COMPARING INQUIRY-BASED TEACHING STRATEGIES FOR IMPROVING AND IMPLEMENTING COMPUTER SIMULATION-BASED INSTRUCTION OF SCIENCE CONCEPTS

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A Dissertation
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MAJOR PROFESSORS: Dr. Harvey Henson and Dr. Peter Fadde

This study compared the learning effectiveness of two inquiry-based strategies for implementing computer simulation-based instruction for teaching science concepts: POE (Predict, Observe, and Explain) and 5E (Engage, Explore, Explain, Elaborate, and Evaluate). Participants in this study, who were pre-service teachers in science education classes, successfully completed worksheets and tests that indicated they both learned key concepts related to density as well as how to use measures of weight and volume to calculate density. Further, participants expressed appreciation of the density simulation's ease of use and consistency of measurements.

In terms of findings and implications, pre and post knowledge tests and worksheets showed no significant differences between using POE and 5E to guide use of a computer-based density simulation. This suggests that either one of these proven and accepted inquiry methods effectively enhance simulation-based learning. The choice of either one can depend on the preferences of the instructor. The POE group completed worksheets faster (38 min.) than the 5E group (41 min). No differences for the knowledge gained, problem-solving skill, and attitudes towards the simulation were shown between POE and 5E. The underlying assumption is that if pre-service teachers have a successful learning experience using science simulations in conjunction with systematic inquiry methods, then they will see the potential and value of using specific inquiry-based teaching strategies when used with computer simulation to teach science

topics.

This study affirmed the benefits of computer simulations and adds to the body of knowledge on the use of computer simulation plus inquiry-based teaching strategies, such as POE and 5E, to teach science. Students could learn about density concepts with either inquiry-based strategy along with computer simulation combinations, and these inquiry+simulation teaching strategy combinations should also allow science teachers and their students, to have a more positive attitude while learning science with computer simulations.

DEDICATION

I dedicate this work to my family. First, I dedicate this work to my daughter: Monteerah Jasmine Lara Noble Greer Fateen; my mother: Baheerah J. Fateen; and my father: Monte I. Fateen. I also dedicate this work to my six sisters: Arlikkah Fateen, Samia Fateen, Fulani Fateen, Shaheerah Fateen Kelly, Badriyyah Fateen, and Jauhar Fateen. Also, I dedicate this work to my five brothers: Monte Fateen II., Khayree Fateen, Marwan Fateen, Tamir Fateen, and Tahir Fateen. Finally, I also dedicate this work to my grandmothers (Essie B. Taylor and Wilma M. Greer), and my aunts, and my uncles, and my cousins, and my nieces, and my nephews.

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LIST OF ABREVIATIONS

5E The 5E inquiry-based learning cycle is abbreviated as Engage, Explore, Explain, Elaborate, and Evaluate

POE The POE inquiry-based teaching strategy, or method, is abbreviated as Predict, Observe, and Explain

CHAPTER 1

INTRODUCTION

Students may have difficulty in understanding science when they are taught science concepts, and teachers may have difficulty teaching and explaining science concepts to students. The reasons for these difficulties often include (1) practical and economic or financial barriers, (2) motivation of learners (or psycho-social barriers), (3) cognitive demand, (4) language, (5) cultural, (5) and misconceptions of learners (Baker & Taylor, 1995; Cobern & Aikenhead, 1997; Johnstone, 1991; UKEssays, 2017).

The Effect of Computer Simulations for Teaching Science

Fortunately, there are many resources available to help teach science, including interactive computer simulations, such as PhET (University of Colorado Boulder, 2019), that allow teachers to more easily teach science concepts to students, that allow teachers to more easily teach difficult science concepts to students, and overall, allow science to be more easily taught and learned. PhET Interactive Simulations creates free interactive math and science simulations that engage students through a game-like environment where students learn through exploration and discovery. PhET stands for "Physics Education Technology," but this project expanded from just physics to include other science disciplines and provides 125 interactive and free simulations (which are translated into more than 65 different languages) for use in education in the fields of chemistry, physics, biology, math, and earth science.

Using computer simulations to teach science concepts has also been found to have education potential (Ash, 2009; Chen & Howard, 2010; Chabalengula, Fateen, Mumba, & Ochs (2016); Gonzalez-Cruz, Rodriguez-Sotres, & Rodriguez-Penagos, 2003; Khan, 2011; Latham & Scully, 2008; Mohanty & Cantu, 2011; Rands, 2012; Zacharia, 2005). The demonstrated educational potential of using computer simulations for teaching science concepts include the following: first, concepts that are usually difficult to understand and difficult to teach, such as phenomena that are unobservable, can be more easily taught when using computer simulations, and therefore, computer simulations allow educators to more easily explain and teach concepts that are usually more difficult to teach and explain (Ash, 2009; Gonzalez-Cruz, Rodriguez-Sotres, & Rodriguez-Penagos, 2003; Latham & Scully, 2008; Rands, 2012). Secondly, with computer simulations, science processes that usually take a long time, such as evolution and ecology processes, are carried out faster (Latham & Scully, 2008; Mohanty & Cantu, 2011; Stafford, Goodenough, & Davies, 2010). Thirdly, with computer simulations, experiments can be more easily carried out, and experimental results can be obtained faster (Latham & Scully, 2008; Winn et al, 2006). Fourth, computer simulations allow learners to practice with difficult concepts, or difficult to observe concepts, by freely changing and manipulating variables within the computer simulation (Trey & Khan, 2008; Zacharia, 2005). Also with computer simulations, difficult concepts, or concepts that are impossible to see, can be more easily practiced by learners, with learners using the computer simulations to change and manipulate variables within the simulations (Trey & Khan, 2008; Zacharia, 2005). Fifth, using computer simulations to teach science allow learners to work at the learners' own pace (Latham & Scully, 2008). Sixth, computer simulations can allow learners to carry out the simulation as many times as the learners want (Latham & Scully, 2008; Rands, 2012). Seventh, computer simulations give learners a more realistic picture of what is happening within a given scientific phenomenon (Cox et al., 2011; Latham & Scully, 2008). Eighth, computer simulations allow learners to visualize ideas that are abstract (Cox et al., 2011). Ninth, and finally, using computer simulations for teaching science can allow learners to be interactively engaged in the learning process (Cox et al., 2011).

Also, incorporating computer simulations was found to have potential for improving learning in science education, especially for the learning of future teachers in science education programs (Ash, 2009; Chen & Howard, 2010; Gonzalez-Cruz, Rodriguez-Sotres, & Rodriguez-Penagos, 2003; Khan, 2011; Latham & Scully, 2008; Mohanty & Cantu, 2011; Rands, 2012; Zacharia, 2005).

Several researchers have found an increase in students' perceptions and understanding when using computer simulations to teach science. For example, Kiboss, Ndirangu, & Wekesa (2004) investigated student perceptions within the classroom environment in the research experiment that involved computer simulations in science education. Using the quantitative methods of the Biology Classroom Environment Questionnaire (BCEQ) to measure perception, they found that perception and understanding increased more for the treatment group than for the control group, and they attributed these increases to the computer simulation used to teach the science topic being learned by the participants. This demonstrated that the use of well-designed computer simulation learning environments can be effective in improving students' knowledge and performance in the science topic. This changes their perceptions of the classroom environment and their attitudes towards the science subject. Results from this study also "once more confirmed earlier findings showing that the use of computers promotes pupils' positive attitudes and perception of the classroom environment" (p. 212). Kiboss, Wekesa, and Ndirangu, (2006) used quantitative measurements to measure participant perception of cell theory, and they found that their program, which involved computer simulations, resulted in better perceptions of the topic of cell division by participants in school biology.

Many studies have shown that computer simulations are more effective in the teaching of science concepts compared to teaching science concepts using laboratory or traditional instruction of science concepts (Akpan, 2001; Chen & Howard, 2010; Kiboss, Ndirangu, & Wekesa, 2004; Kiboss, Wekesa, & Ndirangu, 2006; Trey & Khan, 2008), or was compared to using direct experience on which the computer simulation was based on (Winn et al., 2006). Also, several studies have found that coupling student-centered, inquiry-based learning techniques with computer simulations provided a powerful and valuable teaching combination (e.g. Chen & Howard, 2010; Cox et al., 2011; Honey & Hilton, 2011; Latham & Scully, 2008). Therefore, there has been ample evidence for the effectiveness of computer simulation-based instruction for teaching science, and that success can depend on how instructors use simulations in teaching.

There are many benefits of computer simulation instruction compared to other teaching methods. In terms of comparing computer simulation instruction of science concepts to traditional or other teaching methods, computer simulations in the teaching and learning of science have been found to be beneficial in terms of saving money and saving time, or computer simulations have been shown to be cost effective and take less time, when compared to laboratory demonstrations, for example (Gonzalez-Cruz, Rodriguez-Sotres, & Rodriguez-Penagos, 2003).

In terms of learning gains and outcomes, Stafford, Goodenough, & Davies (2010) and other researchers found that different variables in the use of computer simulations led to higher scores on tests and led to stronger gains in learning (e.g. Ash, 2009; Gonzalez-Cruz, Rodriguez-Sotres, & Rodriguez-Penagos, 2003; Ioannidou et al., 2010; Kiboss, Wekesa, & Ndirangu, 2006; Latham & Scully, 2008). In terms of participants' attitudes of learning with computer simulations, many researchers have found that many participants and students held positive attitudes towards the use of the computer simulation in science education teaching and learning

(Chen & Howard, 2010; Cox et al., 2011; Kiboss, Ndirangu, & Wekesa, 2004; Kiboss, Wekesa & Ndirangu, 2006).

Why Add and Combine Inquiry to Computer Simulation?

Limitations of Using Computer Simulations Alone for Teaching Science

Combining an effective teaching strategy, such as the inquiry-based teaching strategy, with computer simulation in order to teach science should result in science being taught more effectively and efficiently. This combination can result in an increase in learning for learners, and also, the 2-sigma effect (Bloom, 1984) can take place, since there is an opportunity to combine the two established and effective teaching strategies of computer simulation and an inquiry-based teaching strategy, such as POE (or the Predict, Observe, and Explain teaching strategy) or 5E (or the Engage, Explore, Explain, Elaborate, and Evaluate learning cycle).

The 2-Sigma Effect and Combining Inquiry with Simulations for Teaching Science

Ideally, when combining two effective teaching strategies (such as combining computer simulation with an inquiry-based teaching strategy) in order to teach science, an increase in learning for learners can take place and the 2-sigma effect can result (Bloom, 1984). According Bloom (1984), the 2-sigma effect can be accomplished if two effective teaching strategies are combined. According to Bloom's 2-Sigma effect, when average students were provided one-on-one tutoring with learning strategies that were mastery and effective, then these students performed two standard deviations higher than students who learned using conventional instructional strategies (Bloom, 1984). Since one-on-one tutoring may be too expensive and not realistic on a large scale, then if one combines two or three effective teaching strategies instead, such as combining an inquiry-based teaching strategy with computer simulation, then a similar effect to the 2-Sigma effect, or an effect that is as effective as one-on-one tutoring, may result.

Bloom then challenged teachers and researchers to look for and find methods of group instruction and teaching that were as effective as one-to-one tutoring (Bloom, 1984).

Inquiry-based teaching strategies have been shown to be effective for teaching science, and most inquiry teaching strategies were originally created specifically in order to teach science concepts. The two, effective inquiry-based teaching strategies of POE and 5E (the inquiry-based teaching strategies of POE (or Predict, Observe, and Explain teaching strategy) and 5E (or Engage, Explore, Explain, Elaborate, and Evaluate learning cycle) have already been shown in research to be highly effective for teaching science concepts, and POE and 5E were created in order to teach science concepts (Champagne, Klopfer, & Anderson, 1980; Erickson, 2018; Karplus & Thier, 1967). Finally, inquiry-based teaching strategies (such as POE and 5E) combined with computer simulation in order to teach science concepts has already been shown to be effective.

Which Inquiry to Combine with Computer Simulation?

Inquiry-Based Learning

Inquiry-based learning is a type of active learning that begins by posing questions, scenarios, or problems instead of simply portraying a smooth path to knowledge or presenting and giving established facts. The inquiry process is usually helped along by a facilitator (or instructor, or teacher). Inquirers (or learners, or participants, or students) will identify and research issues and questions in order to develop their knowledge or solutions. Inquiry-based learning includes problem-based learning, and it is usually used in research and in small scale projects or investigations (Centre for Excellence in Enquiry-Based Learning, 2010; Dostál, 2015).

Several studies have found that coupling student-centered, inquiry-based learning techniques with computer simulations provided a powerful and valuable teaching combination (e.g. Chen & Howard, 2010; Cox et al., 2011; Honey & Hilton, 2011; Latham & Scully, 2008), and therefore, computer simulation combined with inquiry-based teaching strategies has been shown to be effective for teaching science.

Active Learning. Active learning is a type of learning where teaching strives to involve students in the learning process more directly compared to other teaching methods. Bonwell and Eison (1991) state that "in active learning, students participate in the process and students participate when they are doing something besides passively listening" (p. 7). Active learning is "a method of learning in which students are actively or experientially involved in the learning process and where there are different levels of active learning, depending on student involvement" (Bonwell & Eison 1991). The report for the Association for the Study of Higher Education (ASHE) mentions many different methodologies for promoting active learning. Here, the cited literature indicates that in order to learn, students have to do more than just listen: They have to read, write, discuss, or be engaged in solving problems. This relates to the three learning domains referred to as knowledge, skills and attitudes (KSA), and that this taxonomy of learning behaviors can be thought of as "the goals of the learning process" (Bloom, et al., 1956). In particular, students have to engage in the higher-order thinking tasks such as analysis, synthesis, and evaluation (Renkl, Atkinson, Maier, & Staley, 2002). Therefore, active learning engages students in two things, which include doing things and thinking about the things that they are doing.

Problem-Based Learning. Inquiry-based learning includes problem-based learning, and both POE and 5E are problem-based learning techniques. Problem-based learning (PBL) is a process that uses identified issues within a scenario in order to increase knowledge and understanding. Problem-based learning is student-centered and is a pedagogy where students learn about a subject through the experience of solving an open-ended problem found in the trigger material. The problem-based learning process does not focus on problem solving with a defined solution, but it allows for the development of other desirable skills and attributes, which includes the acquisition of knowledge, and enhanced group communication and collaboration. The problem-based learning process was developed for medical education and has since been broadened in applications for other learning programs. The Problem-based learning process allows for learners to develop skills used for their future practice, and it enhances literature retrieval and critical appraisal, and it encourages ongoing learning in a team environment (Centre for Excellence in Enquiry-Based Learning, 2010; Cote, 2007; Dostál, 2015; Guido, 2016; Huang, 2011; Schmidt, Rotgans, & Yew, 2011; Wood, 2003).

The POE and 5E Inquiry-Based Learning Strategies

The POE (Predict, Observe, Explain) learning strategy and the 5E (Engagement, Exploration, Explanation, Elaboration, and Evaluation) learning cycle strategy were chosen because they have already been shown to be effective for teaching science, and both POE and 5E were specifically created in order to teach science concepts (Champagne, Klopfer, & Anderson, 1980; Erickson, 2018; Karplus & Thier, 1967). Both the 5E learning strategy (Bilgin, Coşkun, & Aktaş, 2013) and the POE learning strategy (Joyce, 2006; Zacharia, 2005) have been shown to be effective learning strategies for teaching science. Both POE (Zacharia, 2005) and 5E have been shown to be a valuable teaching tool when used with computer simulation-based instruction. Learning strategies such as the POE learning strategy combined with computer simulations (Zacharia, 2005) and 5E combined with computer simulation have been previously shown to result in and to provide an effective powerful and very useful learning tool and learning combination for teaching certain science concepts.

The POE, Inquiry-Based, Learning Strategy. Champagne, Klopfer, and Anderson (1980) constructed the POE (predict, observe, explain) teaching method in order to help participating students justify and explore their own ideas. In order to conduct a POE learning activity, an instructor starts by conducting an event that is discrepant. After learners have made careful observations of the outcome, the instructor then guides the learners to an appropriate scientific understanding of the event. For predict (or the launch), the instructor describes to the learners what the instructor will do in the discrepant event. Next, the instructor asks the learners to individually make predictions of what they think will happen and why. These reasons and predictions should be written down. Finally, the instructor have the learners share some of their ideas. For observe (or explore), the instructor conducts the event, and the learners make close observations of the event. The learners should also write down about what they observed and what happened. Learners should also be prompted to take special observations about an important aspect of the result. If learners ask the instructor to perform the experiment again, then the instructor should modify it slightly and try to satisfy and pursue the curiosities of learners. For explain (or summarize), learners attempt to explain any discrepancies between their initial predictions and their final observations. The object of the POE teaching method is for the learners to construct a scientifically appropriate theory about what happened. However, the instructor may need to guide the thinking of the learners through the use of script that is questioning script, and this is a series of root questions that the instructor posed in order to stimulate the learners' prior knowledge and to help guide the learners towards an understanding of the scientific principle underlying the discrepant event. Learners are able to generate their own ideas and personal theories, and also they can build on each other's ideas (and this is a generative approach), rather than being simply told by the instructor what happened in the demonstrations (and this is a transmission approach) (Champagne, Klopfer, & Anderson, 1980; Joyce, 2006).

The 5E, Inquiry-Based, Learning Cycle. The original Learning Cycle was originally credited to Karplus and Thier (1967), who published it in the Science Teacher, and it has been used for science education since it was started. There are many "E" versions of the learning cycle (such as 3E, 4E, 5E, and other modifications) but the basic premise for the learning cycle was that children and learners have an experience with the phenomena in the learning of the topic or concept. The Learning Cycle applied the inquiry approach to teaching into a series of planning strategies. Roger Bybee developed the 5E model, which is the BSCS (or Biological Sciences Curriculum Study, or BSCS 5E) approach to the learning cycle. The 5E learning cycle was started by the Biological Sciences Curriculum Study (or BSCS 5E) in order to teach science. There are four phases in the 5E learning cycle. In phase 1, or the engage phase, the topic is established and each of the learner's interest is captured. In phase 2, or the explore phase, each learner is allowed to construct knowledge in the topic through observation and facilitated questioning. In phase 3, or the explain phase, learners are asked to explain what they have discovered, and the instructor leads a discussion of the topic in order to refine the learners' understanding. In phase 4, or the extend phase, learners are asked to apply what they learned in different but similar situations, and then the instructor guides the learners toward the next discussion topic. The fifth and last E stands for evaluate, where the instructor observes each of the learner's understanding and knowledge, and then leads the learners to assess whether or not what they have learned is true. Evaluation should happen and take place throughout the 5E learning cycle, and evaluation does not take place within its own set phase (Bybee, et al., 2006; Corporation for Public Broadcasting, 2002; Erickson, 2018; Karplus & Thier, 1967).

Why Compare Inquiry Strategies, and Why POE and 5E?

Both POE and 5E are inquiry-based learning techniques that have been shown to be effective for teaching various science concepts, and they have both been shown to be highly effective when each were paired up with computer simulation in order to teach science concepts. Inquiry-based teaching strategies combined with simulation to teach science has been established, but the various inquiry-based teaching strategies have disadvantages.

