey's (1938) contributions to discovery learning, inquiry learning and Kurt Lewin's (1942) role in development of the four stages of action research has made experiential learning highly applicable and useful to the field of education, particularly science education.

Virtual learning environments are three-dimensional environments where learners are able to experience various types of scenarios and situations (Pedersen & Irby, 2014). In the field of science education, virtual learning environments such as VSLs have shown promise in improving students' comprehension and academic achievement (Scalise et al., 2011). With all they can offer to secondary science education, VSLs enable educators to make experimentation more accessible to all students where setting up the laboratory equipment, worrying about the health hazards of chemicals involved in the laboratories, and ethical concerns regarding using animal in dissection are no longer an issue. Though VSLs seem to improve students' academic achievement and science process skills in a secondary science classroom (Yang & Heh, 2007), other evidence from reviewed literature revealed the importance of students' attitude toward science on students' learning and comprehension. Odom et al. (2011) state that there is a direct correlation between students' attitude toward science and learning outcomes.

When students' attitudes toward science are positively improved, students become more engaged and motivated (Ateh & Charpentier, 2014). Students' attitudes toward science also impact their participation during the class, which will ultimately increase their collaboration during discussion or laboratory experimentation. Learning in virtual learning environments has not only improved students' academic performance, but it has also enhanced their attitude toward science as well (Iqbal et al., 2010). Though, many prior research studies indicated that VSLs improve students' learning in science classrooms, too few researches have focused on middle school learning environments. This research study sought to find the effects of VSLs in middle school science classrooms and contribute to the existing body of knowledge in an effort to raise awareness about inclusion of VSLs in secondary science classrooms.

Methods

To evaluate the affects of VSLs on students' cognitive knowledge, attitude toward science, and skill development, a quantitative, descriptive, single group, pretest-posttest design was used. Descriptive research, usually including a number of different types of designs, describes and summarizes the relationship between two or more variables (Hedrick, Bickman & Rog, 1993). This study sought to examine and describe the relationship between VSL and students' learning outcomes. The independent variable used in this study was a VSL about the scientific concepts of buoyancy and density. The dependent variables used in this study were cognitive knowledge, attitude toward science, and mathematical skills, and scientific skills. The participants involved in this study were 56 eighth grade students enrolled in a charter middle school located in Southern California during the academic school year of 2016-2017.

The instruments used in this single group pretest-posttest test design research study were the BDT, a cognitive measure of buoyancy and density knowledge, the ATSI survey, affective measure of students' attitudes toward science, and a VLP, a psychomotor measure of student's science and mathematical skill developments. BDT and ATSI were administered twice: once before Buoyancy and Density Virtual Laboratory to serve as baseline data (pre) and after Buoyancy and Density Virtual Laboratory (post). Students recorded their scientific and mathematical skills on VLP during the VSL. Scientific skills were measured through students' data collection, analysis, and recording on the data table in the VLP. Mathematical skills were measured through students' density calculations for each object. Mathematical calculations were recorded on the mathematical skills page in the VLP.

Key Findings

The analysis of the data collected in this study resulted in several key findings. Each of the involved hypotheses and sub-hypotheses were tested independently. First, the results from statistical analysis revealed an increase in mean scores of pre BDT and post BDT. These findings suggest that participating in VSLs may improve participants' scientific knowledge. The dependent sample *t*-test indicated that the results were not significantly different.

Second, the overall increase in mean scores of Pre ATSI and post ATSI revealed that students' attitude were positively changed by a mean difference of 4.19. The results from dependent sample *t*-test indicated that the results were not statistically significant. The five subscales in ATSI survey measured students' attitudes in subscales of values of science in society, enjoyment of science, motivation toward science, self-concept of science, and anxiety toward science. The second hypothesis was further broken down into five sub-hypothesis pertaining to each of the above subscales.

With regard to students' values of science in society, enjoyment of science, motivation toward science, self-concept of science, and anxiety toward science, the analysis of data revealed the students' attitudes were positively changed. The change in mean scores for each of the five subscales indicated a favorable attitudinal change (Table 6). These results show that VSLs may enhance students' attitudes toward science. The findings from dependent sample *t*-tests for each sub-scale revealed that the results were not significantly different.

The analysis of data from VLPs indicated that students' mathematical skills were not affected while using VSLs. The last key finding indicated that students' scientific skills were improved. The analysis of data indicated that 23.2% of the participants were able to score 32.5 or higher out of possible score of 36.0.

Conclusions, Implications, and Recommendations

The following two conclusions were formulated based on the key findings of this study. First, VSLs were effective in supporting student's understanding of scientific knowledge. Second, VSLs were effective in supporting students' attitude toward science in areas of students' value of science in society, enjoyment of science, motivation toward science, self-concept of science, and diminishing student's anxiety toward science.

VSLs were effective in supporting students understanding of scientific knowledge. The VSL used in this study allowed students to use process of observation, data collection, and data analysis to become familiar with the scientific concept of buoyancy and density. This process is referred to as the action and reflection mentioned by Miller (2004). In the VSL, students used objects and tools available to them to conduct a series of steps that led to the discovery of the concepts of Buoyancy and Density. Students' performance on BDTs indicated that their understanding and knowledge regarding this scientific concept had improved. The findings indicate that VSLs may be as effective as real science laboratories in aiding students with comprehending and synthesizing scientific information. Similar findings also indicate that VSLs can be as effective as physical laboratories, positively impacting students' academic performance (Chou & Liu, 2005; Yang & Heh, 2007). The process of inquiry learning practiced in science laboratories allow students' to use scientific method to collect information related to the scientific concept under study. In this study students practiced this method by going through each step and using materials and tools needed to complete a laboratory activity. This learning environment much like the one used by Pedersen and Irby (2014) allowed students to become engaged in an inquiry activity that was students-directed.