Both POE and 5E (and other inquiry-based teaching strategies) have disadvantages, and therefore it is best to determine which inquiry strategy is the most effective to teach science concepts when inquiry-based teaching is combined with computer simulation. For example, both POE and 5E are problem-based (PBL) learning (PBL) techniques, and some of the disadvantages of PBL include: potentially poorer performance on the tests, learner unpreparedness, instructor unpreparedness, time-consuming assessment, and varying degrees of relevancy and applicability (Guido, 2016). Disadvantages of POE include the following: for primary school students, writing the answer can be a barrier to useful communication of ideas; younger primary students may have difficulty explaining their reasoning; POE is not suitable for all topics or topics that are not "hands-on" or in which it is difficult to get immediate results" (Joyce, 2006), and some researchers say that students are more likely to learn from observations that confirm their predictions (Joyce, 2006). Disadvantages of 5E included the following: limited interactions with the students affected the dynamics of the research setting regarding student behavior and continuity of instruction, and the amount of time spent on science instruction greatly differed from the time spent on other subjects (Campbell, 2006; Enugu, 2016). Therefore, it is important to determine which inquiry strategy is most effective and most efficient and best to use when inquiry is combined with computer simulation in order to teach science.

Since each inquiry teaching strategy has its own disadvantages, it is best to determine which inquiry-based teaching strategy is best to use when inquiry is combined with computer simulation to teach science concepts. This can be done by first combining each inquiry strategy with the computer simulation in order to teach science concepts, and then comparing the results from these different combinations. This should show which combination was the most effective for teaching each specific science concept.

The inquiry-based teaching strategies of POE (or Predict, Observe, and Explain teaching strategy) and 5E (or Engage, Explore, Explain, Elaborate, and Evaluate learning cycle) were compared in this study because both have been shown to be effective to teach science; both has been shown to be effective for teaching science when combined with simulation; and POE and 5E were specifically created in order to teach science concepts. But both POE and 5E (as well as other inquiry-based teaching strategies) have disadvantages; and therefore, it is important to determine which inqiry+simulation combination is the most effective for each specific science concept to be taught.

Effect of POE+Simulation for Teaching Science

POE has been shown to be effective to teach science when combined with computer simulation. Zacharia (2005), for example, found that using the POE model along with computer simulation resulted in "improved science teachers' ability to generate scientifically accurate explanations and fostered in-depth advancement in teachers' search for explanatory scientific information regarding the physical phenomena under investigation. In addition, teachers' explanations became more elaborate, reflecting cause-effect reasoning and formal reasoning." (p. 1741)

Effect of 5E+Simulation for Teaching Science

The 5E inquiry method has been shown to be effective to teach science when it was combined with computer simulation. According to Sarıa et al. (2017), for example, the:

> findings revealed that interactive simulations integrated 5E teaching model caused significantly better acquisition of scientific concepts related to content taught and relatively higher positive attitudes towards physics than traditionally based instruction. The results have also been supported by the thoughts collected from the students in the experimental group at the end of the study. As a result the 5E teaching model integrated with simulations had potential to help eleventh graders improve their physics academic achievement and attitude.

According to Tshewang and Khajornsak (2017), for example, the "simulation and game based learning unit significantly helped the participating students improve their understanding of photoelectric effect ($t = 7.79$, $p < 0.05$). In addition, the students expressed their positive attitudes to the learning unit.

Comparing POE+Simulation and 5E+Simulation for Teaching Science

Both POE and 5E inquiry-based teaching methods have disadvantages, and so it is best to determine which of the two is most effective and the most efficient to teach different science concepts when the inquiry-based teaching strategy is paired-up, or combined, with simulation. Both POE and 5E are problem-based (PBL) learning (PBL) techniques; and some of the disadvantages of PBL include: potentially poorer performance on the tests, learner unpreparedness, instructor unpreparedness, time-consuming assessment, and varying degrees of relevancy and applicability (Guido, 2016). Disadvantages of the POE inquiry method include: for primary school students, writing the answer can be a barrier to useful communication of ideas; younger primary students may have difficulty explaining their reasoning; it is not suitable for all topics; some researchers say that students are more likely to learn from observations that confirm their predictions; and the POE learning strategy is not suitable for all topics, for example, topics that are not "hands-on" or in which it is difficult to get immediate results" (Joyce, 2006). Disadvantages of 5E included: limited interactions with the students affected the dynamics of the research setting regarding student behavior and continuity of instruction, and the amount of time spent on science instruction greatly differed from the time spent on other subjects (Campbell, 2006)

It is important to compare POE and 5E because these two inquiry-based teaching strategies have already been shown to be effective when combined with computer simulation for teaching science concepts, but both POE and 5E have disadvantages. In order to most effectively teach specific science concepts when inquiry and simulation are combined, it is important to determine which inquiry+simulation teaching combination is the most effective and efficient to teach each specific science concept. Therefore, the question to be answered in this study is: which is the best inquiry teaching strategy to use when inquiry is combined with computer simulation in order to teach a specific science concept?

In this current research study, the two well-established, and effective teaching strategies of computer simulation and POE inquiry were combined, and then this combination was compared to the combination of the two well-established, and effective teaching strategies of computer simulation and 5E. These two combinations were then compared in order to determine which combination was the most effective, and possibly the most efficient, for teaching a science topic, since both inquiry-based teaching strategies have disadvantages (as well as advantages).

Bloom's 2-Sigma Effect, Computer Simulations, and Inquiry

In this current study, the two effective teaching strategies of computer simulation and an inquiry-based teaching strategy were combined in order to result in an effective, and possibly an efficient, teaching of a science concept.

This current study combined the inquiry teaching strategy and the computer simulation teaching strategy in order to teach the science topic of density, and the two inquiry strategies of POE (or Predict, Observe, and Explain teaching strategy) and 5E (or Engage, Explore, Explain, Elaborate, and Evaluate learning cycle) were then compared. In particular, each of the two inquiry-based teaching strategies of POE and 5E were first combined with computer simulation to teach the science topic of density, and then they were then compared. The teaching strategies of POE, 5E, and computer simulation have been shown to be effective for teaching science. The POE and 5E inquiry strategies were chosen and compared in this study because both have been shown to be effective for teaching science, and both have been shown to be effective for teaching science when combined with computer simulation. Additionally, both POE and 5E were specifically created in order to teach science concepts. Overall, in this study, the two inquiry strategies (of POE and 5E) were compared when inquiry was combined with simulation to teach science. In particular, the effective and established teaching strategies of computer simulation and POE were combined and then compared to the combination of the two effective and established teaching strategies of computer simulation and 5E in teaching the science topic of density.

Purpose of This Study

This study had two purposes. The first purpose of this study was to compare the learning effectiveness of the two effective and established inquiry-based teaching strategies of POE (Predict-Observe-Explain) and 5E (Engagement, Exploration, Explanation, Elaboration, and Evaluation) for implementing computer simulation-based instruction. The second purpose of this study was to compare participants' attitudes of the computer simulation used based on which inquiry-based strategy was used.

Rationale for This Study

The gaps present in the literature involving computer simulations in science education are the rationales for the current study. Currently, there is a need for science educators to include and involve in-service teachers and pre-service teachers to construct and use computer simulations in their inquiry practices so that the in-service teachers and pre-service teachers can see the potential of computer simulations in terms of helping them, and later their students, generate knowledge as they interact with the computer simulation. In support of this strategy, many authors suggested that combining inquiry-based, student-centered, learning techniques with computer simulations could result in a valuable and powerful teaching combination (e.g. Chen & Howard, 2010; Cox et al., 2011; Honey & Hilton, 2011; Latham & Scully, 2008). Also, other researchers such as Zacharia (2005) suggested that using computer simulations along with applying certain learning cycle strategies, such as the Predict-Observe-Explain (POE) can result in the interactive learning needed to increase understanding.

Significance of This Study

Honey and Hilton (2011) argued that presenting the computer simulation in a personally meaningful scientific context should let learners draw on what they already know, recognize unlikely findings, and ask more effective questions. The computer simulation currently used here, involving density, should allow for this. This study is also significant because pre-service teachers will be the participants. Akpan (2001), suggested that more studies involving pre-service teachers should be carried out, and only a few studies involving pre-service teachers have actually been carried out. So far, none of the studies reviewed have used an inquiry-based computer simulation that uses a 5E learning cycle strategy to teach density - which the current study will carry out. In addition, this study incorporated the Predict, Observe, Explain (POE) learning strategy. Using the POE teaching strategy in combination with computer simulations in teaching has been shown to provide a powerful and useful teaching combination. (Zacharia, 2005) The ultimate goal of this current research is to improve pre-service teachers' learning of science concepts using computer simulation during pre-service teacher training so that, as in-service teachers, they will be able to use computer simulations and select appropriate teaching strategies such as POE and 5E while teaching.

The significance of study is that this adds to the research knowledge about using computer simulation to teach science; this study provides insight on pre-service teacher preparation and learning; and this study provides findings on teaching the topic of density while using computer simulation by comparing two inquiry methods.

Research Questions

The following four research questions guided this study and were answered in this study:

1. Is there a difference in the total amount of time, as measured by the times that each participant started and finished (or completed) the activity worksheets, between pre-service teacher participants who used the density simulation with POE and those who used the density simulation with 5E?

2. Is there a difference in content knowledge, as measured by forced-choice test, between pre-service teachers who used a density simulation with POE and those who used the density simulation with 5E?

3. Is there a difference in problem solving skills, as measured by forced-choice test, between pre-service teachers who used a density simulation with POE and those who used the density simulation with 5E?

4. Is there a difference in attitude toward science, as measured by survey

questions, between pre-service teachers who used a density simulation with POE and those who used the density simulation with 5E?

Definition of Key Terms

Attitude: An attitude is the evaluation of an attitude object, which can range from extremely positive to extremely negative. An attitude can be a positive or negative evaluation of objects, people, activities, events, and ideas, for example. An attitude could be abstract, concrete, or just about anything in the environment (Eagly & Chaiken, 1998; Wood, 2000). Therefore, an attitude is "an enduring evaluation directed towards a particular object, such as a person, institution or event" (Schwarz & Bohner, 2001).

Computer Simulations: The broad definition of computer simulations are as follows: "a computer program that attempts to simulate a model of a particular system. Users can manipulate the model to view how it would behave under various conditions, and the outcome of these changes are made visible or reported as a measurement by the program itself" (Khan, 2011, p. 216). Computer simulations also let learners interact with and observe representations of processes that would otherwise be unobservable or invisible (Khan, 2011).

Content Knowledge: includes an understanding of what makes the learning of certain topics difficult or easy, and it includes the preconceptions and conceptions that students of different ages and backgrounds bring with them to the learning of the most frequently taught lessons and topics (Ball, Thames, & Phelps, 2008). Content knowledge is the body of information and knowledge that teachers teach and that students are expected to learn in a given content area or given subject, such as mathematics, science English language arts, or social studies. Content knowledge generally refers to facts, concepts, principles, and theories that are taught and learned in specific academic courses, rather than to related skills (such as researching, writing, or reading) that students also learn in school (The Glossary of Education Reform, 2016).

Density: The density of a substance, or more specifically the volumetric mass density of a substance, is its mass per unit volume (or mathematically, density is mass divided by volume) (Oil Gas Glossary, 2014; Horton, et al., 2008; Benson, 2008).

Effective: "Producing the intended results, or (of a person) skilled or able to do something well" (Cambridge University Press, n.d.); "producing a decided, decisive, or desired effect" (Merriam-Webster, Incorporated, n.d.); "successful in producing a desired or intended result" (Oxford University Press, n.d.); "produces the result that was intended" (Springer Nature Limited, n.d.); "producing or capable of producing an intended result or having a striking effect" (Vocabulary.com, n.d.).

Learning Strategy: Learning strategies refer to the learners' self-generated feelings, actions, and thoughts that are systematically oriented toward the attainment of the students' goals (Hasanbegovic, 2006).

Pre-Service Teacher: In terms of defining pre-service teacher: "Pre-service teaching is a period of guided, supervised teaching. The student teacher is gradually introduced into the teaching role by a cooperating teacher. The cooperating teacher works with and encourages the student teacher to assume greater responsibility in for instruction and classroom management as the experience progresses. The student teacher begins as an observer and finishes the pre-service teaching experience as a competent professional" (Shirley, 2011). Pre-service teaching is an experience that is essential in in the preparing of future teachers. Even though all education and academic courses, practica, and field activities contribute skills, knowledge, and to prospective teachers, pre-service teaching provides the opportunity to experience the rewards and challenges of assuming the instructional and professional responsibilities of a full-time teacher (Shirley, 2011).

Preservice teacher education is the course that is offered to students before the students join teaching profession and it leads to a degree and certification in order to make a person eligible to join teaching profession (Cote, 2007; Wehmeyer & Schwartz, 1998; Shirley, 2011).

Problem Solving: "Problem solving has been defined as a task, activity, or situation in which the answer is not easily discernible or attainable" (Wehmeyer & Schwartz, 1998). "Problem solving, as a learning strategy, teaches a learner to independently solve a problem while drawing on memory. The learner selects from a variety of responses and then follows through with the correct response" (Charney, Reder, & Kusbit, 1990). "When learners are introduced to problems, they make correct choices based on recall of similar situations and correct choices" (Cote, 2007).

Strong: is defined as "well established" or FIRM (Merriam-Webster Incorporated, n.d.); or Firmly held or firmly established (Oxford University Press, n.d.).

CHAPTER 2

LITERATURE REVIEW

Inquiry-Based Learning Strategies, POE, and 5E

Computer simulations have been shown to be effective for teaching science concepts, but computer simulations alone do not fully teach. Therefore, computer simulations must be paired up with effective teaching methods, such as inquiry-based teaching strategies, so that the 2-Sigma effect can take place and in order for science concepts to be taught in the most effective and efficient way. It has been shown that computer simulations combined with various inquiry-based teaching strategies have been effective for teaching various science concepts.

The POE (or Predict, Observe, and Explain) teaching strategy and the 5E (or Engage, Explore, Explain, Elaborate, and Evaluate) learning cycle are both inquiry-based teaching strategies that have both been shown to be effective for teaching science concepts; and they have both been shown to be highly effective when each of them were combined with computer simulations in order to teach science concepts. The two inquiry strategies of POE and 5E were chosen for this study because both were created in order to teach science; and both have been shown to be effective for teaching science; and were shown to be effective when combined with simulation to teach science. But each of the different inquiry-based teaching strategies have disadvantages for teaching science concepts.

Therefore, it is important to determine which is the best inquiry-based teaching strategy to use when an inquiry-based teaching strategy is combined with computer simulations in order to most effectively and efficiently teach science concepts.

In this current study, the two effective inquiry-based teaching strategies of POE and 5E were each combined with computer simulation in order to teach the science topic of density to pre-service teachers, and these two combinations were compared. It is important to compare the different effective inquiry-based teaching strategies when each are combined with computer simulation to teach specific science concepts in order to determine the most effective inquiry and simulation teaching strategy combination when teaching specific science concepts.

History and Characteristics of Inquiry-Based Learning

Both POE and 5E are inquiry-based learning techniques. Inquiry-based learning is mostly a pedagogical (or it relates to teaching) method, and it was developed in the 1960s during the movement involving discovery learning, and this was in a response to traditional ways of teaching and learning, which included rote learning, direct instruction, and where learners had to memorize information from instructional materials (Bruner, 1961) In terms of the characteristics of learning processes in inquiry-based learning, learning processes that learners engage in during inquiry-learning include the following: (1). learners creating their own questions; (2). learners obtaining supporting evidence in order to answer these questions; (3). learners explaining the evidence that they collected; (4). learners connecting this explanation to the knowledge that the learners obtained from the investigative process; and (5). learners creating a justification and an argument for the explanation that was obtained by the learners (Bell, Urhahne, Schanze, & Ploetzner, 2010). Inquiry-based learning involves making observations; developing questions; doing research in order to find out what information has been recorded already; developing instruments for data collection; developing methods for experiments; collecting data, analyzing data, and interpreting data; outlining possible explanations; and creating and making predictions for future study (National Institute for Health, 2005).

Science Education and Inquiry-Based Learning

Inquiry learning has been used as a tool for learning and teaching for thousands of years, but inquiry has only briefly been in public education (National Research Council., 2000). In older times, Roman and ancient Greek education philosophies concentrated more on oratory for the wealthy upper-class education and concentrated more on the art of domestic and agricultural skills for the middle class. It was not until during the late 17th and 18th century (or the Age of Reason, or the Enlightenment) that the subject of science was looked at as a respectable academic body of knowledge (Murphy, 2005; National Research Council, 2000).

Up until the 1900s, the study of science in education focused more on organizing and memorizing facts, and it seems that some learners are currently still getting this type of science instruction. Philosopher of education at the beginning of the 1900s, John Dewey, was the first to criticize the fact that science education was not taught in a way in order to develop young scientific thinkers. Dewey said that science should be taught as a process and as a way of thinking, and that it should not just be taught as a subject with facts to be memorized (National Research Council, 2000).

While Dewey was the first to draw attention to this issue, much of the reform within science education followed the efforts and work of Joseph Schwab, who was an educator that proposed that science did not need to be a process for identifying facts and stable truths about the world, but instead science should be a flexible and multi-directional inquiry driven process of learning and thinking. Schwab thought that science being taught in the classroom should closely reflect the work of scientists who were practicing. Schwab made and developed three levels of open inquiry that align with the breakdown of the inquiry processes currently seen today (Schwab, 1962). Here, students are first given questions, methods and materials; and then students are challenged to find out and discover relationships between variables. Students are provided with a question, but, the method for research is up to the students to develop. Phenomena are proposed, but students have to develop their own questions and method for research in order to discover relationships among variables. Today, it is currently known that students at all levels of education can successfully develop and experience deeper level thinking skills through scientific inquiry (National Research Council, 1996). The graduated levels of scientific inquiry outlined by Schwab showed that students need to develop thinking skills and strategies before being exposed to higher levels of inquiry (Schwab, 1962). Effectively, these skills have to be scaffolded (or closely watched and evaluated and "checked on") by the instructor until learners are able to develop questions, methods, and conclusions on their own (Banchi & Bell, 2008).

A start for change within North American science education was the 1957 launch of the Soviet Union satellite Sputnik. This science breakthrough caused a lot of concern around the science and technology education American students were getting. In 1958 the U.S. congress passed the National Defense Education Act in order to give science and math teachers enough and adequate teaching materials (National Institute for Health, 2005). The following list shows the six important aspects for America's National Science Education Standards (NSES), that are pivotal and important to inquiry-based learning in science education: (1). learners need to be able to recognize that science is more than just memorizing facts and knowing facts; (2). learners should be given the opportunity to develop new knowledge that builds on students' prior knowledge and scientific ideas; (3). learners will get and develop new knowledge by restructuring their previous understandings of scientific concepts and (4). by adding new information learned; (5). learning is influenced by learners' social environment whereby they have an opportunity to learn from each other; and (6). learners will take control of their learning (National Research Council, 1996).

Why Compare Inquiry Strategies, and Why POE and 5E?

The POE learning strategy and the 5E learning strategy, as well as other inquiry strategies, have disadvantages. The POE learning strategy is not suitable for all questions and in all situations. For example, "It is not suitable for all topics, for example, topics that are not "hands-on" or in which it is difficult to get immediate results" (Joyce, 2006). Both the POE learning strategy and the 5E learning strategy have been shown to be effective learning strategies for teaching science and when combined with computer simulation to teach science. Therefore, comparing the POE learning strategy and the 5E learning cycle strategy will be done in this study. In this current study, the Predict, Observe, Explain (POE) learning strategy will be combined with computer simulation to teach the topic of density and this will be compared to the use of the 5E learning cycle strategy (Engagement, Exploration, Explanation, Elaboration, and Evaluation) combined with computer simulation to teach the topic of density. This current study involved the combination of computer simulation-based instruction with the POE learning strategy, and comparing this with the combination of computer simulation-based instruction with the 5E learning strategy in order to determine which inquiry-based learning strategy was most effective for computer simulation-based instruction for the science topic of density.

Inquiry-Based Teaching Combined with Computer Simulation Teaching

Many studies have found that inquiry-based teaching strategies combined with computer simulation to teach science was effective. For example, Windschitl, Thompson, and Braaten (2008) showed that inquiry-based computer simulation instruction of a science concept was more effective than instruction using the traditional technique of the scientific method. Winn et al.

(2006) showed that teaching the science concept of oceanography by computer simulation instruction was equally as effective as teaching the concept by direct experience in the actual environment on which the simulation was based. This study showed that computer simulation instruction had benefits, such as the experiments in computer simulation being conducted faster and more easily and results being obtained faster.

In terms of coupling student-centered, inquiry-based learning techniques with computer simulations to provide a powerful, effective, and valuable teaching combination (e.g. Chen & Howard, 2010; Cox et al., 2011; Honey & Hilton, 2011; Latham, & Scully, 2008), many studies found the benefit of this coupling. For example, Zacharia (2005) found that the POE learning strategy combined with computer simulation instruction of a science concept provided a powerful and effective teaching tool and was shown to provide a powerful and useful teaching combination.

In terms of implementing and carrying out computer simulation instruction using inquiry-based teaching strategies in science education, many researchers found many benefits and found this combination to be powerful and effective. Using inquiry-based teaching strategies in computer simulation-based instruction provided an effective and efficient teaching tool (Honey & Hilton, 2011). Previous results for using the Predict, Observe, Explain (POE) learning strategy (or POE learning cycle strategy) with other science education simulations showed powerful results.

Many researchers found many benefits of implementing inquiry-based computer simulation instruction of science concepts. Research in science education has indicated that using computer simulations in teaching was associated with greater learning gains, allowed many students to have positive attitudes towards the computer simulations, and has led to better conceptual understanding. The many studies mentioned so far have shown that the effectiveness of computer simulation-based science instruction has been established. The goal now is how best to implement computer simulation-based science instruction. The following studies investigated inquiry-based computer simulation-based science instruction and other aspects. In a different study, Zacharia (2005) found that combining the POE learning strategy with computer simulation instruction of a science concept provided a powerful and effective and useful teaching tool. Concerning conceptual understanding, many researchers found that computer simulations can allow students to have improved conceptual understanding (Khan, 2011; Zacharia, 2005).

Current Literature Involving the Use of Computer Simulations to Teach Science

Research has shown that using computer simulations to help teach science concepts resulted in learners showing improved understanding of science concepts, learners showing greater gains in learning, and learners showing positive perceptions and attitudes about the computer simulations (Khan, 2011; Zacharia, 2005). Using computer simulations to teach science concepts has been found to be cost effective and take less time (Gonzalez-Cruz, Rodriguez-Sotres, & Rodriguez-Penagos, 2003); and, using computer simulations to teach science concepts has also shown effective education potential (Ash, 2009; Chen & Howard, 2010; Gonzalez-Cruz, Rodriguez-Sotres, & Rodriguez-Penagos, 2003; Khan, 2011; Latham & Scully, 2008; Mohanty & Cantu, 2011; Rands, 2012; Zacharia, 2005).

As for learners showing improved understanding of science concepts from science teaching using computer simulations, many researchers found that using computer simulations to teach science improved learner understanding of science concepts (Khan, 2011; Zacharia, 2005). For example, Khan (2011) showed experimental results after computer simulations were used to help teach chemistry, where the *Generate-Evaluate-Modify* (GEM) teaching pattern was used;

and after three semesters, data involving teacher observations and interviews and student survey data were collected. Computer simulations allowed learners to be engaged in the learning process by letting students manipulate and change variables in many different ways. Learners were engaged in the learning process because the computer simulations allowed learners to carry out processes and observe the changes for these processes that usually are hard or impossible to do within actual laboratory experiments; the computer simulations also allowed leaners to analyze problems critically, and the computer simulations allowed processes that are usually not observable to be more explicit, and the computer simulations contributed more to the learning of science more than what textbooks could do, and overall, the computer simulations increased the concept understanding of the topic of chemistry by the learners.

Zacharia (2005) investigated interactive computer simulations using the *Predict–Observe–Explain* (POE) teaching method along with computer simulations. The participants were science teachers who were postgraduate and who were explaining the physical phenomena involved in the concepts of Thermal Physics, Waves/Optics, and Mechanics. Twelve total topics were covered, and learners were either in the experimental group or in the control group. For each topic, each computer simulation was used two times by each student, and help was given when needed, even though the computer simulations were simple to carry out. For each computer simulation, learners had to determine the variables to keep constant or change before seeing the outcome. Learners were also able to run each computer simulation as many times as they wanted in order to determine that the correct outcome took place. Each learner was interviewed twice (using semi-structured interviews) where each learner explained a certain physical phenomenon in the topics of Thermal Physics, Waves/Optics, and Mechanics. The first interview of the learners happened during the prediction part of POE, and the second interview happened during the explanation part of POE.

The control group only used textbook assignments, while the experimental group used computer simulations. The quality and nature of the resulting science teacher explanations were positively impacted by the POE teaching method along with the use of computer simulations in this learning, and the science teachers were more able to generate explanations that were more scientifically accurate. These explanations were also more elaborate, and this reflected formal reasoning and cause-effect reasoning. On the other hand, using textbook assignments did not give the learners enough support when they were attempting to build up their formal scientific explanations. This study, involving POE+simulation, is related to this current research study.

In looking at learners showing greater gains in learning when computer simulations were used to teach science, results such as more effective gains in learning and higher test scores were found (e.g. Stafford, Goodenough, & Davies, 2010) and more effective learning gains were found (e.g. Ash, 2009; Gonzalez-Cruz, Rodriguez-Sotres, & Rodriguez-Penagos, 2003; Ioannidou et al, 2010; Kiboss, Wekesa, & Ndirangu, 2006). For example, Gonzalez-Cruz, Rodriguez-Sotres, & Rodriguez-Penagos (2003) developed a computer software program that showed and simulated an enzyme assay for the enzyme called lactate dehydrogenase (also called enzsimil) in order to investigate and determine the following: if the computer simulation could be an effective aid for science teaching; whether or not learners could use the computer simulation program without being guided or without having help; and how much help a tutor could be during science learning while using a computer simulation. This study is also related to this current study. The learners in this study were undergraduates in a biochemistry course, and there were five total groups studied. The first three groups involved participants who actually worked with the computer simulation program, and these participants had to follow scripts. In these scripts, participants had to follow the following levels of instruction: detailed instruction on the guided scripts was followed by the guided group; intermediate instruction on the semiguided scripts was followed by the semiguided group; and minimal instruction on the unguided scripts was followed by the unguided group. The class group (or the fourth group being studied) and the guided group had the exact same script, but the class group solved the script with help from a tutor in a classroom and did not have access to the computer simulation program. The fifth group, the control group, did not have access to the computer simulation program, and they did not do enzyme kinetics exercises in the classroom, and they had no additional sessions.

In describing the scripts in more detail: for the guided group, participants were given a printed document (or a script) containing full detailed instructions about how to make an enzyme assay in the computer simulation program (also called section 1 of the script), and about how to perform the experiments, and participants were given values for the parameters to be used in those experiments. Closed questions were also included that required participants to analyze their results and asked them to reach conclusions after they were given a set of conditions. For the semiguided group, the script had minimal instructions about how to make an enzyme assay in the computer program, and participants had to choose the range of values for the same parameters that were studied in the guided script. The script also included some general questions to encourage students to analyze their results, and this allowed the students to make mistakes in the experiments and to discuss what they thought was relevant to the study. For the unguided group the script included only section 1 of the guided group script and a list of the parameters to be investigated, and after a week of working things out for themselves, participants wrote a typical laboratory report.

After their respective sessions, the participants either wrote a report or completed their script and undertook a laboratory practical. At the end, an exam was applied to all participants. The reports and exams were graded, and the performance of the experimental groups was analyzed by statistics. Overall, the guided group and semiguided group showed better performance results in exams and reports, indicating that the computer simulation program was effective, and the semiguided group and the unguided group did equally well to each other. The class group and the control group showed poorer performance than the other groups in both the scripts and on the exam. Even though the class group and unguided group showed similar performance, the unguided group did better than the class group. Overall, learners got many learning benefits from the computer program that contained the enzyme assay simulation during science concept learning.

In the study carried out by Ioannidou et al (2010), the researchers made a computer program called *Mr. Vetro Collective Simulation*, which is an infrastructure and an inquiry-based body systems module where social learning is combined in this computer program. Here, computers were connected wirelessly and students and teachers were engaged in the role-playing process at the same time, where on each computer, each group controlled certain physiology variables of one organ. All of the data were then gathered on a center simulation and the composite view of the body organs of the human was projected. The different teams that were in charge of a particular organ worked together to adjust the different parameters in each organ in order to get to homeostasis, which is a point where the body gets to stable equilibrium, and this equilibrium is reached by the many different physiology processes that take place in the body. Next, the learners took pretests and posttests. The following results were obtained: more effective gains in learning for all groups resulted from collaborative computer simulation learning. Student attitudes towards science were neither negatively nor positively effected; also, a positive impact on science inquiry, a positive impact on learning by the students, and a positive impact on interests in issues involving personal health by the students were all shown by the formal evaluation results.

In the study involving Kiboss, Wekesa, and Ndirangu (2006), the researchers made a computer program called a CBIS, or computer-based instruction simulation, and they used it to see how effective it could be at increasing the perception and understanding of the cell division process among students learning biology at the secondary level. Experimental and control group posttest and pretest data showed that the computer-based instruction simulation program (CBIS) resulted in greater perception and large gains in learning of the science concept of cell division.

In the study involving Trey and Khan (2008), the researchers looked at if a computer simulation that used an analogy that was dynamic to represent the unobservable and abstract process of Le Chatelier's Principle could effect learner achievement by learners, and the learners here were 12th grade students learning chemistry. Here, the control group only interacted with the concept using pictures and texts, while the experimental group interacted with the concept using a computer simulation that represented the unobservable and abstract science concept of Le Chatelier's Principle. Concept test results showed the following: the experimental group average test score was greater than the average test score for the control group; and a more effective effect on outcomes in learning were shown by interactive and dynamic analogues that were part of the computer simulation as opposed to analogies represented in the form of static and still pictures and texts.

Latham and Scully (2008) looked at the extent that a computer simulation program called *Critters* approximated the gene and/or environment interactions and the genetic system of real and actual populations. Here, many variables could be looked at in order to determine if the mechanisms in evolution were working during a computer simulation (such as mutations, genetic drift, non-random mating, and natural selection, which were all candidates for evolution mechanisms for learners to study). This program also let learners see the effects after interactions between processes like selection and mutation. Here, in a virtual world, digital organisms were first born, and then the organisms got to acquire resources and grow, and then the organisms mate and reproduce, and then the organisms eventually die. After learners run the model and see screen shots of an organism in the model, learners choose to test of the traits that may be influenced by a mechanism in evolution, and then learners construct and carry out experiment design to address the hypotheses that the learners had. The following results were obtained: the computer simulation program *Critters* let learners change and manipulate many different parameters and allowed learners the opportunity for learning that was inquiry-based (because learners could then predict the outcome before manipulating a parameter, and learners could also test their expectations using the data generated by the simulation); the computer simulation showed the most effect when leaners worked in groups and discussed analysis and planning at each exercise step.

In terms of perceptions, many researchers found that learners had positive perceptions for the computer simulations (Chen & Howard, 2010; Cox et al, 2011; Kiboss, Ndirangu, & Wekesa, 2004; Kiboss, Wekesa, & Ndirangu, 2006). For example, Chen and Howard (2010) wanted to find out what factors would be needed for an earth science simulation experience to be successful for 311 middle school students and seven teachers of middle schools from the four different states of West Virginia, Ohio, New York, and Pennsylvania. Learners had to use real and actual hurricane data and real volcano data to simulate these events again. Next, the TORSA (or Test of Scientific-related Attitudes, which was used to measure middle school students' attitudes toward science) was given, and a posttest was given after learners were exposed to the computer simulation; and a pretest was given before learners interacted with the computer simulation. The following results were obtained: positive attitudes and positive perceptions towards science and improved understanding were all shown by the middle school students; also, student attitude understanding were mostly influence by teachers because of the strategy in teaching used and because of the quality of the preparation by the teachers.

Kiboss, Ndirangu, and Wekesa (2004) looked at how effective a CMS instruction program, or a computer-mediated simulations instruction program, would be for improving outcomes in learning of lessons in cell theory for learners in secondary school. There was a control group and an experimental group, and the experimental group learned using the computer-mediated simulations instruction program, while the control group did not learn using the computer-mediated simulations instruction program. The following tests were given to all students in order to determine how effective the program was on achievement in academics in regards to environment perceptions by students in the classroom, attitudes of students, and cell theory: the Biology Achievement Test (BAT), the Biology Classroom Environment Questionnaire (BCEQ), and the Pupil Attitude Questionnaire (PAQ). The following results were obtained: experimental group learners showed higher mean gains than regular program learners: no relationship between learning outcomes and gender were shown: and the computer-mediated simulations instruction program improved learner performance and knowledge and improved learner attitudes and perceptions for the science concept studied.

Gaps Present Within the Current Body of Research and Literature

Both POE and 5E inquiry-based teaching methods have disadvantages, and so it is best to determine which of the two is most effective to teach different science concepts when the inquiry-based teaching strategy is paired-up, or combined, with simulation. Both POE and 5E are problem-based (PBL) learning (PBL) techniques; and some of the disadvantages of PBL include: potentially poorer performance on the tests, learner unpreparedness, instructor unpreparedness, time-consuming assessment, and varying degrees of relevancy and applicability (Guido, 2016). Disadvantages of the POE inquiry method include: for primary school students, writing the answer can be a barrier to useful communication of ideas; younger primary students may have difficulty explaining their reasoning; it is not suitable for all topics; and some researchers say that students are more likely to learn from observations that confirm their predictions (Joyce, 2006). Disadvantages of 5E included: limited interactions with the students affected the dynamics of the research setting regarding student behavior and continuity of instruction, and the amount of time spent on science instruction greatly differed from the time spent on other subjects (Campbell, 2006)

Literature has shown that there are many benefits to using computer simulations to teach science and science concepts, but there are also many deficiencies that have been pointed out as well, and these deficiencies are included in the following list: the contexts where the computer simulation teaching of science takes place, how effective computer simulations are for teaching science, how individual learners react to computer simulation features when computer simulations are used to help teach science, and the research designs used to investigate the use of computer simulations in teaching science concepts.

In terms of research designs, for many studies, mixed results were obtained after both experimental groups and control groups were used. For example, Stafford, Goodenough and Davies (2010) found that some students did well on the test after being exposed to the computer simulation and others only did well after the lecture. The effectiveness of using computer simulations for teaching science has been determined by some researchers (Akpan, 2001; Honey & Hilton, 2011; Ioannidou et al, 2010). For example, Ioannidou et al (2010) determined and found that learner attitudes toward the computer simulation after exposure to the computer simulation during science teaching were neither negative nor positive. Also, Honey and Hilton (2011) said that the current body of research involving computer simulation use for teaching science is not effective and has many gaps and weaknesses since it is difficult to measure the effectiveness of computer simulations in teaching science. To fix this problem, Honey and Hilton (2011) said that this can be fixed and rectified by many different researchers studying and reporting research data involving many different computer simulations to teach many different science topics while changes and innovations of the computer simulations are taking place, and they said that researchers need to allow evidence from ongoing and past research to build up and accumulate for many different computer simulations.

This current research study is responding to this call with the investigation of the use of a density computer simulation to teach the science topic of density. Also, this current study will investigate how to most efficiently and to most effectively deliver computer simulation-based instruction by comparing different inquiry-based learning methods or strategies used in computer simulation-based instruction, and this should add to the building-up body of research on computer simulation-based instruction in science education. The focus here is on how to most efficiently and effectively deliver computer simulation-based instruction.

In terms of ways that students respond to computer simulations, many authors have suggested that different individual learners and different groups of learners respond differently to computer simulation features (e.g. Akpan, 2001; Honey & Hilton, 2011). Some researchers such as Akpan (2001) suggested that different types of learners should be studied when carrying out computer simulation science learning. In answering this call, this current research study will involve pre-service teachers as participants who are studying the topic of density and using a density computer simulation to learn the science topic of density. This should add to the current body of research involving the use of computer simulations to teach science concepts. In this current study, the participants are pre-service teachers, and this data should add to the computer simulation science teaching body of research.

In terms of the features of the research designs used to investigate computer simulation use for teaching science concepts, several researchers (such as Honey & Hilton, 2011) said that research involving the use of computer simulations to help teach science should be improved and made better by clearly listing and pointing out the outcomes from learning that the researchers want, which should include research design features that are hypothesized and that activate learning. Honey and Hilton (2011) also said that researchers should specify and point out participant learning outcomes that resulted from participant learners interacting directly with the computer simulation.

In looking at design features, many researchers (such as Honey & Hilton, 2011) indicated that science education involving computer simulation should be improved by clearly pointing out the learning outcomes that are desired, including hypothesized design features that activate learning; and specifying student learning outcomes resulting from direct interaction with the computer simulation. So, many researchers indicated that research should improve the understanding of how computer simulations "can best motivate learners, engage them in active investigations, and build understanding of science processes as well as concepts" (Honey & Hilton, 2011, p. 121). Also, when using computer simulations to teach science, the context that the computer simulation is used in can effectively shape how participants learn science concepts and it can significantly shape if learning actually took place, so whether and how learners learn science can be effectively shaped by the context where computer simulation teaching is used. Windschitl, Thompson, and Braaten (2008) mentioned that strategies and models and computer simulations should be used as tools to help learners generate knowledge about a topic or concept instead of being used as end products of inquiry, which researchers seem to do.

In addition, some researchers (e.g. Justi & Gilbert, 2002) said that many teachers do not realize how valuable computer simulations and models are for teaching science concepts, and when these teachers use these strategies, the teachers do not effectively engage the participant learners. In terms of the context where computer simulations are used to teach science, some researchers said that computer simulations should be introduced to participant learners before a concept is formally instructed as opposed to exposing participant learners to the computer simulation after instruction of a science concept, because this should let participant learners generate knowledge better about the concept.