It is worth mentioning that VSLs allow students to access materials easily and re-do the steps involved in the laboratory frequently. The participants in this study had access to materials and tools throughout the Virtual Laboratory and were able to successfully complete the necessary steps involved in the laboratory. This allowed students to use the trial and error strategy to constantly reflect on their learning processes. A study by Lahoud and Krichen (2010) suggest that accessibility of materials in virtual environments is a key factor in helping learners complete their tasks successfully. The access to materials and re-doing the process of performing the scientific experiment may be time consuming and require careful planning in real laboratories. The findings stated by Tekbıyık and Ercan (2015) revealed that students performing a physical circuit laboratory had to re-create and re-form the circuit while students performing a virtual circuit laboratory had the chance to go through this process more efficiently. Participants of this study were able to complete all the necessary steps and gather the necessary data within a reasonable time frame.

In the Buoyancy and Density Virtual Laboratory participants were able to spend more time on making observations by using the scientific tools to gather data and information rather than dealing with physical error for measurements. The graduated cylinder made careful measurements for students to record during the VSL. With that being said, students could still make mistakes in recording and measuring the mass and volume in the VSLs, but they did not have to set up and clean the digital scale or take the objects out of the graduated cylinder. Though VSLs allow students to have less setup time and more time to gather information, the time needed to plan and reflect between each trial may be reduced or even eliminated (De Jong, Linn, & Zacharia, 2013). Contrary to this claim, the participants of this study had an opportunity to pause, reflect, calculate, and generate a hypothesis for each object that was included in the

Virtual Laboratory. The participation in the VSL allowed students to practice scientific skills such as gathering and analyzing information by using the scientific tools and equipment such as a digital scale and a graduated cylinder. The completion and accuracy of the scores, which were mentioned in the previous chapter, indicate that the majority of the students spent time to make observations and gather information regarding the mass and volume of the object in the VSLs. Similar findings from Shegog et al. (2012) was reported in which students were able to go through the steps necessary to successfully complete the laboratory protocol.

As it was mentioned in the previous chapter, though students' scientific knowledge improved, the difference in mean scores were not statistically significant. Several factors may have resulted in this outcome. This study used a single group pretest-posttest design that only included 56 participants. Random sampling was not an option due to the nature of the learning environment where participants were enrolled and placed in classrooms determined by the administration. Additionally, only one scientific concept was used to measure students' scientific knowledge. Moreover, one type of VSL, adopted by McGraw-Hill Publication, was used in this study. All of these factors may have contributed to the overall results of this study.

The findings from this study and the literature review indicate that VSLs are effective in supporting students' scientific knowledge in secondary science classrooms, but further study and implementation of these technological tools is needed particularly in the middle school setting. With the advancement of technological tools in secondary science classrooms, instructional practices should consider including virtual environments especially if providing real science laboratories is a challenge.

VSLs were effective in supporting students' attitude toward science in areas of students' enjoyment of science, motivation toward science, self-concept in science, value of

science in society, and diminishing student's anxiety toward science. In this study, students' overall attitude toward science was changed positively after using the buoyancy and density VSL. In addition to the findings of this research study, similar studies have indicated that using virtual science simulations have a positive impact on students' attitude toward science (Kim, 2006; Odom et al., 2011; Pyatt, & Sims, 2012). As it was mentioned previously, the motive behind this study was to determine if VSLs could be as effective as real science laboratories in supporting students' learning outcomes. The results of this study were consistent with previous studies on this topic (Pyatt, & Sims, 2012; Tüysüz, 2010) indicating that VSLs, though may not become a replacement for real science laboratories, can become alternative tools when real science laboratories are not available due to budget constraints, health and time concerns, or lack of preparation time.

Another reason why a majority of previous research concluded that VLEs have positive impacts on students' attitudes had to do with students' attitude toward technology and computers. A study by Mouza (2008) stated that students' level of motivation and engagement increased dramatically when they started implementing the use of laptops during instruction. When students have the ability to independently complete the steps to collect data without any limitation of materials, they feel more confident to re-do the steps they might have missed during the process of data collection and are motivated to re-do the steps involved in scientific method. The environment designed within this virtual laboratory allowed students to independently perform each step and collect data that was produced by them. This was evident from the observed completion rate. Moreover, students' motivation to produce, collect, and record data in the data table of their VLP was another indication of their motivation and participation in the

VSL. Motivated students develop a sense of self-efficacy, which is a major contributing factor to students' interest in science and its related fields and career (Jocz et al., 2014).

As presented in the first conclusion, VSLs had a positive effect on students' scientific knowledge. Several research studies have stated that students' attitudes toward science are associated with academic performance and participation in advanced science courses (Chen & Howard, 2010; Marszalek, Stoddard, & Wrobel, 2011). The results of these studies coincide with the key findings from this research study.

Though, this study was specific to one concept of the eighth grade physical science curriculum, the findings have added another piece of evidence about the effects of VSLs on students' attitudes toward science. The inclusion of VSLs in secondary science classrooms has shown promising results in improving students' attitudes toward science, but not enough studies have been conducted to examine students' attitudinal changes in simulated science environments. Researchers are urged to conduct further studies in this field before making remarkable conclusions about VSLs and student's attitude toward science (Scalise et al., 2011).

Recommendations for research. In order to sufficiently strengthen the pool of findings in this field of study, the following recommendations for research are suggested. The sample size for this study only included 56 participants, which may have affected the statistical significance of the results. Including a larger sample size in future studies will provide opportunities for the researchers to test the significance of their results for more conclusive evidence. Though, recommending another type of research design such as true experimental design is very ideal, its implementation in a general public school setting may not be possible. Students in general public school settings are enrolled in specific class sections and random selection of the participants may not be feasible. Additionally, it is recommended that future research studies utilize another type of assessment tools to examine the changes in students' scientific knowledge and attitude toward science more in-depth. For instance, the use of other types of assessment tools such as semi-structured interviews and open-ended questions would allow future researchers to further analyze students' attitudinal changes when VSLs are implemented.