This Current Study: Comparing POE+Simulation and 5E+Simulation

In this current study, the effective and established teaching strategies of computer simulation and POE were combined and then compared to the combination of the two effective and established teaching strategies of computer simulation and 5E for teaching of the science education topic of density. It has been established that computer simulation instruction of science concepts is effective, and it has been established that combining inquiry-based methods with computer simulation instruction provides a powerful and effective tool for teaching science concepts. The goal now is to determine how best to implement inquiry-based computer simulation instruction of specific science concepts. In this study, the two effective and established teaching strategies of computer simulation and POE are combined and then compared to the combination of the two effective and established teaching strategies of computer simulation and 5E for teaching the science education topic of density. It has been suggested that there is a need for science teachers and educators to involve pre-service and in-service teachers to construct and use computer simulations in their inquiry practices so that they can see the potential of simulations in terms of helping the educators, and later their students, generate knowledge as they interact with the simulation. This current study will involve pre-service teachers as participants, and this should add to the significance of this study. Other researchers suggested that using simulations along with the application of a certain learning cycle strategies such as the Predict-Observe-Explain (POE) can provide the interactive learning needed to increase understanding (Joyce, 2006; Zacharia, 2005); so the learning cycle strategies of POE and 5E should help improve computer simulation-based teaching. Research involving computer simulation and 5E for teaching science, or the 5E teaching model integrated with computer simulation, had potential to help eleventh grade participants improve their physics academic achievement and attitude, and resulted in participants showing a potential to improve their physics academic achievement and attitude (Sarıa et al., 2017).

The science topic of density was studied in this current study. Honey and Hilton (2011) argued that presenting the simulation in a personally meaningful scientific context would allow students to draw on what they already know, ask more effective questions, and recognize unlikely findings. Therefore, the topic of density and the density computer simulation used here should provide for this.

The two effective inquiry strategies of POE and 5E have been shown to be effective for teaching science, and the POE and 5E teaching strategies have been shown in research to be effective teaching strategies when used with computer simulation for teaching science concepts.

It has also been shown that inquiry combined with simulation to teach science has been effective. But it is crucial to determine which inquiry strategy is best to use when combined with simulation in order to bring about the most effective teaching strategy to teach specific science concepts. So, it is important to determine the most effective teaching strategy to use when combining inquiry with simulation to teach specific science concepts.

Also, it is important to compare the two effective teaching strategies of POE and 5E when both are combined with computer simulation in order to determine the most effective combination when the inquiry teaching strategy is combined with computer simulation. Therefore, in this current research, the two effective and established teaching strategies of computer simulation and POE were combined and then compared to the combination of the two effective and established teaching strategies of computer simulation and 5E in teaching of the science topic of density. So, it was important to determine which inquiry-based teaching strategy is best to use with computer simulation to most effectively teach specific science concepts when inquiry and simulation are combined to teach science.

CHAPTER 3

METHODOLOGY

The research methodology of this study is presented in this chapter. First, the purpose of this study and the research questions of this study are revisited and discussed. Next, the research design is discussed along with research methods and the variable of this study. Next, the participants and the context of this study are discussed. Next, the validity and reliability of instruments of this study are discussed. Finally, the analysis of the data is discussed.

Purpose of This Study

This study had two purposes. The first purpose of this study was to compare the learning effectiveness of the two effective and established inquiry-based teaching strategies of POE (or the Predict-Observe-Explain (POE) learning cycle strategy) and 5E (or the Engagement, Exploration, Explanation, Elaboration, and Evaluation (5E) learning cycle strategy) for implementing computer simulation-based instruction. The second purpose of this study was to compare participants' attitudes of the computer simulation used based on which inquiry-based strategy was used.

Research Questions

The following four research questions guided this study and were answered in this study:

1. Is there a difference in the total amount of time, as measured by the times that each participant started and finished (or completed) the activity worksheets, between pre-service teacher participants who used the density simulation with POE and those who used the density simulation with 5E?

2. Is there a difference in content knowledge, as measured by forced-choice test, between pre-service teachers who used a density simulation with POE and

those who used the density simulation with 5E?

3. Is there a difference in problem solving skills, as measured by forced-choice test, between pre-service teachers who used a density simulation with POE and those who used the density simulation with 5E?

4. Is there a difference in attitude toward science, as measured by survey questions, between pre-service teachers who used a density simulation with POE and those who used the density simulation with 5E?

Research Design, Research Methods, and Variable of This Study

Research Design

Quantitative and qualitative data were collected in this study, and therefore, this study involved mixed methods data collection. The instruments for this study were a pre-test and post-test which were adapted from the Ed informatics site (http://www.edinformatics.com/math_science/mvd_quiz.htm) (Appendix A & B). In addition, an activity worksheet for the POE learning strategy (Appendix C) and an activity worksheet for the 5E learning strategy (Appendix D) was administered to the participants. Finally, a survey instrument that contained the Likert Scale survey and open-coding survey questions (Appendix E) and was adapted from an instrument created by Glynn & Koballa (2006) was administered to the students.

The quantitative pre-test/post-test change scores, and activity worksheet data were analyzed using t-test analysis. Data analysis to see if there were significant differences between responses of the two treatment groups (POE or 5E) on the overall attitude questionnaire and on specific items in the attitude questionnaire was carried out on Likert scale data. Qualitative attitude questionnaire questions were analyzed using open-coding data analysis.

In this study, the POE learning cycle strategy was used along with computer simulation to teach the science concept of density, and this was compared with the 5E learning strategy that was used along with computer simulation to teach the science concept of density. This study had two treatment groups, which were the POE group and the 5E group. In six different classes containing pre-service teacher participants, there were a total of 67 participants in this study, where the POE treatment group contained 34 participants and the 5E treatment group contained 33 participants. The different classes were different science courses for different levels of students, therefore, there was a need to randomly assign within classes instead of assigning in-tact classes in a quasi-experimental fashion. In each of the six different classes, random samples were used, where each student was randomly assigned to either the POE treatment group (which had 34 participants) or the 5E treatment group (which had 33 participants).

All participants first took a pre-test on the topic of density in order to compare whether or not the POE and 5E treatment groups differed significantly in content knowledge before the instructional interventions, in order to make sure that the two treatment groups were equivalent in pre-existing content knowledge and problem-solving skill. Next, all participants completed a computer simulation activity worksheet, either a POE or 5E version, while participants interacted with the density computer simulation. For each class, one-half of students completed Version A of the activity worksheet (which involved the density computer simulation and the POE learning strategy), and the other half of students completed Version B of the activity worksheet (which involved the density computer simulation and the 5E learning strategy).

Research Methods

Participants were randomly assigned to either the POE treatment group or the 5E treatment group. After taking the pre-test, participants then completed the computer simulation activity worksheet (either for POE or 5E) while interacting with the density computer simulation located on the internet website of https://www.explorelearning.com/. (Gizmos, 2019). Participants used the scale located within the computer simulation to weigh each of the various items and record the weight of each item. Next, participants placed each item into a graduated cylinder that was filled with a known amount of liquid in order to determine the volume of each item. Next, participants indicated on their worksheet whether each object floated or sank in water that was in a beaker in the density computer simulation. Participants then used the weight and the volume obtained from the computer simulation to calculate the density of each item. Participants then answered the activity worksheet questions that followed, based on the data collected and based on the calculations carried out. All participants then completed the post-test. Finally, all participants answered Likert Scale survey questions and open-ended survey questions that were located in the survey instrument.

Variables of This Study

In an experiment, the two main variables are the dependent variable and the independent variable. A dependent variable is the variable being tested and measured in a scientific experiment. The independent variable is a variable that is controlled or changed in a scientific experiment in order to test the effects on the dependent variable. The independent variable is a variable believed to affect a dependent variable, and this is the variable that a researcher will manipulate and change to see if it makes a dependent variable change. A dependent variable is dependent on the independent variable. As a researcher changes the independent variable, the effect on the dependent variable is observed and recorded. So, the independent variable and the dependent variable may be viewed in terms of cause and effect. If an independent variable is changed, then an effect is seen in the dependent variable. The values of both independent variable and the dependent variable may change in an experiment and are recorded. The difference is that the value of the independent variable is controlled by the researcher, while the value of the dependent variable only changes in response to the independent variable. Overall, the dependent variable is the variable a researcher is interested in, and an independent variable is the variable believed to affect the dependent variable. This is the variable that the researcher, will change and manipulate to see if it makes the dependent variable change (Merriam-Webster Incorporated, n.d.). So the dependent variables of this current study include comparing the following: comparing the time to complete POE activity worksheet and 5E activity worksheet, comparing the posttest scores, comparing the posttest minus pretest change scores between the POE group and the 5E group, comparing the POE activity worksheet scores versus the 5E activity worksheet scores, and comparing the Likert scale survey question scores between the POE group and the 5E group.

The Participants and the Context of This Study

In this study, there were a total of 67 pre-service teacher participants (in a total of 6 different classes) who were randomly assigned to either the POE (34 participants) treatment group or the 5E (33 participants) treatment group. The participants attended a Midwestern University located in USA and were enrolled in advanced methods science classes. The participants should have all taken the necessary science integrated classes that covered the science concepts of physical science and life science. In looking at the participant demographic information, of the 67 total participants in the POE and 5E research groups, 60 of the participants were female, and 7 of the participants were male.

Validity and Reliability of Instruments

Assessing validity and the reliability of a research instrument used during an education research study provides important analytics that are used to understand threats and estimate errors that may occur during measurement procedures. Validity is concerned with the accuracy of the research results, and reliability refers to whether or not the same results are obtained every time a test is given (Fraenkel & Wallen, 2009). Alternatively, validity is the extent to which a measurement, a conclusion, or a concept is well-founded and likely corresponds accurately to the real world. The word valid is derived from the Latin word of validus, which means strong; and so, validity is based on the strength of a collection of different types of evidence and data. (Brains, Willnat, Manheim, & Rich, 2011).

In looking at the validity for this study, overall, the validation of the all of the test items in all of the instruments used in this research study (which included the pretest, the posttest, the POE activity worksheet, the 5E activity worksheet, the Likert Scale survey questions, and the open-ended survey questions) was done by two university educators. In this research study, all participants first took a pre-test on the topic of density in order to compare whether or not the POE and 5E treatment groups differed significantly in content knowledge before the instructional interventions, in order to make sure that the two treatment groups were equivalent in pre-existing content knowledge and problem-solving skill. For the pretest and the posttest, which were adapted from the Ed informatics site (http://www.edinformatics.com/math_science/mvd_quiz.htm) (Appendix A & B), once the density questions were added, one STEM science education university researcher and one university researcher looked over and validated the density pretest and posttest questions. Therefore, the validation of all 9 items in the pretest and all 9 items in the posttest was done by two was done by two university educators. For the POE activity worksheet and the 5E activity worksheet, one STEM science education, university researcher and one university researcher looked over and validated the density questions in the POE activity worksheet and the 5E activity worksheet. For the survey questions (the four Likert Scale survey questions and the five open-ended survey questions), once the survey questions involving density were added, one STEM science education university researcher and one university researcher looked over and validated the survey questions.

In this research study, all participants first took a pre-test on the topic of density in order to compare whether or not the POE and 5E treatment groups differed significantly in content knowledge before the instructional interventions, in order to make sure that the two treatment groups were equivalent in pre-existing content knowledge and problem-solving skill.

In this experiment, the Cronbach’s alpha value was used to determine the reliability of the pretest, the posttest, and the Likert Scale Survey questions. According to Gliem and Gliem (2003), the reliability coefficient for Cronbach’s alpha usually ranges between 0 and 1, even though there really is no actual lower limit to the coefficient; and the closer that the Cronbach’s alpha coefficient is to 1.0, then there is a greater internal consistency of the items in the scale, meaning that more of the items in the instrument are related to each other.

According to Tavakol, M., & Dennick, R. (2011), if test items are correlated to each other, then the Cronbach's alpha value is increased, but a high Cronbach's alpha value does not always mean that there is a high degree of internal consistency. This is because the Cronbach's alpha value is also affected by how long the test is. If the test is too short, then the Cronbach's alpha value is lowered, or decreased. Therefore, in order to increase the Cronbach's alpha value, more items that are related to each other and that are testing the same concept should be added to the test. The Cronbach's alpha value is a property of the scores from a specific sample of testees. So, investigators should not rely on published Cronbach's alpha values and estimates; and investigators should measure the Cronbach's alpha value each and every time a test is given, or administered (Tavakol & Dennick, 2011).

Next, all participants completed a computer simulation activity worksheet, either a POE or 5E version, while participants interacted with the density computer simulation. For each class, one-half of students completed Version A of the activity worksheet (which involved the density computer simulation and the POE learning strategy), and the other half of students completed Version B of the activity worksheet (which involved the density computer simulation and the 5E learning strategy). Also, the purpose of adding the few open-ended questions to the POE activity worksheet and the 5E activity worksheet was to collect responses that could help clarify or explain the quantitative data results.

The Cronbach's alpha value was used to determine the reliability of the pretest and the posttest, and these were determined to be the following: the reliability of the pretest was determined to be (Cronbach's alpha value = 0.694), and the reliability of the posttest was determined to be (Cronbach's alpha value = 0.572). This is shown in Table 1.

Table 1

Cronbach's alpha Values for Instruments Used in this Study

Instrument	Cronbach's alpha Value	Mean (M) (Average Score for the Instrument)
Pretest (*n* = 87, for 9 Items)	0.694	6.79 (Out of 9 Total)
Posttest (*n* = 87, for 9 Items)	0.572	7.80 (Out of 9 Total)
Likert Scale Survey (*n* = 67, for 4 Items)	0.930	17.49 (Out of 20 Total)

While filling out the computer simulation activity worksheet, participants interacted with the computer simulation online, experimenting and learning about different aspects of density using the computer simulation. All participants then answered post-test questions to test participants' content knowledge and problem-solving skill for the POE or 5E after instructional interventions.

For the pretest, the 67 total participant scores plus the 20 control group participant scores (for an *n* = 87 total) were used to calculate the Cronbach's alpha value for the nine pretest questions. For the posttest, the 67 total participant scores plus the 20 control group participant scores (for an *n* = 87 total) were used to calculate the Cronbach's alpha value for the nine posttest questions. For the four Likert Scale survey questions, the 67 total participant scores (for an *n* =

67 total) were used to calculate the Cronbach's alpha value. These reliability values are all shown in Table 1.

Finally, all participants answered survey questions (open-ended survey questions and Likert scale survey questions which were adapted from an instrument created by Glynn & Koballa, 2006). In this survey questions instrument, participants indicated their attitudes about science and their attitudes about the computer simulation after using it either with POE or 5E. The purpose of adding the qualitative open-ended survey questions (survey questions 5 - 9) to the survey questions instrument was to collect responses that could help explain or clarify the quantitative, Likert scale survey questions (survey questions 1 - 4). The Cronbach's alpha reliability value for the Likert Scale survey questions indicate that it is reliable in its internal consistency (Cronbach's alpha value = 0.93), as shown in Table 1.

So overall, in this research study, Cronbach's alpha (α) values were used to calculate and represent the reliability of all of the quantitative data research instruments (the pretest, the posttest, and Likert Scale Survey values), as shown in Table 1. All three quantitative data instruments used in this study (the pretest, the posttest, and the Likert Scale survey questions) had Cronbach's alpha values that were in the acceptable range. According to George and Mallery (2003), any Cronbach's alpha value below the value of 0.5 is considered to be unacceptable; and any Cronbach's alpha value above 0.5 is considered to be in the acceptable range.

Analysis of Data

Analysis of Pretest, Posttest, and Activity Worksheets Quantitative Data

The t-test (t) (or the individual samples t-test) was used to compare the two mean scores between the simulation+POE treatment group and the simulation+5E treatment group for the pre-test. The t-test (or the individual samples t-test) was used to compare the two mean scores between the simulation+POE treatment group and the simulation+5E treatment group for the post-test. Also, the t-test (or the paired samples t-test) was used to compare the two mean scores for the pre-test and the post-test for the control group. The t-test (or the paired samples t-test) was also used to compare the two mean scores for the pre-test and post-test for the simulation+POE treatment group and for the simulation+5E treatment group. The t-test (or the individual samples t-test) was used to compare the pre-test/post-test average change for the simulation+POE treatment group and the simulation+5E treatment group. Finally, the t-test (or the individual samples t-test) was used to compare the two mean scores between the simulation+POE treatment group and the simulation+5E treatment group for the POE worksheet and the 5E worksheet.

Analysis of Likert Scale Quantitative Data

Likert scale questions were analyzed to determine participants' attitude about the computer simulation and teaching method combination after using it and participant attitudes about science. This showed whether there were significant differences between responses of the two treatment groups (POE and 5E) on the overall Likert Scale survey questions and on specific items located in the Likert Scale survey questions.

Analysis of Open-ended Qualitative Data

Open Coding was used to analyze the open-ended survey questions to determine themes that were held by research participants. Participants' attitudes about the computer simulation and teaching method (POE or 5E) combination after participants had interacted with and used them were analyzed. Additional details (and/or discussion) of how the quantitative data was analyzed will be presented in the results section of Chapter 4.

CHAPTER 4

RESULTS

Purpose and Research Questions for This Study

This study had two purposes. The first purpose of this study was to compare the learning effectiveness of the two effective and established inquiry-based teaching strategies of POE [or the Predict-Observe-Explain (POE) learning cycle strategy] and 5E [or the Engagement, Exploration, Explanation, Elaboration, and Evaluation (5E) learning cycle strategy] for implementing computer simulation-based instruction. The second purpose of this study was to compare participants' attitudes of the computer simulation.

The following research questions were answered in this chapter:

1. Is there a difference in the total amount of time, as measured by the times that each participant started and finished (or completed) the activity worksheets, between pre-service teacher participants who used the density simulation with POE and those who used the density simulation with 5E?

2. Is there a difference in content knowledge, as measured by forced-choice test, between pre-service teachers who used a density simulation with POE and those who used the density simulation with 5E?

3. Is there a difference in problem solving skills, as measured by forced-choice test, between pre-service teachers who used a density simulation with POE and those who used the density simulation with 5E?

4. Is there a difference in attitude toward science, as measured by survey questions, between pre-service teachers who used a density simulation with POE and those who used the density simulation with 5E?

This chapter represents the results of the analyses of the quantitative and qualitative measures that address the research questions. Quantitative tests were performed using SPSS, and qualitative analyses included open coding.

Results for Research Questions

Research Question 1

Research question 1 asks: "Is there a difference in the total amount of time, as measured by the times that each participant started and finished (or completed) the activity worksheets, between pre-service teacher participants who used the density simulation with POE and those who used the density simulation with 5E?" Table 2 compares the average times that participants in each treatment group completed the activity worksheets, where the independent samples T-*test* was used to compare these times. The POE treatment group average time to complete the POE activity worksheet was 38.12 minutes, and the 5E treatment group average time to complete the 5E activity worksheet was 41.09 minutes. The p-value was greater than 0.05 (or $p = 0.15$), and this indicates that there was no significant statistical difference between the POE treatment groups' average time to complete the activity worksheet and the 5E treatment groups' average time to complete the activity worksheet.