Furthermore, assessing students' scientific knowledge in other fields of science, such as Earth and Life science, with various grade groups in middle school is another suggestion that would strengthen the pool of current research about the effectiveness of VSLs. It is recommended also that future researchers utilize various types of VSLs from different publications that utilize improved options for analytics to measure students' psychomotor skills. The Buoyancy and Density VSL used in this study did not provide the necessary analytics to monitor and measure students' mathematical and scientific skills. Utilizing various types of VSLs from different publications would also help gather information regarding the most effective VSLs in secondary science classrooms.

Furthermore, considering the flexibility, ease of use, and lower price value of VSLs, it is recommended that future research further study these virtual learning environments and further examine their values in secondary science classrooms. Although, this study focused on only one VSL, the researcher believes that VSLs are a valuable tool that may provide learners with opportunity to practice methods used by scientists even when school environments are not equipped with real science laboratories. When including real laboratories at school sites are not possible, VSLs can provide students with an environment that allows them to conduct experiments that otherwise may not have been possible without appropriate supplies and laboratory space. The value of studying these virtual learning environments is vast and considering what these technological tools can offer to science education makes them ideal and valuable tools to include in future research.

Recommendations for practice. Due to the findings of this research study, it is recommended that instructors and educational practitioners include VSLs in their professional practice and monitor students' scientific knowledge throughout the implementation process. This study only captured students' scientific knowledge on one scientific concept and measured their attitude toward science after using one VSL over a one week time period.

Since the findings from this research study and previous studies suggested that VSLs were effective tools in positively changing students' attitudes toward science, instructors and practitioners are encouraged to include and further study the effect of such a tool in their classrooms, especially if providing real science laboratories are not possible due to budget constraints or large classroom sizes. It is recommended that the publications in charge of designing the VSLs communicate with secondary science instructors and practitioners to further improve the design and analytic components of the learning environments. Increased communication between publishers and secondary science instructors would allow publishers to explore educators' suggested improvements to available VSLs and expose them to ideas that should be considered when designing VSLs so that they are more authentic. Additionally, there is a desire for tools to include opportunities to practice the scientific methods, and provide better analytics. Moreover, the collaboration between the science instructors and publishers that design VSLs would educate publishers about pedagogical strategies instructors use during class, including the procedures and steps students complete to successfully complete the VSL. These examples could then be taken and used to inform VSL design such that they reflect the teaching methodologies teachers practice in secondary science classrooms. For instance, allowing students to take additional steps to generate a hypothesis and record the hypothesis before testing them would allow students to practice the scientific method during the scientific experiment.

Though this research study and previous literature indicate that VSLs may be as effective as the real science laboratories, further implementation of such tools is needed within various grade levels of middle schools students, fields of science, and publications. The additional practice of implementing VSLs in middle school classrooms will aid educators to modify their pedagogical strategies in order to use these technological tools more effectively to improve students' learning outcomes.

Study Validity and Limitations

This study was conducted in a charter middle school in Southern California. The participants of this study were enrolled in two eighth grade classes in the beginning of the academic school year by the administrative team. Magnolia Science Academy 6 follows state mandated science content standards and the McGraw Hill publication provides educational resources such as textbooks and online resources. The descriptive nature of this research study imposed further steps in assuring the study's validity. The researcher confirmed that the assessment tools chosen for this research study were valid and reliable. Data collected using these assessment tools were reviewed extensively before the statistical analysis. SPSS, a statistical analysis software tool was used to ensure the accuracy of the statistical analysis.

Additionally, to ensure all students would have the same experiences during the procedure and data collection time frame, a five-day experiment plan was designed (Figure 3). Planning the days of the data collection procedures carefully, assured that the time gap between the pre and post tests were sufficiently pasted. Moreover, direct content instruction between the post and pre assessments was eliminated to ensure students' attitude, knowledge, and skill were not affected by another variable. These necessary steps have been taken to minimize variables that may have changed the results.

Several limitations were imposed on this research study. The number of participants for this study was limited to 56 and while all students participated in this study, the findings of this study cannot be applied to general middle school students. Further, the limited number of participants made it challenging to study the significance and relationships on students' academic and attitude improvement. Moreover, this study only pertained to one STEM focused charter middle school that focused on only one grade group of middle school students and covered only the science concepts pertaining to density and buoyancy. The Buoyancy and Density VSL did not provide the researcher with analytics required to measure psychomotor skills. Due to the lack of analytics and ability to track students' exact steps within the module, the researcher was unable to effectively monitor students' mathematical and scientific skills. In the previous section, it was mentioned that publications in charge of designing the VSLs should include better analytics that would allow the instructors to measure students' learning outcomes more effectively. Though the sample size of this study was limited to only 56, the findings of this study will not only contribute to the growing evidence in the field of virtual learning, but it will also inform current educators and educational practitioners about the usefulness of VSLs in secondary science classrooms.

Closing Remarks

Due to the lack of time, school budget constraints, and focus on content-based standards, providing real, authentic science laboratories has become a struggle for many secondary schools. Without science laboratories being part of the daily curriculum, students lose the opportunity to practice scientific skills and learn the content through conducting experiments. The process of learning becomes factual and ultimately leads to rote memorization of facts and content. Such practice in secondary science classrooms, particularly in middle school, would not only prohibit students from practicing the scientific method, it may also affect their interest and attitude toward science and science related career fields. Recent technological advancements in the field of education have made VSLs readily available to educators in secondary science classrooms. Aside from the flexibility, ease of use, and low cost these virtual learning environments provide to secondary schools, VSLs provide students opportunities to practice the scientific method during the process of experimentation and experience the steps scientists take to complete a laboratory task. The findings from this research study are valuable and can inform instructors, administrators, and educational publishers about the practical significance of these educational tools in secondary science classrooms. From saving money and space to practicing inquiry learning and scientific methods, VSLs would make a worthwhile contribution to science education particularly in middle and high school settings.

Unfortunately, the potential of these technological tools have not yet been fully explored in middle school classroom settings. This descriptive, single group, pretest-posttest design study sought to assess gains within each of Bloom's domains of learning outcomes following participation in a VSL for eighth grade students at a charter middle school in Southern California. The results of this research study conclude that VSLs improved students' cognitive knowledge and enhanced students' attitudes toward science, and it revealed that most students were able to use their scientific skills to collect and analyze data in the VSL. The findings from this study will add to the growing literature in regards to the effects of VSLs on middle school student's three domains of learning. Furthermore, with rapid change in educational technology and implementation of Virtual Learning Environments, educational researchers and practitioners are urged to further examine the effects of VSLs on middle school students' learning outcomes.

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APPENDIX A

Pre Buoyancy and Density Test

Instruction: Circle the correct response for each question. Make sure that your answer is clearly marked.

1) _____________ is a physical property

A) Oxidation

B) Density

C) Flammability

D) Combustibility

2) Density depends on ____.

A) weight

B) mass

C) mass and volume

D) volume

3) Archimedes' Principle helps to explain the relationship between ____.

A) kinetic energy and density

B) temperature and density

C) pressure and density

D) buoyancy and density

4) A cork is able to float on water because it is ____.

A) a crystalline solid

B) equal in density to water

C) small in size

D) less dense than the water

5) Which is the upward force on a swimmer that balances the downward force of gravity and keeps the swimmer from sinking?

A) atmospheric pressure

B) buoyant force

C) density

D) Pascal

6) Use the information in Figure 5 to choose the gas that would be the best choice to use to fill a balloon that would float in air.

A) carbon dioxide

B) nitrogen

C) hydrogen

D) oxygen

Densities of Some Common Gasses

Gas	Density (g/cm^3)
air	0.00119
carbon dioxide	0.00198
nitrogen	0.00125
hydrogen	0.00008
oxygen	0.00133

Figure 5

7) Vashti has a balloon filled with air. When she places it on the surface of a pond, the balloon floats. What would happen to the balloon if Vashti filled the balloon with sand and then placed it on the pond's surface?

A) The balloon would sink.

B) The balloon would burst.

C) The balloon would float in the air.

D) The balloon would float in the water.

8) A box sinks when placed in water. What could you change about the box to make it

float?

A) density
B) temperature

C) atmospheric pressure

D) Archimedes' principle

9) Lam has three identical 1-L bottles. One is filled with water, another is filled with air, and the third bottle is filled with soil. What is the same about all three bottles?

A) density

B) volume

C) mass

D) weight

10) Which of the following objects will float in water?

A) a solid wooden cube with a volume of 15 cm^3

B) a solid lead cube with a volume of 1 cm^3

C) a solid stone cube with a volume of 9 cm^3

D) a solid iron cube with a volume of 8 cm^3

11) In which direction does the pressure exerted by the water push on the sphere in Figure 3?

A) upward

B) downward

C) to the side

D) in all directions

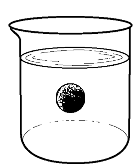


Figure 3

APPENDIX B

Post Buoyancy and Density Test

Instruction: Circle the correct response for each question. Make sure that your answer is clearly marked.

1) Which is the upward force on a swimmer that balances the downward force of gravity and keeps the swimmer from sinking?

A) atmospheric pressure

B) buoyant force

C) density

E) Pascal

2) ____________ is a physical property

F) Oxidation

G) Density

H) Flammability

I) Combustibility

3) Which of the following objects will float in water?

A) a solid wooden cube with a volume of 15 cm^3

B) a solid lead cube with a volume of 1 cm^3

C) a solid stone cube with a volume of 9 cm^3

D) a solid iron cube with a volume of 8 cm^3

4) Archimedes' Principle helps to explain the relationship between ____.

A) kinetic energy and density

B) temperature and density

C) pressure and density

D) buoyancy and density

5) A cork is able to float on water because it is ____.

A) a crystalline solid

B) equal in density to water

C) small in size

D) less dense than the water

6) Use the information in Figure 5 to choose the gas that would be the best choice to use to fill a balloon that would float in air.

A) carbon dioxide

B) nitrogen

C) hydrogen

D) oxygen

Densities of Some Common Gasses

Gas	Density (g/cm^3)
air	0.00119
carbon dioxide	0.00198
nitrogen	0.00125
hydrogen	0.00008
oxygen	0.00133

Figure 5

7) Density depends on ____.

A) weight

B) mass

C) mass and volume

D) volume

8) Vashti has a balloon filled with air. When she places it on the surface of a pond, the balloon floats. What would happen to the balloon if Vashti filled the balloon with

sand and then placed it on the pond's surface?

A) The balloon would sink.

B) The balloon would burst.

C) The balloon would float in the air.

D) The balloon would float in the water.

9) A box sinks when placed in water. What could you change about the box to make it float?

A) density

B) temperature

C) atmospheric pressure

D) Archimedes' principle

10) Lam has three identical 1-L bottles. One is filled with water, another is filled with air, and the third bottle is filled with soil. What is the same about all three bottles?

A) density

B) volume

C) mass

D) weight

11) In which direction does the pressure exerted by the water push on the sphere in Figure 3?

A) upward

B) downward

C) to the side

D) in all directions

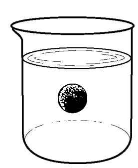
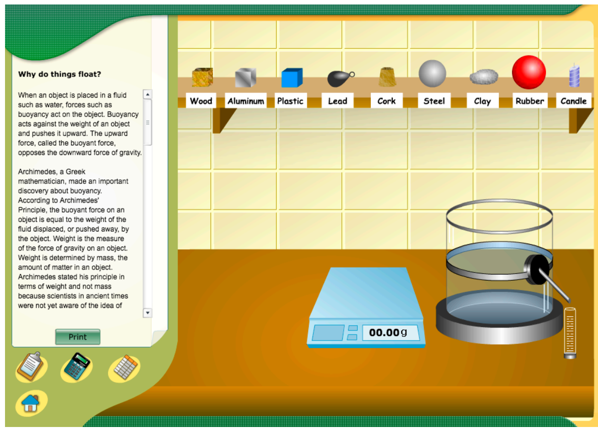


Figure 3

APPENDIX C

Virtual Laboratory Packet (VLP)

Buoyancy and Density
Virtual Laboratory Packet



Student's Name:

Class:

Virtual Lab URL:

http://glencoe.mheducation.com/sites/dl/free/0078741858/365081/CT01.html

Forces and Fluids

Virtual Lab: Why do things float?