Table 2

Compare Times for POE and 5E to Complete Activity Worksheets

Group	*Mean (M) for Time Taken to Complete Worksheets (Minutes)	*Standard Deviation (SD)
*POE (N=34)	38.12	5.00
*5E (N=33)	41.09	5.03

*Mean Difference (Minutes, POE Time Minus 5E Time) = -2.97
*p-value (p, Independent Samples T-Test) = 0.70
*t-value (t) = -2.42
*degrees of freedom (*df*) = 65

Research Question 2

Research question 2 asks: "Is there a difference in content knowledge, as measured by forced-choice test, between pre-service teachers who used a density simulation with POE and those who used the density simulation with 5E?" Table 3 compares the average pretest scores for knowledge of density between the POE treatment group with the average pretest scores for the 5E treatment group, where the independent samples T-*test* was used to compare these scores. The POE average pretest score was 7.09, and the 5E average pretest score was 6.94. The p value was greater than 0.05, or $p = 0.29$, indicating that there was no significant statistical difference between the POE groups' average pretest score and the 5E groups' average pretest score. In summary, the average pretest scores between these two treatment groups were statistically the same, and this also indicates that both treatment groups started at the same level, and there was "no difference" in pre-existing knowledge of density between the two treatment groups.

Table 3

Compare Pretest Scores for POE and 5E

Group	*Pretest Mean (M) (Average Scores out of 9 Total Points on the Pretest)	*Standard Deviation (SD)
*POE (N=34)	7.09	1.40
*5E (N=33)	6.94	1.20

*Mean Difference (Minutes, POE Time Minus 5E Time) = 0.15
**p*-value (*p*, Independent Samples T-Test) = 0.29
**t*-value (*t*) = 0.47
*degrees of freedom (*df*) = 65

Table 4 compares the average posttest scores for the POE treatment group with the average posttest scores for the 5E treatment group, where the independent samples T-*test* was used to compare these scores. The POE average posttest score was 8.26 and the 5E average posttest score was 8.03. The *p* value was 0.99, greater than 0.05, and there was no significant statistical difference between the POE groups' average posttest score and the 5E groups' average posttest score.

Table 4

Compare Average Posttest Scores for POE and 5E

Group	*Posttest Mean (M) (Average Scores Out of 9 Total Points on the Posttest)	*Standard Deviation (SD)
*POE (N=34)	8.26	0.79
*5E (N=33)	8.03	0.89

*Mean Difference (Minutes, POE Time Minus 5E Time) = 0.23
**p*-value (*p*, Independent Samples T-Test) = 0.99
**t*-value (*t*) = -1.15
*degrees of freedom (*df*) = 65

Table 5 shows control group data, where 20 participants only took the pretest and the posttest, but they did not participate in any of the treatment groups. The average score for the pretest was 6.05. The average score for the posttest was 6.55. The *p* value was greater than 0.05, or $p = 0.26$, indicating that there was no significant statistical difference between the pretest average score and the posttest average score.

Table 5

Data Comparing Pretest Scores and Posttest Scores for the Control Group

Test	* Mean (M) (Average for the Control Group, N=20)	*Standard Deviation (SD)
*Pretest	6.05	1.61
*Posttest	6.55	1.10

*Mean Difference (Minutes, POE Time Minus 5E Time) = 0.50
*p-value (p, Independent Samples T-Test) = 0.06
*t-value (t) = 2.03
*degrees of freedom (df) = 19

Table 6 compares the average pretest scores with the average posttest scores for the POE treatment group, where the paired samples T-*test* was used to compare these scores. The difference between the pretest mean and the posttest mean was 1.17 points, and the *p* value was 0.00, less than 0.05, and there is significant statistical difference between the POE groups' average pretest score and average posttest score.

Table 6

Change Score from Pretest to Posttest for POE

Test	* Mean (M) (Average Score for POE) (# of POE participants, N=34)	*Standard Deviation (SD)
*Pretest	7.09	1.40
*Posttest	8.26	0.79

*Mean Difference (in Minutes, from POE Time Minus 5E Time) = 1.17
**p*-value (*p*, Independent Samples T-Test) = <0.01
**t*-value (*t*) = -6.16
*degrees of freedom (*df*) = 33

Table 7 compares the average pretest scores with the average posttest scores for the 5E treatment group, where the paired samples T-*test* was used to compare these scores. The difference between the pretest mean and the posttest mean was 1.09 points, and the *p* value was 0.00, less than 0.05, and there is significant statistical difference between the 5E groups' average pretest score and average posttest score.

Table 7

Change Score from Pretest to Posttest for 5E

Test	* Mean (M) (Average Score for 5E) (# of 5E participants, N=33)	*Standard Deviation (SD)
*Pretest	6.94	1.20
*Posttest	8.03	0.88

*Mean Difference (in Minutes, from POE Time Minus 5E Time) = 1.09
**p*-value (*p*, Independent Samples T-Test) = <0.01
**t*-value (*t*) = -5.56
*degrees of freedom (*df*) = 32

Table 8 compares the average change scores from pretest to posttest for the POE treatment group and the 5E treatment group, where the independent samples T-*test* was used to compare these scores. The POE average change score was 1.17 points and the 5E average change score was 1.09 points. The *p* value was 0.40, greater than 0.05, and there was no significant statistical difference between the POE groups' average change score and the 5E groups' average change score. The average change score for the POE group is equal to the average change score for the 5E group.

Table 8

Compare Pretest to Posttest Change Scores for POE and 5E

Group	* Mean (M) (Average for the Change Score from Posttest Average Score Minus Prettest Average Score)	*Standard Deviation (SD)
*POE (N=33)	1.18	1.25
*5E (N=33)	1.09	1.17

*Mean Difference (in Minutes, from POE Time Minus 5E Time) = 0.09
**p*-value (*p*, Independent Samples T-Test) = 0.76
**t*-value (*t*) = 0.31
*degrees of freedom (*df*) = 65

Table 9 compares the average simulation activity worksheet score (or intervention score) of the POE treatment group with the average simulation activity worksheet score (or intervention score) for the 5E treatment group, where the independent samples T-*test* was used to compare these scores. The POE average posttest score was 9.97 and the 5E average posttest score was 9.79. The *p* value of 0.21 was greater than 0.05, so there was no significant statistical difference between the POE groups' average score and the 5E groups' average score, even though there was a 3.3 % difference between the POE average worksheet score and the 5E average worksheet score, and the POE average score was higher than the 5E average score. In summary, this indicates that the average scores between these two treatment groups were statistically the same. Also, the *p*-values of less than 0.05 for the "pretest to posttest change scores" for both the POE group and the 5E group indicates that there was a great amount of knowledge gained for both the POE group and the 5E group.

Table 9

Compare Activity Worksheet Scores for POE and 5E

Group	* Mean (M) (Average for the Change Score from Posttest Average Score Minus Prettest Average Score)	*Standard Deviation (SD)
*POE (N=34)	9.97	0.94
*5E (N=33)	9.79	1.90

*Mean Difference (in Minutes, from POE Time Minus 5E Time) = 0.18
*p-value (p, Independent Samples T-Test) = 0.62
*t-value (t) = 0.50
*degrees of freedom (df) = 65

Research Question 3

Comparison and Analysis of the POE Worksheet and the 5E Worksheet: The POE Worksheet. Research question 3 asks: "Is there a difference in problem solving skills, as measured by forced-choice test, between pre-service teachers who used a density simulation with POE and those who used the density simulation with 5E?" In this section of this document, the POE worksheet and the 5E worksheet will be compared. Regarding the POE Worksheet, students first obtained the volume of each of the objects in the density computer simulation (Figure 1). Students then used the scale (Figure 2) to obtain the weight of each object. Students then placed each object into a liquid-filled graduated cylinder in order to obtain the volume of each object.

Form the hypothesis:

- Compare the density of each object with the density of water to determine whether each object will float in water or sink in water.
- Water has a density of 1.0 g/mL (or 1.0 grams per milliliters).
- If an object has a density that is <u>lower</u> than the density of water, then the object will <u>float</u> In water.
-If an object has a density that is <u>higher</u> than the density of water, then the object will <u>sink</u> In water.
-Determine if each object will float or sink in liquid water by comparing the density of the object with the density of water.

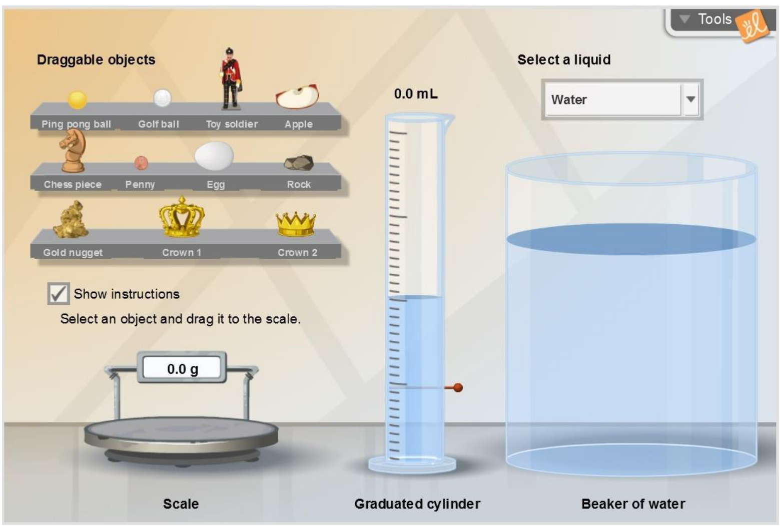


Figure 1. POE Worksheet (Shows the Density Computer Simulation of the POE Worksheet)

Students then recorded the weight and volume for each object in the computer simulation (shown in Figure 1, which shows parts of the POE worksheet). Students then used a calculator to calculate the density of each object by dividing the weight by the volume (density = weight/volume). Next, for the POE method (on the POE worksheet), students were at the "Predict" phase, where students predicted whether each object will float in the beaker of water (which is shown in Figure 1 for the POE worksheet) or whether each object will sink in the beaker of water after comparing the density of each object with the density of water (the density of water is 1g/mL or 1 grams per milliliters). If an object had a density that was less than 1 g/mL then it should have floated in the beaker of water. If an object had a density that was more than 1 g/mL then it should have sank in the beaker of water.

In the table shown in Figure 2, students first predicted whether each object will float or sink in the beaker of water by circling either “Float” or “Sink” under the “Predict” column in the table located in Figure 2. Next, for “Observe” of POE (shown in Figure 1 and Figure 2 of the POE worksheet), students observed what actually happened by placing each object in the beaker of water. Students then circled either “Float” or “Sink” under the “Observe” column in the table located in Figure 2. Figure 4 also shows "Observe" and "Explain" of the POE worksheet.

Next, for “Explain” of POE (shown in Figure 3 (in the table) and Figure 4 for the POE worksheet), students explained why each object floated or sank in the beaker of water by comparing the density of each object with the density of water, and this is shown in the table in Figure 2. Also, for “Explain” of POE, shown in Figure 2 and Figure 3 and Figure 4 for the POE worksheet, students then answered the various questions about density (questions A1, A2, A3, A4, A5, A6, B1, B2, B3, B4, and B5).

Step 1: Obtain the weight of each object (weight in grams (or g)) by placing each object on the scale (picture of scale shown above) and record the weight of each object in the table below.

Name of Each Object	Measure Weight (grams or g)	Measure Volume (milliliters or mL)	Calculate Density (g/mL)	**Predict** Will the Object Float or Sink in Water? (Circle Your Answer)		**Observe** Does the Object Float or Sink in Water? (Circle Your Answer)		**Explain** Does the Object have a Higher or Lower Density than Water? (Circle Your Answer)	
Ping Pong Ball				Float	Sink	Float	Sink	Higher	Lower
Golf Ball				Float	Sink	Float	Sink	Higher	Lower
Toy Soldier				Float	Sink	Float	Sink	Higher	Lower
Apple				Float	Sink	Float	Sink	Higher	Lower
Chess Piece				Float	Sink	Float	Sink	Higher	Lower
Penny				Float	Sink	Float	Sink	Higher	Lower
Egg				Float	Sink	Float	Sink	Higher	Lower
Rock				Float	Sink	Float	Sink	Higher	Lower
Gold Nugget				Float	Sink	Float	Sink	Higher	Lower
Crown 1				Float	Sink	Float	Sink	Higher	Lower
Crown 2				Float	Sink	Float	Sink	Higher	Lower

Step 2: Obtain the volume of each object (volume in milliliters (or mL)) by placing each object in the liquid in the graduated cylinder (picture of graduated cylinder shown above) and record the volume of each object in the table above.

Step 3: Calculate the density of each object and record the densities in the table above.

Predict

Step 4: Based on the density of each object, predict whether each object will float or sink in liquid water by circling your answer in the table above as either float or sink under the column listed as "Predict" (liquid water has a density of 1.0 g/mL (or 1.0 grams per milliliters)).

Figure 2. POE Worksheet (Shows "Predict" of POE)

Observe

Step 5: (Now to compare the density of each object with the density of water); Place each object in the water located in the container (picture of container shown above) and indicate whether each object FLOATED in water or SANK in water (circle your answer as either Float OR Sink in the table)

Explain

Step 6: Indicate in the table whether each object had a HIGHER density than water or a LOWER density than water (circle your answer): (density units are in grams per milliliters (or g/mL)) and water has a density of 1.0 g/mL (or 1.0 grams per milliliters)).

Step 7: Use the information in the table above to answer the following questions:

Figure 3. POE Worksheet (Shows "Observe" and "Explain" of POE)

Explain

Step 6: Indicate in the table whether each object had a HIGHER density than water or a LOWER density than water (circle your answer): (density units are in grams per milliliters (or g/mL)) and water has a density of 1.0 g/mL (or 1.0 grams per milliliters)).

Step 7: Use the information in the table above to answer the following questions:

A1. Which items floated in liquid water?

____

____

A2. How do the density of these items compare to that of liquid water? Is each density higher or lower than the density of water? Water has a density of 1.0 g/mL (or 1.0 grams per milliliters)).

____

A3. Which items sank in liquid water? ____

____

A4. How do the density of these items compare to that of liquid water? Is each density higher or lower than the density of water? Water has a density of 1.0 g/mL (or 1.0 grams per milliliters)).

____

A5. If an item has a density less than the density of liquid water, will the item float or sink in liquid water? (Circle your answer)

A6. If an item has a density greater than the density of liquid water, will the item float or sink in liquid water? (Circle your answer)

B1. Why does oil float on water? (Circle Your Answer)

A. Because oil does not dissolve in water

B. Because oil is less dense than water

C. Because water weighs more than oil (or is heavier than oil)

D. Because oil does not dissolve in water and oil is also is less dense than water

B2. The amount of matter that an object has is called its _______________ (Circle Your Answer)

A. Volume **B.** Mass **C.** Weight **D.** Density

B3. What property does a graduated cylinder (shown above) measure? (Circle Your Answer)

A. Mass **B.** Volume **C.** Weight **D.** Density

B4. If the units of milliliters (or mL) are used to measure volume, and the units of gram (or g) is used to measure mass, then what will the resulting units for density be? (Circle Your Answer)

A. grams **B.** mL **C.** g/mL **D.** g - mL

B5. Why is liquid water more-dense than ice? ____

____

Figure 4. POE Worksheet (Shows "Explain" of POE)

Comparison and Analysis of the POE Worksheet and the 5E Worksheet: The 5E Worksheet. Regarding the 5E worksheet, for "Engage" of 5E (Figure 5), students first "Formed the hypothesis" by obtaining the mass (by using the scale) and then obtaining the volume (by placing each object into a volume of liquid that is located in a graduated cylinder) of each object. Next students calculated the density of each object (by using a calculator to divide mass by volume, where density = mass/volume). Students then wrote the mass and volume and density in the table located in Figure 6 of the 5E worksheet. Students then placed each object into the "Beaker of water" (shown in Figure 5), and then students circled either "Float" or "Sink" for each object in the table located in Figure 7. Students then circled either "Higher" or "Lower" (in the table located in figure 6) to indicate whether each item had a higher density than water or a lower density than water. In the table located in figure 7, students then compared the density of each object to the density of water (which is 1 g/mL). In terms of "Explain," "Elaborate," and "Evaluate" of 5E (located in Figure 6 and Figure 7), students then answered the various questions regarding density (questions A1, A2, A3, A4, A5, A6, B1, B2, B3, B4, and B5).

Engage

Form the hypothesis:

- Compare the density of each object with the density of water to determine whether each object will float in water or sink in water.
- Water has a density of 1.0 g/mL (or 1.0 grams per milliliters).
- If an object has a density that is lower than the density of water, then the object will float In water.
-If an object has a density that is higher than the density of water, then the object will sink In water.
-Determine if each object will float or sink in liquid water by comparing the density of the object with the density of water.

Explore

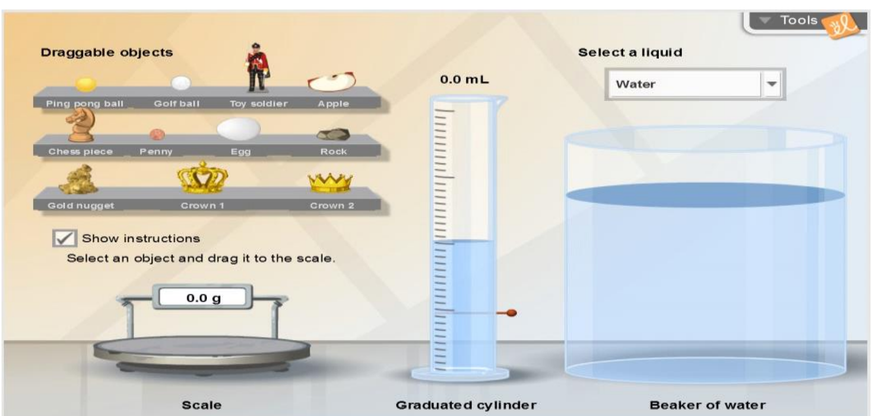


Figure 5. 5E Worksheet: (“Engage” and “Explore” of 5E); (Density Computer Simulation)

Step 1: Obtain the weight of each object (weight in grams (or g)) by placing each object on the scale (picture of scale shown above) and record the weight of each object in the table below.

Name of Each Object	**Measure Weight (grams or g)**	**Measure Volume (milliliters or mL)**	**Calculate Density (g/mL)**	**Does the Object Float or Sink in Water? (Circle Your Answer)**		**Does the Object have a Higher or Lower Density than Water? (Circle Your Answer)**	
Ping Pong Ball				Float	Sink	Higher	Lower
Golf Ball				Float	Sink	Higher	Lower
Toy Soldier				Float	Sink	Higher	Lower
Apple				Float	Sink	Higher	Lower
Chess Piece				Float	Sink	Higher	Lower
Penny				Float	Sink	Higher	Lower
Egg				Float	Sink	Higher	Lower
Rock				Float	Sink	Higher	Lower
Gold Nugget				Float	Sink	Higher	Lower
Crown 1				Float	Sink	Higher	Lower
Crown 2				Float	Sink	Higher	Lower

Step 2: Obtain the volume of each object (volume in milliliters (or mL)) by placing each object in the liquid in the graduated cylinder (picture of graduated cylinder shown above) and record the volume of each object in the table above.

Step 3: Calculate the density of each object and record the densities in the table above.

Step 4: Indicate in the table whether each object had a HIGHER density than water or a LOWER density than water (circle your answer): (density units are in grams per milliliters (or g/mL)) and water has a density of 1.0 g/mL (or 1.0 grams per milliliters)).