When an object is placed in a fluid such as water, forces such as buoyancy act on the object. Buoyancy acts against the weight of an object and pushes it upward. The upward force, called the buoyant force, opposes the downward force of gravity.

Archimedes, a Greek mathematician, made an important discovery about buoyancy. According to Archimedes' Principle, the buoyant force on an object is equal to the weight of the fluid displaced, or pushed away, by the object. Weight is the measure of the force of gravity on an object. Weight is determined by mass, the amount of matter in an object. Archimedes stated his principle in terms of weight and not mass because scientists in ancient times were not yet aware of the idea of mass.

Archimedes' Principle explains why an object will float or sink. If the object displaces an amount of water that weighs as much as or more than the object, the object will float. For example, even though a beach ball displaces only a small amount of water, the mass of the displaced water is greater than the mass of the beach ball. This is why the beach ball floats. An object that has more weight and mass than the water it displaces, such as a rock, will not float.

In this Virtual Lab, you will find the mass of an object using an electronic balance. You will then predict if an object will float by comparing its mass to the mass of the water displaced by the object.

To do this Virtual Lab, you will need to convert the volume of the water displaced from milliliters (mL) to grams (g). The mass of 1 mL of fresh water is 1 g. If you know the volume of water displaced, you also know the mass of the water displaced. For example, if the volume of water displaced is 5 mL, the mass of the water displaced is 5 g. If the volume is 2.7 mL, the mass is 2.7 g, and so on.

Objectives:

- State Archimedes' Principle.
- Describe Archimedes' Principle in terms of buoyancy.
- Predict whether objects will float or sink in water.

Procedure:

1. Find the mass of an object by dragging it to the electronic balance. Record its mass in the Table.

2. Drag the object above the tank and drop it into the water.

3. Read the graduated cylinder. Record in the Data Table the volume of the water displaced by the object (Page 4).

4. Compare the mass of the object to the volume of the water displaced. Remember to convert the volume of the water to its mass in grams.

5. Calculate the density of the object. Make sure to show your work on Mathematics' skill pages (Pages 5-7) and use appropriate unit. Make sure to box your final answer for each object.

6. Based on your calculation, hypothesize whether the object sank or floated and record your prediction on the Data Table provided by in the laboratory packet (Page 4).

7. To test your hypothesis, click the radio button next to "float" or "sink." Check your hypothesis by clicking Watch What Happened.

8. Did the object sink or float? Enter the results of the experiment in the Data Table provided in the laboratory packet. (Page 4).

9. Repeat steps 1-6 for each object. Make sure to show your calculation for each object in the space provided in the laboratory packet.

10. Complete the Journal Questions. Record your answer on your laboratory packet (Pages 8-9).

Data Table

Material	Mass (g)	Volume of Water Displaced in (mL)	Prediction (Sink or Float)	Test Result (Sink or Float)

Mathematics' Skill Page

Use the following pages to show your density calculations.

Wood:

Aluminum:

Plastic:

Lead:

Cork:

Steel:

Clay:

Rubber:

Candle:

Journal Questions

Question 1: State Archimedes' Principle in terms of buoyancy. How does Archimedes' Principle explain whether an object will float or sink in water?

Answer 1:

Question 2: In this Virtual Lab which objects floated? Which objects sank? Did your results prove Archimedes' Principle? How do you know?

Answer 2:

Question 3: Use your understanding of Archimedes' Principle to predict whether the following objects will float or sink in water: Object A with a mass of 15.7 grams that displaces 15.9 milliliters of water Object B with a mass of 4.2 grams that displaces 1.6 milliliters of water Object C with a mass of 9.4 grams that displaces 4.7 milliliters of water Object D with a mass of 11.4 grams that displaces 19.7 milliliters of water

Answer 3:

Question 4: Clay can float in water. Describe what you might do to a piece of clay to make it float in water. Hint: The clay needs to displace more water than it does in its current shape.

Answer 4:

Question 5: In this Virtual Lab a solid rubber ball with a mass of 5.9 grams sank in water. A hollow rubber ball with the same mass floats in water. Explain why this might be.

Answer 5:

APPENDIX D

Pre Attitude Toward Science Inventory

ATTITUDE TOWARD SCIENCE INVENTORY (ATSI)

ASTI Item Statements		1 = Strongly Agree 6 = Strongly Disagree					
1	Science is useful for solving the problems of everyday life.	1	2	3	4	5	6
2	Science is something that I enjoy very much.	1	2	3	4	5	6
3	I like the easy science assignments best.	1	2	3	4	5	6
4	I do not do very well in science.	1	2	3	4	5	6
5	Doing science labs or hands-on activities is fun.	1	2	3	4	5	6
6	I feel at ease in science class.	1	2	3	4	5	6
7	I would like to do some extra or un-assigned reading in science.	1	2	3	4	5	6
8	There is little need for science in most of today’s jobs.	1	2	3	4	5	6
9	Science is easy for me.	1	2	3	4	5	6
10	When I hear the word “science”, I have a feeling of dislike.	1	2	3	4	5	6
11	Most people should study some science.	1	2	3	4	5	6
12	I would like to spend less time in school studying science.	1	2	3	4	5	6
13	Sometimes I read ahead in our science book.	1	2	3	4	5	6
14	Science is helpful in understanding today’s world.	1	2	3	4	5	6
15	I usually understand what we are talking about in science.	1	2	3	4	5	6
16	I do not like anything about science.	1	2	3	4	5	6
17	No matter how hard I try, I cannot understand science.	1	2	3	4	5	6
18	I feel tense and upset when someone talks to me about science.	1	2	3	4	5	6

19	I often think, "I cannot do this", when a science assignment seems hard.	1	2	3	4	5	6
20	Science is of great importance to a country's development.	1	2	3	4	5	6
21	It is important to know science in order to get a good job.	1	2	3	4	5	6
22	It does not disturb or upset me to do science assignments.	1	2	3	4	5	6
23	I would like a job that does not use any science.	1	2	3	4	5	6
24	I enjoy talking to people about science.	1	2	3	4	5	6
25	I enjoy watching a science program on television.	1	2	3	4	5	6
26	I am good at working science labs and hands-on activities.	1	2	3	4	5	6
27	I like the challenge of science assignments.	1	2	3	4	5	6
28	You can get along perfectly well in everyday life without science.	1	2	3	4	5	6
29	Working with science upsets me.	1	2	3	4	5	6
30	I remember most of the things I learn in science class.	1	2	3	4	5	6
31	It makes me nervous to even think about doing science.	1	2	3	4	5	6
32	I would rather be told scientific facts than find them out from experiments.	1	2	3	4	5	6
33	Most of the ideas about science are not very useful.	1	2	3	4	5	6
34	It scares me to have to take a science class.	1	2	3	4	5	6
35	The only reason I am taking science is because I have to.	1	2	3	4	5	6
36	It is important for me to understand the work I do in the science class.	1	2	3	4	5	6
37	I have a good feeling toward science.	1	2	3	4	5	6
38	Science is one of my favorite subjects.	1	2	3	4	5	6
39	I have a real desire to learn science.	1	2	3	4	5	6
40	If I do not see how to do a science assignment right away, I never get it.	1	2	3	4	5	6

Student ID# --

APPENDIX E

Post Attitude Toward Science Inventory

ATTITUDE TOWARD SCIENCE INVENTORY (ATSI)

ASTI Item Statements		1 = Strongly Agree 6 = Strongly Disagree					
1	Science is useful for solving the problems of everyday life.	1	2	3	4	5	6
2	Science is something that I enjoy very much.	1	2	3	4	5	6
3	I like the easy science assignments best.	1	2	3	4	5	6
4	I do not do very well in science.	1	2	3	4	5	6
5	Doing science labs or hands-on activities is fun.	1	2	3	4	5	6
6	I feel at ease in science class.	1	2	3	4	5	6
7	I would like to do some extra or un-assigned reading in science.	1	2	3	4	5	6
8	There is little need for science in most of today's jobs.	1	2	3	4	5	6
9	Science is easy for me.	1	2	3	4	5	6
10	When I hear the word "science", I have a feeling of dislike.	1	2	3	4	5	6
11	Most people should study some science.	1	2	3	4	5	6
12	I would like to spend less time in school studying science.	1	2	3	4	5	6
13	Sometimes I read ahead in our science book.	1	2	3	4	5	6
14	Science is helpful in understanding today's world.	1	2	3	4	5	6
15	I usually understand what we are talking about in science.	1	2	3	4	5	6
16	I do not like anything about science.	1	2	3	4	5	6
17	No matter how hard I try, I cannot understand science.	1	2	3	4	5	6
18	I feel tense and upset when someone talks to me about science.	1	2	3	4	5	6

19	I often think, "I cannot do this", when a science assignment seems hard.	1	2	3	4	5	6
20	Science is of great importance to a country's development.	1	2	3	4	5	6
21	It is important to know science in order to get a good job.	1	2	3	4	5	6
22	It does not disturb or upset me to do science assignments.	1	2	3	4	5	6
23	I would like a job that does not use any science.	1	2	3	4	5	6
24	I enjoy talking to people about science.	1	2	3	4	5	6
25	I enjoy watching a science program on television.	1	2	3	4	5	6
26	I am good at working science labs and hands-on activities.	1	2	3	4	5	6
27	I like the challenge of science assignments.	1	2	3	4	5	6
28	You can get along perfectly well in everyday life without science.	1	2	3	4	5	6
29	Working with science upsets me.	1	2	3	4	5	6
30	I remember most of the things I learn in science class.	1	2	3	4	5	6
31	It makes me nervous to even think about doing science.	1	2	3	4	5	6
32	I would rather be told scientific facts than find them out from experiments.	1	2	3	4	5	6
33	Most of the ideas about science are not very useful.	1	2	3	4	5	6
34	It scares me to have to take a science class.	1	2	3	4	5	6
35	The only reason I am taking science is because I have to.	1	2	3	4	5	6
36	It is important for me to understand the work I do in the science class.	1	2	3	4	5	6
37	I have a good feeling toward science.	1	2	3	4	5	6
38	Science is one of my favorite subjects.	1	2	3	4	5	6
39	I have a real desire to learn science.	1	2	3	4	5	6
40	If I do not see how to do a science assignment right away, I never get it.	1	2	3	4	5	6

Student ID# ---

APPENDIX F

ATSI Information Sheet

Subscale	Statement #	Statement	Possible Range of Score
Value	1, 8*, 11, 14, 20, 21, 28, 33*	1. Science is useful for solving the problems of everyday life. 8. There is little need for science in most of today's jobs. 11. Most people should study some science. 14. Science is helpful in understanding today's world. 20. Science is of great importance to a country's development. 21. It is important to know science in order to get a good job. 28. You can get along perfectly well in everyday life without science. 33. Most of the ideas about science are not very useful.	(8-48) (8 = Most favorable) (48 = Most unfavorable)
Enjoy	2, 5, 12*, 16*, 23*, 24, 25, 38	2. Science is something that I enjoy very much. 5. Doing science labs or hands-on activities is fun. 12. I would like to spend less time in school studying science. 16. I do not like anything about science. 23. I would like a job that does not use any science. 24. I enjoy talking to people about science. 25. I enjoy watching a science program on television. 38. Science is one of my favorite subjects.	(8-48) (8 = Most favorable) (48 = Most unfavorable)
Motivation	3*, 7, 13, 27, 32*, 35*, 36, 39	3. I like the easy science assignments best. 7. I would like to do some extra or un-assigned reading in science. 13. Sometimes I read ahead in our science book. 27. I like the challenge of science assignments. 32. I would rather be told scientific facts than find them out from experiments. 35. The only reason I am taking science is because I have to. 36. It is important for me to understand the work I do in the science class. 39. I have a real desire to learn science.	(8-48) (8 = Most favorable) (48 = Most unfavorable)
Self	4*, 9, 15, 17*, 19*, 26, 30, 40*	4. I do not do very well in science. 9. Science is easy for me. 15. I usually understand what we are talking about in science. 17. No matter how hard I try, I cannot understand science. 19. I often think, "I cannot do this", when a science assignment seems hard. 26. I am good at working science labs and hands-on activities. 30. I remember most of the things I learn in science class. 40. If I do not see how to do a science assignment right away, I never get it.	(8-48) (8 = Most favorable) (48 = Most unfavorable)
Anxiety	6, 10*, 18*, 22, 29*, 31*, 34*, 37	6. I feel at ease in science class. 10. When I hear the word "science", I have a feeling of dislike. 18. I feel tense and upset when someone talks to me about science. 22. It does not disturb or upset me to do science assignments. 29. Working with science upsets me. 31. It makes me nervous to even think about doing science. 34. It scares me to have to take a science class. 37. I have a good feeling toward science.	(8-48) (8 = Most favorable) (48 = Most unfavorable)