Step 5: (Now to compare the density of each object with the density of water); Place each object in the water located in the container (picture of container shown above) and indicate whether each object FLOATED in water or SANK in water (circle your answer as either Float OR Sink in the table)

Explain

Step 6: Use the information in the table above to answer the following questions:

Figure 6. 5E Worksheet: “Engage” and “Explore” and "Explain" of 5E

Explain

Step 6: Use the information in the table above to answer the following questions:

A1. Which items floated in liquid water? ____

____

A2. How do the density of these items compare to that of liquid water? Is each density higher or lower than the density of water? Water has a density of 1.0 g/mL (or 1.0 grams per milliliters)).

____

A3. Which items sank in liquid water? ____

____

A4. How do the density of these items compare to that of liquid water? Is each density higher or lower than the density of water? Water has a density of 1.0 g/mL (or 1.0 grams per milliliters)).

____

A5. If an item has a density less than the density of liquid water, will the item float or sink in liquid water? (circle your answer)

A6. If an item has a density greater than the density of liquid water, will the item float or sink in liquid water? (circle your answer)

Elaborate, Evaluate

B1. Why does oil float on water? (Circle Your Answer)

A. Because oil does not dissolve in water

B. Because oil is less dense than water

C. Because water weighs more than oil (or is heavier than oil)

D. Because oil does not dissolve in water and oil is also is less dense than water

B2. The amount of matter that an object has is called its _______________ (Circle Your Answer)

A. Volume **B.** Mass **C.** Weight **D.** Density

B3. What property does a graduated cylinder (shown above) measure? (Circle Your Answer)

A. Mass **B.** Volume **C.** Weight **D.** Density

B4. If the units of milliliters (or mL) are used to measure volume, and the units of gram (or g) is used to measure mass, then what will the resulting units for density be? (Circle Your Answer)

A. grams **B.** mL **C.** g/mL **D.** g - mL

B5. Why is liquid water more-dense than ice? ____

____

Figure 7. 5E Worksheet: “Explain” and “Elaborate” and "Evaluate" of 5E

Comparing the POE Worksheet Questions and the 5E Worksheet Questions. When comparing scores for each of the worksheet questions for POE and 5E worksheets (located in Table 10 for Questions A1, A2, A3, A4, A5, A6, B1, B2, B3, B4, and B5, where all of the questions are the same for both worksheets) for the POE worksheet (Figure 5) and the 5E worksheet (Figure 8), out of the total score of 11 points, the average score for the POE group was 9.97 out of 11 total points. The average score for the 5E group was 9.79 out of 11 total points. The percent (%) difference between the POE worksheet average score and the 5E worksheet average score was 1.8%, where the POE group obtained a 1.8 % higher score than the 5E group. According to the Table 10, the POE group obtained higher scores for all of the questions except for questions A1, A3, and B5, where the 5E group obtained higher scores than the POE group.

Table 10:

Analysis and Comparison of the POE Worksheet and the 5E Worksheet

Worksheet Question	POE Average Score for Worksheet Question	5E Average Score for Worksheet Question	Percent Difference (%)
A1	0.91	0.97	**6 %
A2	1	0.97	3 %
A3	0.91	0.97	**6 %
A4	1	0.97	3 %
A5	1	0.97	3 %
A6	1	0.97	3 %
B1	0.97	0.91	6 %
B2	0.79	0.61	**23 %
B3	0.97	0.94	3 %
B4	0.97	0.97	0 %
B5	0.44	0.55	**20 %
Total Score (Out of 11 Total Points)	9.97	9.79	1.8 %

**For Questions Where the 5E Group Had a Higher Score than the POE Group
*Mean Difference (POE Worksheet Score Minus 5E Worksheet Score) = 0.18
*p-value (p, Independent Samples T-Test) = 0.62
*t-value (t) = 0.50
*degrees of freedom (df) = 65

Research Question 4 (Quantitative Data)

Likert Scale Survey Quantitative Data Results. Research question 4 asks: "Is there a difference in attitude toward science, as measured by survey questions, between pre-service teachers who used a density simulation with POE and those who used the density simulation with 5E?" Figure 8 shows the Likert Scale survey that was used in this experiment. With this survey, participants had to choose how strongly they feel about each comment or question. If participants strongly agreed with a comment or question, then participants used a pen or pencil to fill in the circle that is associated with the number five (5). If participants strongly disagreed with a comment or question, then participants filled in the circle that was associated with the number one (1). The total amount of points indicates how strongly or weakly participants feel about the thing that is associated with the Likert Scale survey questions and/or comments. The higher the total number of points are, the more strongly participants agree about the survey questions and/or comments. The lower the total number of points were, the more strongly participants disagreed with the survey questions and/or comments.

(**Instructions:** Choose and/or Fill in the blank of the appropriate answer.)

1. After this lesson, I am confident about using computer simulations in teaching the topic of density. (attitudes about teaching the topic of density)

(1)=strongly disagree	(2)=disagree	(3)=uncertain	(4)=agree	(5)=strongly agree
O	O	O	O	O

2. Computer simulations are valuable for teaching. (value of the computer simulations)

(1)=strongly disagree	(2)=disagree	(3)=uncertain	(4)=agree	(5)=strongly agree
O	O	O	O	O

3. Computer simulations seem useful in learning about density; simulations are useful in teaching science concepts (expected use of computer simulations)

(1)=strongly disagree	(2)=disagree	(3)=uncertain	(4)=agree	(5)=strongly agree
O	O	O	O	O

4. I feel confident about using computer simulations to help teach the topic of density in the future (confidence in using the computer simulations to teach the topic of density)

(1)=strongly disagree	(2)=disagree	(3)=uncertain	(4)=agree	(5)=strongly agree
O	O	O	O	O

Figure 8. Likert Scale Survey Instrument

Table 11 compares the average total Likert Scale survey score of the POE treatment group with the average total Likert Scale survey score for the 5E treatment group, where the independent samples T-*test* was used to compare these scores. The Likert scale questions were analyzed using Likert Scale survey data analysis to determine participants' attitude about the computer simulation after using it and participant attitudes about science, which should show if there are significant differences between responses of the two treatment groups on the overall attitude questionnaire and on specific items on the attitude questionnaire. The POE average total Likert Scale survey score was 17.59 and the 5E average total Likert Scale survey score was 17.39. The p value was greater than 0.05, or $p = 0.61$, and this indicates that there was no significant difference between the POE groups' average score and the 5E groups' average score. In summary, both groups gave statistically similar Likert Scale opinion survey scores for both teaching methods.

Table 11

Compare Likert Scale Survey Data for POE and 5E

Group	* Likert Scale Survey Mean (M) (Average for the Change Score from Posttest Average Score Minus Pretest Average Score)	*Standard Deviation (SD)
*POE (N=34)	17.59	2.18
*5E (N=33)	17.39	3.07

*Mean Difference (in Minutes, or POE Time Minus 5E Time) = 0.20
*p-value (p, Independent Samples T-Test) = 0.61
*t-value (t) = -2.99
*degrees of freedom (df) = 65

Table 12 compares the average Likert Scale survey scores for the individual Likert Scale questions for the POE treatment group with the average Likert Scale survey scores for the individual Likert Scale questions for the 5E treatment group, and the independent samples T-*test* was used to compare the total scores. There was no significant difference between the POE groups' average score and the 5E groups' average score, and the average scores for the individual questions were statistically similar for these two treatments. The POE group gave higher Likert Scale question points for all four of the Likert Scale questions. For the Likert Scale survey question #1, which states: "*After this lesson, I am confident about using computer simulations in teaching the topic of density. (attitudes about teaching the topic of density)*," the POE group gave a higher score than the 5E group, and this score was 1.4 % higher. For the Likert Scale survey question #2, which states: "*Computer simulations are valuable for teaching. (value of the computer simulations)*," the POE group gave a higher score than the 5E group, and this score was 5.7 % higher, and this was the highest percent difference score for all Likert Scale questions. For the Likert Scale survey question #3, which states: "*Computer simulations seem useful in learning about density; simulations are useful in teaching science concepts (expected use of computer simulations)*," the POE group gave a higher score than the 5E group, and this score was 2.5 % higher, and this is the second highest percent difference of the Likert Scale questions. For the Likert Scale survey question #4, which states: "*I feel confident about using computer simulations to help teach the topic of density in the future (confidence in using the computer simulations to teach the topic of density)*," the POE group gave a higher score than the 5E group, and this score was 0.5 % higher, and this was the lowest percent difference score for all Likert Scale questions.

In summary, both groups gave statistically similar Likert Scale opinion survey scores for both teaching methods (POE and 5E), even though the POE group gave higher Likert Scale total scores and higher individual scores for all Likert Scale questions, and this is indicated in Table 11 and in Table 12.

Table 12

Compare Individual Likert Scale Survey Data for POE and 5E

*Question	*Average Score for POE Participants (N=34)	*Average Score for 5E Participants (N=33)	*Percent Difference (%)
*Likert Scale Question #1 (Out of 5 Total Points)	4.32	4.26	1.4 %
*Likert Scale Question #2 (Out of 5 Total Points)	4.56	4.3	5.7 %
*Likert Scale Question #3 (Out of 5 Total Points)	4.41	4.3	2.5 %
*Likert Scale Question #4 (Out of 5 Total Points)	4.24	4.22	0.5 %
*Likert Scale Total Score (Out of 20 Total Points)	17.59 (or 88%)	17.39 (or 87%)	1.1 %

*For the Likert Scale points for each question, the highest score of 5 means that participants strongly agreed with the question.
*The Lowest score of 1 means that participants strongly disagreed with the question.
*Independent Samples T-test to Compare Likert Scale Opinion Survey Data for POE (N=34) and 5E (N=33)
**p*-value = 0.61; *POE (Mean = 17.59; Standard Deviation = 2.18); *5E (Mean = 17.40, Standard Deviation = 3.07); *t(65) = -2.99
*The *p*-value was greater than 0.05, *So there is no Significant statistical difference between the two groups (POE and 5E)

Summary of the Analysis of Quantitative Data Results

Table 13 list shows a summary of the quantitative results analysis: (1) both groups started at the same level of knowledge about the topic of density (since they had comparable average pretest scores that were statistically comparable, shown in Table 3); (2) both groups got high average posttest scores that were statistically comparable (shown in Table 4); (2b) both groups gave comparable pretest-to-posttest change scores that were statistically comparable (shown in Table 7, Table 8, and Table 9); (3) both groups got high worksheet scores that were statistically comparable (shown in Table 10 and Table 11); and (4) both groups gave equally high Likert Scale opinion survey total scores for both teaching methods (shown in Table 11 and Table 13). In looking at the individual worksheet question scores for both groups (Questions A1, A2, A3, A4, A5, A6, B1, B2, B3, B4, and B5 located on Table 10), the POE group obtained higher scores for all of the questions except for questions A1, A3, and B5, where the 5E group obtained higher scores than the POE group for these three questions. The next section answers question 4 using the qualitative open-ended survey data.

Table 13

Summary of Quantitative Data

Scores	POE Average Score (N=34)	5E Average Score (N=33)	*p*-value
Time to Complete Worksheet	38.12 Minutes	41.09 Minutes	0.70
Pretest Scores	7.09	6.94	0.29
Posttest Scores	8.26	8.03	0.99
(Posttest - Pretest) Scores	1.18	1.09	0.76
Workseet Scores	9.97	9.79	0.62
Likert Scale Scores	17.59	17.39	0.61

*For POE, the change in average score from Pretest to Posttest was 1.18, and the *p*-value comparing the POE Pretest and Posttest scores was less than 0.01(this is statistically significant);

*For 5E, the change in average score from Pretest to Posttest was 1.09, and the *p*-value comparing Pretest and Posttest scores was less than 0.01 (this is statistically significant).

Research Question 4 (Qualitative Data)

Analysis of Open-Ended Survey Questions. Research question 4 asks: Is there a difference in attitude toward science, as measured by survey questions, between pre-service teachers who used a density simulation with POE and those who used the density simulation with 5E? Applying thematic analysis (Guest, MacQueen, & Namey, 2012), some emerging themes were noticed from the results of the five open-ended survey questions (questions 5, 6, 7, 8, and 9) that were located in the attitude survey questionnaire. This study used of open-ended survey questions in the survey questionnaire (Ackley, 2010; Creswell & Poth, 2009), and coding was used to analyze these questions (Hay, 2005). There were no pre-existing codes, but we came up with the codes while coding was taking place.

Thematic analysis is usually used to analyze qualitative research data, where the pinpointing, the examining, and the recording of themes, or patterns, within the data is done. Themes are patterns that are noticed and seen across the data sets, and these themes are important for the describing of a phenomenon, and the themes are associated with a specific research question. Thematic analysis identifies the ideas within the data, and coding is the major process for developing themes within raw data by reorganizing important moments within the data and encoding it before the interpretation of the data is made. With thematic analysis, themes within the data is examined, and thematic analysis is useful for capturing intricacies of meaning within a data set (Braun & Clarke, 2006; Boyatzis, 1998; Daly, Kellehear, & Gliksman, 1997; Guest, MacQueen, & Namey, 2012).

Regarding the analysis and interpretation of qualitative data, in qualitative research, data is first gathered, and then the data is interpreted (or coded and then analyzed), and then reports are written. Coding is a process that is used in qualitative research, where the data is characterized in order to help with the analysis of this data. Analysis of qualitative data involves collecting open-ended qualitative data, which it involves asking the participants general questions; and then it involves developing an analysis (by using coding) from this qualitative, open-ended, information and data that was supplied by the participants. Analysis of qualitative data first involves understanding and making sense out of the text data that was supplied by the participants of the study by using coding (and this is comparable to peeling off the layers from an onion); and then it involves interpreting a larger meaning of this qualitative data (Creswell & Poth, 2009).

An open-ended question is phrased as a statement that requires a response to be made by participants. The responses by the participants can be compared to information that is already known to the person asking the question. Open-ended questions cannot be answered with simply a static response or with a "yes" or "no" response (Ackley, 2010). This study used open-ended questions in order to get open-ended text data from participants.

In qualitative research, a two-step process to coding is applied. This starts with basic coding, which is used in order to distinguish the overall themes. This is followed by a more interpretive, and more in-depth coding, where more specific patterns and trends can be interpreted (Hay, 2005). This study uses grounded coding for the qualitative research, which has to do with allowing notable patterns and themes to emerge directly from the qualitative data and documents themselves (Grbich, 2013; Saldaña, 2015).

As coding is being done and applied, axial coding can be applied, and this is a process of selecting and picking out core thematic categories that are present in the qualitative research data in order to discover and find out about common relations and common patterns that are seen (Grbich, 2013). For qualitative research, the cycle coding method is carried out before categories are constructed. The cycle coding method that is used in this study is the "In Vivo Coding" method, where coding of the words and phrases and terms used by the participants themselves is done. And so the participants own words are coded and looked at and observed (Ryan & Bernard, 2003).

Analysis of Open-Ended Survey Question #5. With respect to the open-ended survey question #5 (see Table 14), asking in what ways did the density computer simulation help the participants understand the topic of density, the strongest theme was that the visual aspect of the simulation aided participants' understanding (coded as "visual helps understanding"), and the majority of participants in the POE group (71%) and the 5E group (61 %) indicated that the computer simulation provided a good visual that helped the participants understand the topic better. Clearly, participants felt that the visual aspect of the computer simulation helped most of participants understand better.

Table 14

Participant Responses to Open-Ended Survey Question #5: "In what ways did the density computer simulation help you understand the topic of density?"

*Emerging Themes	*Number of POE Participants	*Percent (%) of POE Participants	*Number of 5E Participants	*Percent of (%) 5E Participants
*The computer simulation provided a good visual that helped the students understand the topic better, and so the visual helped students understand better	24	71 %	20	61 %
*The computer simulation was very understandable and was easy to understand	9	26 %	9	27 %
*The computer simulation was explorative and used many examples to explain density	1	3 %	1	6 %
*Being able to manipulate the variables	0	0 %	2	3 %
*The computer simulation was interactive	0	0 %	1	3 %

Also, 26% of the POE group of participants (and 27 % of the 5E group of participants) indicated that the computer simulation was very understandable, and therefore the computer simulation was easy to understand for some of the participants. One POE participant said that the simulation was "... an explorative experiment that used many examples to explain density."

One POE participant mentioned that simulation helped this participant understand the topic of density because of guidance: "The use of the guided practice help to make me understand."

For the POE group, 71% of the responses were coded as "visual part of simulation" that helped them understand density included:

- "The simulation helped me visually understand density."
- "It provided me with a visual representation of the subject. It also allowed me to visually see the objects being used."
- "Provided a visual for me to see which objects floated and which sank. This helped when calculating density."
- "Visualizing the concept help me understand."

For the 5E group (61%), responses coded as "visual part of simulation" helped them understand density included:

- "Actually see the item sink or float helped with my understanding."
- "I was able to easily see the measurements and change the liquid to see what floated and what didn't."
- "It gave me a visual to better understand density instead of explaining in words."

In addition, for question #5, several POE participants (26%) said that the simulation was easy to understand, and the following list shows example comments made by these participants:

- "It helped me to understand why less dense objects float in water and what some of those objects might be."
- "It helped me understand density further, and what density actually is."

- "It showed the correlation between mass, volume, and density in an easy-to-comprehend way."

Also, for question #5, some 5E participants (27%) said that the simulation was easy to understand, and the following list shows example comments made by these participants:

- "I sometimes get mass and density confused, so I believe the simulation helped me differentiate a little bit."
- "The use of many different objects helped me understand density. Many people may have thought a penny would float because it's so light."
- "By being able to compare densities of different items, I got a better understanding."

The 5E participants were more likely to mention that the simulation was explorative and that simulation used many examples to explain density, and participants were able to manipulate variables, and that the simulation was interactive:

- "It allowed me to explore the concept in an easy way."
- "I was able to easily change what object I used and what liquid it was in."
- "I don't think it helped teach me about density it just helped me explore the subject further."
- "I was able to manipulate objects and play around to see the density of each and look at contributing factors."
- "It was interactive and helped me to find the density of objects using experimentation."

Overall, participants in both the POE group (71%) and the 5E group (61%) pointed out the visual strength of the computer simulation. Participants in both groups said that the computer simulation was easy to understand, but the 5E group pointed out more ways that the simulation helped them understand density; and a few participants in the 5E group specified that they were able to explore (3% of 5E participants), manipulate variables (6% 5E of participants), and that the simulation was interactive (3% of 5E participants). Participants said similar things for the POE group and the 5E group, but the 5E group pointed out more ways that the simulation helped them learn and more ways that the simulation helped them understand the relationship between mass and volume.

Analysis of Open-Ended Survey Question #6. With respect to the open-ended ended survey question #6 (see Table 15), asking how did the density computer simulation help participants understand the relationship between mass (or weight) and volume, the majority of the POE group of participants (65%) and the 5E group of participants (46%) indicated that visually seeing the objects placed on the scale and placed in the graduated cylinder helped them understand the relationship between mass and volume. Also, many of the POE group of participants (24%) and the 5E group of participants (24%) indicated being able to manipulate (and change) the variables and doing the measurements helped them understand the relationship between mass and volume. Some of the POE participants (12%) and a few of the 5E group of participants (3%) indicated that doing the actual calculations to find density allowed them to understand the relationship between mass and volume. Overall, the majority of both POE and 5E groups gave similar responses, but the 5E participants were more likely to give more various other responses (27%).