The * indicates that the score will be reversed because the statements were worded in the negative.

APPENDIX G

Parental Consent Information Sheet

PEPPERDINE UNIVERSITY

Graduate School of Education and Psychology

PARENT/LEGAL GUARDIAN CONSENT TO PARTICIPATE IN RESEARCH

COGNITIVE KNOWLEDGE, ATTITUDE TOWARD SCIENCE, AND SKILL DEVELOPMENT IN VIRTUAL SCIENCE LABORATORIES

Your child is invited to participate in a research study conducted by Mahya Babaie, Doctorate Candidate and faculty advisor, Dr. Kay Davis at Pepperdine University, because you are the parents/guardian of an 8th grade middle school student enrolled in Ms. Babaie's science class at Magnolia Science Academy # 6. Your son/daughter's participation is voluntary. You should read the information below, and ask questions about anything that you do not understand, before deciding whether to participate. Please take as much time as you need to read the informed consent form. You may also decide to discuss participation with your family or friends. You will be given a copy of this form for you records.

PURPOSE OF THE STUDY

The purpose of this single group pretest-posttest design study is to assess gains within each of Bloom's domains of learning outcomes following participation in a Virtual Science Laboratory (VSL) for eighth grade students at Magnolia Science Academy # 6 charter Middle School in Southern California.

STUDY PROCEDURES

If your son/daughters agrees to voluntarily participate in this study, he/she will be asked to participate in a five day research study to complete four assessments in the form of a pre-Buoyancy and Density assessment, post-Buoyancy and Density assessment, pre-Attitude Toward Science Inventory, and post-Attitude Toward Science Inventory. In addition to these assessments, participants will be asked to complete a Virtual Science Laboratory where their observations and calculations are going to be recorded in a Virtual Laboratory Packet. The anticipated time to complete each assessment and the VSL is about 40 minutes. Participants do not have to answer any questions that they don't want to. They may skip the questions and move to the next question.

POTENTIAL RISKS AND DISCOMFORTS

The potential and foreseeable risks associated with participation in this study may include feeling uncomfortable answering some or all of the questions. Your child does not have to answer any question if they don't want to.

POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

While there are no direct benefits to the study participants, there are several anticipated benefits to society, educational researchers, and educators. We hope that this study will help researchers and educators learn more about the affects of Virtual Science Laboratories on students' cognitive knowledge, attitude toward science, and skill development. This research may help advance knowledge in the field of educational technology and implementation of Virtual Science Laboratories in secondary science classrooms; however there is no direct benefit to your child for participating in this study.

CONFIDENTIALITY

I will keep your son/daughter's records for this study confidential as far as permitted by law. However, if I am required to do so by law, I may be required to disclose information collected about you. Examples of the types of issues that would require me to break confidentiality are if your child tells me about instances of child abuse and elder abuse. Pepperdine University's Human Subjects Protection Program (HSPP) may also access the data collected. The HSPP occasionally reviews and monitors research studies to protect the rights and welfare of research subjects.

The data will be stored on a password-protected computer in the principal investigator's place of work. The data will be stored for a minimum of three years. The data collected will be coded and de-identified with a pseudonym and transcript data will be maintained separately.

PARTICIPATION AND WITHDRAWAL

Your son's/daughter's participation is voluntary. His/her refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. He/she and/or you may withdraw consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study.

ALTERNATIVES TO FULL PARTICIPATION

The alternative to participation in the study is not participating or completing only the items which you feel comfortable.

EMERGENCY CARE AND COMPENSATION FOR INJURY

If you child is injured as a direct result of research procedures, you will receive medical treatment; however, you or your insurance will be responsible for the cost. Pepperdine University does not provide any monetary compensation for injury

INVESTIGATOR'S CONTACT INFORMATION

I understand that the investigator is willing to answer any inquiries I may have concerning the research herein described. I understand that I may contact Dr. Kay Davis at kay.davis@pepperdine.edu if I have any other questions or concerns about this research.

RIGHTS OF RESEARCH PARTICIPANT – IRB CONTACT INFORMATION

If you have questions, concerns or complaints about your rights as a research participant or research in general please contact Dr. Judy Ho, Chairperson of the Graduate & Professional Schools Institutional Review Board at Pepperdine University 6100 Center Drive Suite 500 Los Angeles, CA 90045, 310-568-5753 or gpsirb@pepperdine.edu

APPENDIX I

Student Assent Information Sheet

PEPPERDINE UNIVERSITY

Graduate School of Education and Psychology

CHILD ASSENT FORM TO PARTICIPATE IN RESARCH AGES 7-13

COGNITIVE KNOWLEDGE, ATTITUDE TOWARD SCIENCE, AND SKILL DEVELOPMENT IN VIRTUAL SCIENCE LABORATORIES

Your instructor, Ms. Babaie wants to learn about the affects of Virtual Science Laboratories on students' cognitive knowledge, attitude toward science, and skill development. One way to learn about this topic is to do a research study; the people doing the study are called researchers.