Table 15

Participant Responses to Open-Ended Survey Question #6: "How did the density computer simulation help you understand the relationship between mass (or weight) and volume?"

*Emerging Themes	*Number of POE Participants	*Percent (%) of POE Participants	*Number of 5E Participants	*Percent of (%) 5E Participants
*visually seeing the objects placed on the scale and placed in the graduated cylinder helped them understand the relationship between mass and volume	22	64 %	15	46 %
*doing the calculations to find density	4	12 %	1	3 %
*measuring mass and volume, changing and manipulating variables	8	24 %	8	24 %
*I already knew	0	0 %	1	3 %
*easy to understand	0	0 %	2	6 %
*provided many objects that I could compare	0	0 %	2	6 %
*mass and volume not always connected	0	0 %	2	6 %
*It did not help me, it only helped me explore	0	0 %	2	6 %

For question #6, 65% of the POE group (22 participants) said that the "visual part of simulation" helped them understand density. The following list shows example comments made by this POE group of participants for question #6:

- “I could see the process taking place. The two different ways of measuring but it provided a more accurate reading of measure.”
- “You saw it fold out by measuring both & then testing the density.”
- “This simulation showed mass & volume side by side which helped compare the two.”

Also, 46% of the 5E group (15 participants) said that the "visual part of simulation" helped them understand density. The following list shows example comments made by this 5E group of participants for question #6:

- “Once again, I am a visual learner, so seeing the comparison on the screen and the paper makes it helpful.”
- “By being able to see the scale and liquid rising and visuals help tie it all together.”
- “It again helped me to visualize it rather than just being told about it.”

Along with visualizing, the benefit of the simulation was for participants to actually conduct measurements. Many participants in the POE group (24%) mentioned that the measuring mass and volume and "doing measurements" and "manipulating variables" helped them understand density. The following list shows example comments made by this POE group of participants for question #6:

- “It allowed me to measure the weight and volume of each object to determine whether it was less than 1 (water's density) and would float or was greater than 1 and would sink.”
- “I liked that you first measured the weight of the object on the scale and used a graduated cylinder for the volume. After gathering the information, we were able to see if the object would float or sink.”
- “By physically dragging each item to the liquid and visually seeing what happens based on their densities.”

For question #6 (Table 15), many 5E participants (24%) said that measuring and "manipulating variables" helped them understand density. The following list shows example comments made by this 5E group of participants for question #6:

- “By using the two different types of measuring it helped me make the difference.”
- “It allowed me to measure both the weight and volume with no room for human error.”
- “Mass=weight=scale; volume=cylinder; even if an object weighs more it might have a smaller volume.”

Analysis of Open-Ended Survey Question #7. Regarding the open-ended ended survey question #7 (see Table 16), asking, "After using the density computer simulation, are you able to explain why objects that have a lower density than the density of liquid water float on water, while objects that have a higher density than liquid water sink in water?" The great majority of the POE group of participants (97%) and of the 5E group of participants (85%) said “Yes.” One of the POE participants (3%) was not sure (along with 0% of the 5E participants). Two of the 5E participants (6%) said no (along with 0% of the POE participants); and some of the 5E participants (9%) gave various other responses.

Table 16

Participant Responses to Open-Ended Survey Question #7: "After using the density computer simulation, are you able to explain why objects that have a lower density than the density of liquid water float on water, while objects that have a higher density than liquid water sink in water?"

*Emerging Themes	*Number of POE Participants	*Percent (%) of POE Participants	*Number of 5E Participants	*Percent of (%) 5E Participants
*Yes	33	97 %	28	85 %
*No	0	0 %	2	6 %
*Not sure but I know what will float and what won't	1	3 %	0	0 %
*I knew it does but I do not know why	0	0 %	1	3 %
*I would like to practice more	0	0 %	1	3 %
*they float	0	0 %	1	3 %

The following list shows example comments made by most of the POE group of participants (97%) for question #7:

- “Yes, but being able to explain it to children would take a bit longer as I need to internalize the information first.”
- Yes and I can set up an example to show the class if needed based on the simulation.”
- “Yes I would feel comfortable explaining this concept to a classroom.”
- “Yes, I would even let kids onto this simulation.”

Also, for question #7 (Table 16), the majority of the 5E group of participants (85%) said, "Yes," that they were sure about high density objects and low density objects in water. The following list shows examples of these comments made by this 5E group of participants for question #7:

- "Yes! D=m/v ; Using the simulation showed me how to calculate mass & volume, which helped me to figure out density."
- "Yes this helped me understand density of water & objects and how it effects sinking & floating."
- "After the simulation I would be able to better explain why. The simulation helped me understand it better so it would definitely help."

Two 5E participants in the 5E group said "No" about the density of different objects in water: "No, but I could try. The force of gravity is stronger than the buoyant force of the water in the case of denser objects." One of the 5E participants was not sure about different objects in water: "I know that it does but I do not know why."

So far, for most of the survey questions, the benefits of simulation (based on the emerging themes) appear to include "visual" and "manipulation." For question #8, the benefits of simulation also included "visual" and "manipulation."

Analysis of Open-Ended Survey Question #8. Regarding the open-ended ended survey question #8 (see Table 17), asking "What were the strengths of the density computer simulation?," many of the participants in the POE group of participants (43%) and the 5E group (42%) said that the visual aspect of the computer simulation was a strength. Also, many in the POE group (56%) and the 5E group of participants (58%) gave various responses that included the following emerging themes: the computer simulation was interactive and participants were able to easily change and manipulate the variables, which were easy to manipulate and change. Other themes were that the computer simulation was quick and easy, it was easy to set up, it was cheap, it was not messy, it was fun, it was easy to understand, and that it was a different way to learn.

Table 17

Participant Responses to Open-Ended Survey Question #8: "What were the strengths of the density computer simulation?"

*Emerging Themes	*Number of POE Participants	*Percent (%) of POE Participants	*Number of 5E Participants	*Percent of (%) 5E Participants
*The visual aspect of the computer simulation was a strength	15	43 %	14	42 %
*The computer simulation was interactive; changing and manipulating variables was easy; it was fun (like video game, lets students work independently)	8	24 %	17	52 %
*it was not messy	3	9 %	1	3 %
*the computer simulation was easy to understand; cheap; quick and easy to set up; it was not messy	8	24%	0	0 %
*it was a different way to learn	0	0%	1	3 %

Some comments by the group of POE participants (43%) indicating that the "visual part of simulation" was a strength included:

- "Gives a visual and hands on approach."
- "It allowed you to visually see what you were trying to learn."
- "The strengths for me is that I am a very visualized learner so this helps me a lot."

For question #8 (Table 17), 42% of the 5E group said that the "visual part of simulation" was a strength. The following list shows example comments made by this 5E group of participants for question #8:

- "It gave a visual aid as well as having multiple objects to use to experiment."
- "It allows students to visualize mass, volume and density. Visuals are very beneficial."
- "The density computer simulation help students visualize how a higher mass can change the volume of it. It can help students who are visual learners."

For question #8 (Table 17), many POE participants (56%) gave the following emerging theme comments and "various comments" about the computer simulation strengths that includes the following: "not messy, and easy to work with, was fast, easy to follow, easy to interact with, interactive, and easy to set up." The following list shows example comments made by this POE group of participants for question #8:

- "Gives students a chance to try out putting objects in water without the cleanup or mess."
- "Quick; easy to follow."
- "I liked the interactive exploration of the simulation."
- "Fun, interactive, informative."
- "It also lets students compare various objects and allows for students to predict outcomes numerous times.
- This is also easy for students to access at home if they have internet."
- "have the tools readily available and easy to navigate and have the object you may not be

able to find (ex. Gold nugget or crown)."

- "The simulation was easy to use-step by step"

For question #8 (Table 17), many 5E participants (58%) gave the following emerging theme comments and "various comments" about the computer simulation strengths that includes the following: "not messy, and easy to work with, was fast, easy to follow, easy to interact with, and easy to set up." The following list shows example comments made by this 5E group of participants for question #8:

- "Showing the mass and volume without having the supplies for each student."
- "I also thought it was easy to move the objects place to place and read all the measurements."
- "It was very easy to setup. It was engaging."
- "Easy to use, organized, interesting."
- "The strengths were the ability to see all the different aspects that would be needed for its experiment, but we were able to receive our results faster."
- "easy to navigate"

Several participants in the POE group (24%) said that the computer simulation was "easy to understand and use:"

- "Easy to understand."
- "The simulation was easy to understand"

Also for the POE group, some of the various comments indicated that the computer simulation was "easy to use" as well as the "visualizing" and "manipulating" strengths of computer simulation, which included:

- "Easy to use, exact answers, didn't have to get your hands dirty."
- "Materials that are well known, the instructions, and the format is simple for anyone to use."

- “This is a great resource to use if the school does not have all of the right equipment for this experiment. There is also significantly less planning involved with this than an actual experiment.”

***Analysis of Open-Ended Survey Question #9*.** Regarding the open-ended survey question #9 (see Table 18), asking "What were the weaknesses of the density computer simulation?," many of the POE group of participants (29%) and of the 5E group of participants (24%) indicated that the computer simulation was not hands on. Some of the POE group (15%) and the 5E group of participants (15%) indicated that the computer simulation could have provided a more clear explanation of the topic of density, since they think that the explanation provided was not clear enough. Some of the POE group of participants (15%) and the 5E group of participants (28%) indicated that computer simulations had no weaknesses. Some of the POE group of participants (9%) and the 5E group of participants (6%) indicated that computer simulations relied too much on having a computer and having internet. For question #9 (Table 18), 21% (or 7) of the POE participants and 9% (or 3) of the 5E participants did not answer question #9 and left this question blank. Of the 3% of POE participants and the 3% of the 5E participants, one participant noted: “There was not a calculator provided. = some students may struggle using a computer and finding a calculator.” A few of the POE participants (9%) and the 5E participants (15%) gave various other responses.

Table 18

Participant Responses to Open-Ended Survey Question #9: "What were the weaknesses of the density computer simulation?"

*Emerging Themes	*Number of POE Participants	*Percent (%) of POE Participants	*Number of 5E Participants	*Percent of (%) 5E Participants
*not hands on	10	29 %	8	24 %
*it relies too much on computer and internet	3	9 %	2	6 %
*There is no clear explanation of density; need a more clear explanation of density	5	14 %	5	15 %
*There were NO weaknesses	5	15 %	9	28 %
*no calculator was provided in simulation	1	3 %	1	3 %
*Various other responses	3	9 %	5	15 %
*Blank (participants left this area blank & no response was given)	7	21 %	3	9 %

The following list shows example comments made by the POE group of participants (29%) indicating that the computer simulation was "not hands on":

- “You aren't able to hold the objects. This would have given you a physical grasp on what that density felt like.”
- “Some students may still benefit more from an actual hands-on experiment versus a computer simulation.”
- “Some sutdents might not further understand since it was not directly hands-on. Might not be enough computers in a classroom.”
- Not hands on so students can't feel the objects to understand its mass.”

For question #9 (Table 18), 24% of the 5E group (8 participants) indicated that the computer simulation was "not hands on," and the following list shows example comments made by this 5E group of participants for question #9:

- ”I think kids learn better when activities are hands-on in person.”
- ”The weaknesses are that the students can't touch the objects. They can't use objects around the room to compare to the density of water.”
- ”I like actually doing the activities. So I think that is a weakness. With simulation you can see what is happening, however, you are not actually measuring the mass or volume, it is just told you.”
- ”It was not hands on, so some students may struggle with understanding.”

As well, 15% of the POE group (5 participants) indicated that the computer simulation had "no clear explanation of why” less dense objects float in water and more dense objects sink in water. The following list shows example comments made by this POE group of participants for question #9:

- “It did not really explain how to find volume or the role it played.”
- “It gives a good visual representation but does not tell how or why.”

In addition, 15% of the 5E group (5 participants) indicated that the computer simulation gave "no clear explanation of why" less dense objects float in water and more dense objects sink in water. The following list shows example comments made by this POE group of participants for question #9:

- "The weakness is that it doesn't explain why or how."
- "Certain aspects were still left unknown=(it did not explain matter or reasoning behind everyting)=and afterwards I am still at a loss of words to explain why it happens."
- "It didn't explain anything."
- "My only weakness is that it does not explain why the density of it is higher or lower affects if it sinks or not."

In addition, 9% of the POE group (3 participants) indicated that the simulation "relies on computers & internet" too much, and the following list shows example comments made by this POE group of participants for question #9:

- "Need a computer; need to teach students how to use computer program; provides only a few objects."
- "It relies on the internet and web browser to work correctly. It might be easier for students to cheat to fill out the information by looking at another student's screen."

Also, 6% of the 5E group (2 participants) indicated that the computer simulation "relies on computer & internet" too much. The following shows these two comments made by these 5E participants for question #9:

- "The only weakness is that all schools may not have computer to use this simulation."
- "Students can get distracted by computers."

For question #9 (Table 18), 9% of the POE group (or 3 participants) and 15% of the 5E group (or 5 participants) indicated various other themes. For example, two POE participants left the emerging theme that the computer simulation had "disproportionate objects," and that the objects were all the same size in the simulation, but they are different sizes in real life. The following list shows example comments made by this 5E group of participants for question #9:

- "The objects were odd, such as crown 1 & 2. They were small but had large matter."
- "#1-everything was the same proportion. So the cram was the size of a ping pong ball and a penny. #2-I had to replace the objects. Some students might have a hard time. If another object were dropped on the scale then the other object should self replace."

Also, 6% of the 5E group (2 participants) left the emerging theme that the computer simulation did not comply with reality or science, and the following shows these comments made by these two 5E participants for question #9:

- "It left no room for error, which is very important to the learning process."
- "The computer simulation made you drop the items on top of the beaker or the cylinder to put an item into it, instead of above like you would in real life."

Summary of the Analysis of Qualitative Data Results

Overall for the open-ended survey questions, the answers given by participants in both groups were similar, and participants in both groups showed positive perceptions and attitudes for the density computer simulation used in this research study. The 5E group had some indications of more critical thinking (based on qualitative data analysis), and the 5E participants seemed to have more varied responses for the open-ended survey questions. The 5E group seemed to have pointed out more weaknesses than the POE group, and the 5E group seem to have pointed out more emerging themes than the POE group. Also, the major themes with all of the qualitative, open-ended survey questions were (1) Visualization, (2) Manipulation, and (3) Logistics. Many of the literature review sources indicated these as major themes when using computer simulation to teach science, and they indicated that these themes were benefits of using simulation to teach science. This study further verifies the computer simulation benefits, and the qualitative results in this current research study affirmed the benefits of simulations to help learners understand science processes by allowing them to visualize (Cox et al, 2011; Khan,

2011) processes and by allowing them to manipulate (Khan, 2011; Latham & Scully, 2008; Zacharia, 2005) variables in “real world” ways. Therefore, more studies like this current study needs to be done in order to strengthen the research information about inquiry+simulation teaching combinations and to verify the benefits of inquiry+simulation teaching combinations and to strengthen research information about using inquiry+simulation teaching combinations for teaching specific science concepts.

CHAPTER 5

DISCUSSION

In this study, POE+simulation was compared to 5E+simulation in order to determine which combination was the most effective for teaching the science topic of density. The purpose of study was to: investigate how to most efficiently and effectively teach the science topic of density using computer simulation by comparing effectiveness of POE combined with computer simulation vs. 5E combined with computer simulation; and to compare participant opinions of the computer simulation used based on which inquiry-based strategy was used.

This discussion chapter will start with a summary of findings addressing the research questions, and then implications for teaching science concepts using simulations and implications for further research will be discussed. In this study, POE+simulation was compared to 5E+simulation in order to determine which combination was the most effective for teaching the science topic of density. This study investigated how to most efficiently and effectively teach the science topic of density using computer simulation by comparing effectiveness of POE combined with computer simulation vs. 5E combined with computer simulation; and to compare participant opinions of the computer simulation used based on which inquiry-based strategy was used.

Research Questions

The following four research questions guided this study and were answered in this study:

1. Is there a difference in the total amount of time, as measured by the times that each participant started and finished (or completed) the activity worksheets, between pre-service teacher participants who used the density simulation with POE and those who used the density simulation with 5E?

The POE activity worksheet and the 5E activity worksheet were used to answer question #1. In comparing POE and 5E, in terms of the time taken to complete each activity worksheet, the POE group completed the activity worksheet in 38 minutes average, and the 5E group completed the worksheet in 41 minutes average. The difference between the two groups was not statistically significant.

The pre-test and the posttest were used to answer the question #2 and question #3 about content knowledge (which was measured by pretest and posttest) and problem-solving skills comparison (which was measured by the activity worksheet questions).

2. Is there a difference in content knowledge, as measured by forced-choice test, between pre-service teachers who used a density simulation with POE and those who used the density simulation with 5E?

The pre-test, the posttest were used to answer question #2. In both the pre-test and post-test of knowledge about density, the POE group scored higher, although the differences were non-significant, statistically. The groups were essentially equivalent in prior knowledge, and also in acquired knowledge after using the simulation with either POE or 5E inquiry frameworks.

3. Is there a difference in problem solving skills, as measured by forced-choice test, between pre-service teachers who used a density simulation with POE and those who used the density simulation with 5E?

The POE activity worksheet and the 5E activity worksheet were used to answer question #3. Overall, the problem solving skills was statistically the same for both groups.

Survey questions, which contained the Likert Scale survey questions (quantitative) and the open-ended (or open-coding) survey questions, were used to answer question #4. Therefore, survey questions were used to answer question #4, which was the following:

4. Is there a difference in attitude toward science, as measured by survey questions, between pre-service teachers who used a density simulation with POE and those who used the density simulation with 5E?

Attitude questionnaire data were analyzed using Lickert scale statement analysis; and open-coding was used to analyze the open-ended survey questions. In terms of the attitudes and perceptions of the participants (or Research Question 4a (From Quantitative Data, Likert Scale Survey Questions 1-4)), Lickert scale statement analysis for both the POE+simulation combination and the 5E+simulation combination were statistically comparable, but POE+simulation combination was 17.59 average points out of 20 total points. The average Lickert scale score for the 5E+simulation combination was 17.39 average points out of 20 total points. Since the *p* value of 0.61 was greater than 0.05, then there was no significant difference between the POE+simulation combination and the 5E+simulation combination; and this indicates that the average scores between these two groups were statistically comparable and statistically the same. But the POE group gave a higher average score than the 5E group, although the results between the POE group and the 5E group were not statistically significant. For "Research Question 4 (From Qualitative Data, Open-Ended Survey Questions 5-9)," the qualitative, open-ended survey results in this current research study affirmed the benefits of simulations to help learners understand science processes by allowing them to visualize (Cox et al, 2011; Khan, 2011) processes and by allowing them to manipulate (Khan, 2011; Latham & Scully, 2008; Zacharia, 2005) variables in "real world" ways.