Your mom/dad/parent/guardian/Legally Authorized Representative (LAR) have told us we can talk to you about the study. You also can talk this over with a family member. It's up to you if you want to take part, you can say "yes" or "no". No one will be upset with you if you don't want to take part.

If you do want to take part, you will be asked to participate in a five day research study to complete four assessments in the form of a pre-Buoyancy and Density assessment, post-Buoyancy and Density assessment, pre-Attitude Toward Science Inventory, post-Attitude Toward Science Inventory. In addition to these assessments, you will be asked to complete a Virtual Science Laboratory where your observations and calculations are going to be recorded in a Virtual Laboratory Packet. The anticipated time to complete each assessment and the VSL is about 40 minutes. You do not have to answer any questions you don't want to. You may skip those questions and move to the next question.

Researchers don't always know what will happen to people in a research study. We don't expect anything to happen to you, but you might not like answering some or all of the questions. You do not have to answer any question you don't want to.

Your answers will not be graded. Only the researchers will see your answers.

If you have any questions, you can ask the researchers.

If you want to take part in the study, please write and then sign your name at the bottom. You can change your mind if you want to, just tell the researchers.

APPENDIX J

IRB Approval

PEPPERDINE

Pepperdine University
24255 Pacific Coast Highway
Malibu, CA 90263
TEL: 310-506-4000

NOTICE OF APPROVAL FOR HUMAN RESEARCH

Date: June 20, 2016

Protocol Investigator Name: Mahya Babaie

Protocol #: 16-02-216

Project Title: Cognitive Knowledge, Attitude Toward Science, and Skill Development in Virtual Science Laboratories

School: Graduate School of Education and Psychology

Dear Mahya Babaie:

Thank you for submitting your application for exempt review to Pepperdine University's Institutional Review Board (IRB). We appreciate the work you have done on your proposal. The IRB has reviewed your submitted IRB application and all ancillary materials. Upon review, the IRB has determined that the above entitled project meets the requirements for exemption under the federal regulations 45 CFR 46.101 that govern the protections of human subjects.

Your research must be conducted according to the proposal that was submitted to the IRB. If changes to the approved protocol occur, a revised protocol must be reviewed and approved by the IRB before implementation. For any proposed changes in your research protocol, please submit an amendment to the IRB. Since your study falls under exemption, there is no requirement for continuing IRB review of your project. Please be aware that changes to your protocol may prevent the research from qualifying for exemption from 45 CFR 46.101 and require submission of a new IRB application or other materials to the IRB.

A goal of the IRB is to prevent negative occurrences during any research study. However, despite the best intent, unforeseen circumstances or events may arise during the research. If an unexpected situation or adverse event happens during your investigation, please notify the IRB as soon as possible. We will ask for a complete written explanation of the event and your written response. Other actions also may be required depending on the nature of the event. Details regarding the timeframe in which adverse events must be reported to the IRB and documenting the adverse event can be found in the *Pepperdine University Protection of Human Participants in Research: Policies and Procedures Manual* at community.pepperdine.edu/irb.

Please refer to the protocol number denoted above in all communication or correspondence related to your application and this approval. Should you have additional questions or require clarification of the contents of this letter, please contact the IRB Office. On behalf of the IRB, I wish you success in this scholarly pursuit.

Sincerely,

Judy Ho, Ph.D., IRB Chairperson

cc: Dr. Lee Kats, Vice Provost for Research and Strategic Initiatives

APPENDIX K

Human Subjects Research Certificate

COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI)

GRADUATE & PROFESSIONAL SCHOOL SOCIAL & BEHAVIORAL RESEARCH - BASIC/REFRESHER CURRICULUM COMPLETION REPORT

Printed on 04/14/2014

LEARNER	Mahya Babaie [redacted] The United State of America
DEPARTMENT	Education
PHONE	[redacted]
EMAIL	
INSTITUTION	Pepperdine University
EXPIRATION DATE	04/13/2017

SOCIAL & BEHAVIORAL RESEARCH - BASIC/REFRESHER : Choose this group to satisfy CITI training requirements for Investigators and staff involved primarily in Social/Behavioral Research with human subjects.

COURSE/STAGE:	Basic Course/1
PASSED ON:	04/14/2014
REFERENCE ID:	12796068

REQUIRED MODULES	DATE COMPLETED	SCORE
Belmont Report and CITI Course Introduction	04/14/14	3/3 (100%)
Students in Research	04/14/14	10/10 (100%)
History and Ethical Principles - SBE	04/14/14	5/5 (100%)
Defining Research with Human Subjects - SBE	04/14/14	5/5 (100%)
The Regulations - SBE	04/14/14	5/5 (100%)
Assessing Risk - SBE	04/14/14	5/5 (100%)
Informed Consent - SBE	04/14/14	5/5 (100%)
Privacy and Confidentiality - SBE	04/14/14	5/5 (100%)
Research with Prisoners - SBE	04/14/14	4/4 (100%)
Research with Children - SBE	04/14/14	4/4 (100%)
Research in Public Elementary and Secondary Schools - SBE	04/14/14	4/4 (100%)
International Research - SBE	04/14/14	3/3 (100%)
Internet Research - SBE	04/14/14	5/5 (100%)
Research and HIPAA Privacy Protections	04/14/14	5/5 (100%)
Vulnerable Subjects - Research Involving Workers/Employees	04/14/14	4/4 (100%)
Conflicts of Interest in Research Involving Human Subjects	04/14/14	3/5 (60%)

For this Completion Report to be valid, the learner listed above must be affiliated with a CITI Program participating institution or be a paid Independent Learner. Falsified information and unauthorized use of the CITI Progam course site is unethical, and may be considered research misconduct by your institution.

Paul Braunschweiger Ph.D.
Professor, University of Miami
Director Office of Research Education
CITI Program Course Coordinator