Implications

The goal of this research was to compare the teaching combination of simulation plus POE with the teaching combination of simulation plus 5E in order to determine the most effective teaching combination for teaching a specific science concept (density). Since both inquiry-based teaching strategies of POE and 5E have disadvantages, it is important to determine which is the best teaching strategy to use when combining with computer simulation to teach specific science concepts. Also, once the pre-service teachers learn science concepts using computer simulation combined with inquiry-based techniques during education training, then as in-service teachers, they will construct and use these combinations in their inquiry practices and see the potential of these combinations in terms of helping them, and later their students, generate knowledge as they interact these combinations of effective teaching strategies.

Results in this current research study affirmed the benefits of simulations to help learners understand science processes by allowing them to visualize (Cox et al, 2011; Khan, 2011) processes and by allowing them to manipulate (Khan, 2011; Latham & Scully, 2008; Zacharia, 2005) variables in “real world” ways. Participants in this study, who were pre-service teachers in science education classes, successfully completed work sheets and tests that indicated they both learned key concepts related to density as well as how to use measures of weight and volume to calculate density. Further, participants expressed appreciation of the density simulations ease of use and consistency of measurements. Therefore, more studies like this current study needs to be done in order to strengthen the research information about inquiry+simulation teaching combinations and to verify the benefits of inquiry+simulation teaching combinations and to strengthen research information about using inquiry+simulation teaching combinations for teaching specific science concepts.

Quantitative analysis of pre and post-intervention knowledge tests, Likert-scale analysis, and worksheets showed that there were no meaningful differences between using POE and 5E to guide use of the density simulation. This suggests that either one of these proven and accepted inquiry methods effectively enhance simulation-based learning. The choice of either one can depend on the preferences of the instructor. The POE group completed the activity worksheets faster (at 38 average minutes) than the 5E group (which completed the 5E activity worksheets at 41 average minutes), but there was no difference between the two groups for the knowledge gained, problem-solving, and attitudes towards the simulation.

Results from this current research study add to the body of knowledge involving the use of computer simulation along with the inquiry-based teaching strategies, such as POE and 5E, to teach science. More data involving different science-subjects to be taught, different computer simulations to be used, and the teaching to be done in different contexts and different settings need to be carried out in order to further strengthen and increase knowledge involving the use of computer simulations combined with other teaching strategies in order to teach science.

These results also indicate that density computer simulations are useful in helping determine the best method to use when using computer simulation to teach science, and participants can learn about certain concepts after learning with the most effective inquiry-based teaching strategy with computer simulation, and this should also allow students to have a more positive attitude and perception while learning with the most effective combination when computer simulation is used to teach science. Results in this current research study affirmed the benefits of simulations to help learners understand science processes by allowing them to visualize (Cox et al, 2011; Khan, 2011) processes and by allowing them to manipulate (Khan, 2011; Latham & Scully, 2008; Zacharia, 2005) variables in "real world" ways.

Recommendations

Future research involving preservice teachers and the computer simulations used in this study should focus on studying additional science education topics and more and different computer simulations. More studies like this current study needs to be done in order to strengthen the research information about inquiry+simulation teaching combinations and to verify the benefits of inquiry+simulation teaching combinations and to strengthen research information about using inquiry+simulation teaching combinations for teaching specific science concepts.

One recommendation would be to compare actual teaching methods with teaching methods such as POE+simulation or 5E+simulation. For example, participants can be doing actual research such as actual research measurements and actual calculations while doing actual lab experiments and measurements and calculations compared to doing these in the simulation. Or a teacher can be doing actual lecturing and teaching such as old fashioned lecturing and teaching and this can be compared to this being done in the simulation and/or comparing this with POE+simulation or 5E+simulation. And so, actually doing measurements and doing actual physical measurements like actually measuring weight and volume and other actual physical measurements and comparing this to weight/volume/and/or other physical measurements being done in simulations or physical measurements being compared to measurements being done in computer simulation programs.

Implications for Teacher Education

This study was done in order to investigate the most effective combination when an inquiry-based teaching method is combined with computer simulation to teach certain science topics. The underlying assumption is that if pre-service teachers have a successful learning experience using science simulations in conjunction with systematic inquiry methods, then they will see the potential and value of using specific inquiry-based teaching strategies when used with computer simulation to teach specific science topics.

Overall Findings and Implications

Pretest and post knowledge tests and worksheet test results showed no meaningful differences between using POE and 5E to guide use of the density simulation. This suggests that either one of these proven and accepted inquiry methods effectively enhance simulation-based learning. The choice of either one can depend on the preferences of the instructor. The POE group completed worksheets faster (38 min.) than 5E group (41 min), but overall, there was no difference for the knowledge gained, problem-solving, and attitudes towards the simulation.

Implications for Teaching Science Using Combined Simulation+Inquiry

This study affirmed the benefits of simulations, and this study adds to the body of knowledge on use of computer simulation plus inquiry-based teaching strategies, such as POE and 5E, to teach science. Students could learn about density concepts with either inquiry-based strategy along with computer simulation, and this should also allow science teachers, and their students, to have a more positive attitude while learning with computer science simulations.

Conclusions

In summarizing the finding of the quantitative data, Table 13 shows the following results: (1) both groups started at the same level of knowledge about the topic of density (since they had comparable average pretest scores that were statistically comparable, shown in Table 2); (2) both groups got high average posttest scores that were statistically comparable (shown in Table 3); (2b) both groups gave comparable pretest-to-posttest change scores that were statistically comparable (shown in Table 5, Table 6, and Table 7); (3) both groups got high worksheet scores that were statistically comparable (shown in Table 8 and Table 9); and (4) both groups gave equally high Likert Scale opinion survey total scores for both teaching methods (shown in Table 10 and Table 11).

In summarizing the finding of the quantitative data, overall for the open-ended survey questions, the answers given by participants in both groups were similar, and participants in both groups showed positive perceptions and attitudes for the density computer simulation used in this research study. The 5E group had some indications of more critical thinking (based on qualitative data analysis), and the 5E participants seemed to have more varied responses for the open-ended survey questions. The 5E group seemed to have pointed out more weaknesses than the POE group, and the 5E group seem to have pointed out more emerging themes than the POE group. Also, the major themes with all of the qualitative, open-ended survey questions were (1) Visualization, (2) Manipulation, and (3) Logistics. Many of the literature review sources indicated these as major themes when using computer simulation to teach science, and they indicated that these themes were benefits of using simulation to teach science. This study further verifies the computer simulation benefits, and the qualitative results in this current research study affirmed the benefits of simulations to help learners understand science processes by allowing them to visualize (Cox et al, 2011; Khan, 2011) processes and by allowing them to manipulate (Khan, 2011; Latham & Scully, 2008; Zacharia, 2005) variables in “real world” ways. Therefore, more studies like this current study needs to be done in order to strengthen the research information about inquiry+simulation teaching combinations and to verify the benefits of inquiry+simulation teaching combinations and to strengthen research information about using inquiry+simulation teaching combinations for teaching specific science concepts.

There were no meaningful differences between using POE and 5E to guide use of the density simulation. POE and 5E were statistically comparable, and there was no statistical difference between POE and 5E. This suggests that either one of these proven and accepted inquiry methods effectively enhance simulation-based learning. The choice of either one can depend on the preferences of the instructor. The POE group completed the activity worksheets faster (at 38 average minutes) than the 5E group (which completed the 5E activity worksheets at 41 average minutes), but there was no difference between the two groups for the knowledge gained, problem-solving, and attitudes towards the simulation.

Results from this current research study should add to the body of knowledge involving the use of computer simulation along with the inquiry-based teaching strategies, such as POE and 5E, to teach science. More data involving different science subjects to be taught, different computer simulations to be used, and the teaching to be done in different contexts and different settings need to be carried out in order to further strengthen and increase knowledge involving the use of computer simulations combined with other teaching strategies in order to teach science.

These results also indicate that density computer simulations are useful in helping determine the best method to use when using computer simulation to teach science, and participants can learn about certain concepts after learning with the most effective inquiry-based teaching strategy with computer simulation; and this should also allow students to have a more positive attitude and perception while learning with the most effective combination when computer simulation is used to teach science. Results in this current research study affirmed the benefits of simulations to help learners understand science processes by allowing them to visualize (Cox et al, 2011; Khan, 2011) processes and by allowing them to manipulate (Khan, 2011; Latham & Scully, 2008; Zacharia, 2005) variables in "real world" ways.

Overall, participants liked and learned from both inquiry+simulation combinations (the POE+simulation and the 5E+Simulation combinations). Research to "prove" the value of simulation-based science learning has been done, and now the goal of studies can be to "improve" the use of inquiry+simulation-based teaching in science education. The assumption is that, if pre-service teachers use inquiry+simulation combinations successfully while they are learning and training to be teachers, then they are more likely to use these tools and methods in their future teaching of science concepts.

REFERENCES

Ackley, B. J., & Ladwig, G. B. (2010). *Nursing diagnosis handbook: An evidence-based guide to planning care*. Maryland Heights, Mo: Mosby. ISBN 9780323071505. Available from https://www.abebooks.com/9780323071505/Nursing-Diagnosis-Handbook-Evidence-Based-Guide-0323071503/plp

Akpan, J. P. (2001). Issues associated with inserting computer simulations into biology instruction: A review of the literature. *Electronic Journal of Science Education*, *5*(3), l. Retrieved from https://wolfweb.unr.edu/homepage/crowther/ejse/akpan

Ash, K. (2009). High-tech simulations linked to learning. *Education Week*, *28*(28), 20-23. Retrieved from https://www.edweek.org/ew/articles/2009/04/08/28games_ep.h28.html

Baker, D. & Taylor, P. C. S. (1995). The effect of culture on the learning of science in non-western countries: the results of an integrated research review. *International Journal of Science Education*, *17*(6), 695-704. doi:10.1080/0950069950170602. Available from https://www.tandfonline.com/doi/abs/10.1080/0950069950170602

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, *59*(5), 389-407. 10.1177/0022487108324554. Available from https://doi.org/10.1177/0022487108324554 Retrieved from https://journals.sagepub.com/doi/pdf/10.1177/0022487108324554 & https://www.math.ksu.edu/~bennett/onlinehw/qcenter/ballmkt.pdf & https://www.researchgate.net/publication/255647628_Content_Knowledge_for_Teaching_What_Makes_It_Special

Banchi, H., & Bell, R. (2008). The many levels of inquiry. *Science and Children*, *46*(2), 26–29.

Retrieved from http://www.miseagrant.umich.edu/lessons/files/2013/05/The-Many-Levels-of-Inquiry-NSTA-article.pdf

Benson, T. (2008). Gas Density. *Glenn Research Center*. Retrieved from https://web.archive.org/web/20130414132531/http://www.grc.nasa.gov/WWW/BGH/fluden.html

Bell, T., Urhahne, D., Schanze, S., & Ploetzner, R. (2010). Collaborative inquiry learning: models, tools, and challenges. *International Journal of Science Education*, *3*(1), 349–377. Retrieved from https://pdfs.semanticscholar.org/6650/9144b5a7284f6a0e2333b89aa0d6128eb983.pdf

Bilgin, I., Coşkun, H., & Aktaş, I. (2013). The effect of 5E learning cycle on mental ability of elementary students. *Journal of Baltic Science Education*, *12*(5), 592-607. Retrieved from https://www.researchgate.net/publication/287705967_The_effect_of_5e_learning_cycle_on_mental_ability_of_elementary_students

Bloom, B. (1984). The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher*, *13*(6), 4-16. Retrieved from http://web.mit.edu/5.95/readings/bloom-two-sigma.pdf & http://web.mit.edu/bosworth/MacData/afs.course/5/5.95/readings/bloom-two-sigma.pdf

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives: The classification of educational goals*. Handbook I: Cognitive domain. New York, NY: David McKay Company. Available from https://www.scirp.org/(S(lz5mqp453edsnp55rrgjct55))/reference/ReferencesPapers.aspx?ReferenceID=463242

Bonwell, C. C., & Eison, J. A. (1991). Active learning: Creating excitement in the classroom. *ASHE-ERIC Higher Education Reports*. Retrieved from https://eric.ed.gov/?id=ED336049 & https://files.eric.ed.gov/fulltext/ED336049.pdf

Boyatzis, R. (1998). *Transforming qualitative information: Thematic analysis and code development*. Thousand Oaks, CA: Sage Publications, Inc. Available from https://us.sagepub.com/en-us/nam/transforming-qualitative-information/book7714 & https://psycnet.apa.org/record/1998-08155-000

Brains, C. L., Willnat, L., Manheim, J. B., & Rich, R. C. (2011). *Empirical Political Analysis, 8th Edition*. Boston, MA: Longman. ISBN-13: 978-0205791217. ISBN-10: 0205791212.

Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*. *3*(2), 83. doi:10.1191/1478088706qp063oa. Available from https://www.tandfonline.com/doi/abs/10.1191/1478088706qp063oa

Bruner, J. S. (1961). The act of discovery. *Harvard Educational Review*, *31*, 21–32. Available from https://www.scirp.org/(S(i43dyn45teexjx455qlt3d2q))/reference/ReferencesPapers.aspx?ReferenceID=1412275

Bybee, R., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). *The BSCS 5E instructional model: Origins and effectiveness*. Colorado Springs, CO: BSCS. Retrieved from https://bscs.org/sites/default/files/_legacy/BSCS_5E_Instructional_Model-Full_Report.pdf

Cambridge University Press. (n.d.). Retrieved from https://dictionary.cambridge.org/us/dictionary/english/effective

Campbell, M. (2006). *The effects of the 5e learning cycle model on students' understanding of force and motion concepts* (Master's Thesis). Retrieved from http://stars.library.ucf.edu/cgi/viewcontent.cgi?article=1808&context=etd (809)

Centre for Excellence in Enquiry-Based Learning. (2010). What is Enquiry-Based Learning (EBL)? The University of Manchester. Retrieved from http://www.ceebl.manchester.ac.uk/ebl/

Chabalengula, V., Fateen, R., Mumba, F. & Ochs, L.K. (2016). Effect of Inquiry-Based Computer Simulation Modeling on Pre-service Teachers' Understanding of Homeostasis and their Perceptions of Design Features. *Journal of Computers in Mathematics and Science Teaching*, *35*(3), 225-248. Waynesville, NC USA: Association for the Advancement of Computing in Education (AACE). Available from https://www.learntechlib.org/p/150938/

Champagne, A. B., Klopfer, L. E., & Anderson, J. H. (1980). Factors influencing the learning of classical mechanics. *American Journal of Physics*, *48*, 1074-1079. https://doi.org/10.1119/1.12290 Retrieved from https://files.eric.ed.gov/fulltext/ED180829.pdf & https://aapt.scitation.org/doi/pdf/10.1119/1.12290?class=pdf

Charney, D., Reder, L., & Kusbit, G. (1990). Goal setting and procedure selection in acquiring computer skills: A comparison of tutorials, problem solving, and learner exploration. *Cognition & Instruction*, *7*(4), 323–342. doi:10.1207/s1532690xci0704_3. Available from: https://www.tandfonline.com/doi/abs/10.1207/s1532690xci0704_3

Chen, C. -H., & Howard, B. (2010). Effect of live simulation on middle school students' attitudes and learning toward science. *Educational Technology & Society*, *13*(1), 133–139.

Available from https://eric.ed.gov/?id=EJ880083

Cobern, W. W. & Aikenhead, G. (1997). Cultural aspects of learning science. *Scientific Literacy and Cultural Studies Project.* Mallinson Institute for Science Education. National Association for Research in Science Teaching. Chicago, IL. Available from http://scholarworks.wmich.edu/science_slcsp/13 Retrieved from https://scholarworks.wmich.edu/cgi/viewcontent.cgi?article=1012&context=science_slcsp

Corporation for Public Broadcasting. (2002) The 5 E's. Retrieved from http://enhancinged.wgbh.org/research/eeeee.html

Cote, D. (2007). Problem-based learning software for students with disabilities. *Intervention in School & Clinic*, *43*(1), 29-37. https://journals.sagepub.com/doi/abs/10.1177/10534512070430010401 Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.558.8282&rep=rep1&type=pdf

Cox, A. J., Junkin, W. F., III., Christian, W., Belloni, M., & Esquembre, F. (2011). Teaching physics (and some computation) using intentionally incorrect simulations. *Physics Teacher*, *49*(5), 273-276. Available from https://www.researchgate.net/publication/253003731_Teaching_Physics_and_Some_Computation_Using_Intentionally_Incorrect_Simulations

Creswell, J. W., & Poth, C. N. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd ed). Thousand Oaks, CA, US: Sage Publications, Inc., 183-218. ISBN13: 9781412965576. ISBN10: 1412965578. Available from https://www.textbooks.com/Research-Design-Qualitative-Quantitative-and-Mixed-Methods-Approaches-3rd-Edition/9781412965576/John-W-

Creswell.php?CSID=AWT3Q23JOSQAOMAKMTKDTDSCB &
https://books.google.com/books/about/Qualitative_Inquiry_and_Research_Design.html?id=UgFIMQAACAAJ

Daly, J., Kellehear, A., & Gliksman, M. (1997). *The public health researcher: A methodological approach*. Melbourne, Australia: Oxford University Press. Available from https://www.scirp.org/(S(351jmbntvnsjt1aadkposzje))/reference/ReferencesPapers.aspx?ReferenceID=1753470

Dostál, J. (2015). *Inquiry-based instruction: Concept, essence, importance and contribution*. Olomouc: Palacký University. Available from https://www.researchgate.net/publication/278406129_Inquiry-based_instruction_concept_essence_importance_and_contribution Retrieved from https://www.researchgate.net/profile/Jiri_Dostal5/publication/278406129_Inquiry-based_instruction_concept_essence_importance_and_contribution/links/5580465108ae0e061932b24b/Inquiry-based-instruction-concept-essence-importance-and-contribution.pdf

Eagly, A. H., & Chaiken, S. (1998). Attitude structure and function. In D.T. Gilbert, Susan T. Fiske, and G. Lindzey (eds.), *Handbook of Social Psychology* (4th ed., pp. 269–322). New York: Oxford Univeristy Press. Available from https://www.scholars.northwestern.edu/en/publications/attitude-structure-and-function

Edinformatics. (1999). Mass volume density quiz (Level 1). Retrieved from http://www.edinformatics.com/math_science/mvd_quiz.htm

Enugu, R. K. (2016). *Challenges pre-service science teachers face when implementing a 5E inquiry model of instruction* (Master's Thesis). Texas Christian University, Fort Worth, Texas. Retrieved from https://repository.tcu.edu/bitstream/handle/116099117/10925/Enugu_tcu_0229M_10660.pdf?sequence=1&isAllowed=y

Erickson, K. (2018). 5Es Overview: The 5E instructional model. Retrieved from https://nasaeclips.arc.nasa.gov/teachertoolbox/the5e

Fraenkel, J., & Wallen, N. (2009). How to design and evaluate research in education. Boston, MA: McGraw-Hill. ISBN-13: 978-0078097850. ISBN-10: 0078097851.

George, D., & Mallery, P. (2003). *SPSS for Windows step by step: A simple guide and reference fourth edition (11.0 update).* Boston: Allyn & Bacon. Retrieved from https://wps.ablongman.com/wps/media/objects/385/394732/george4answers.pdf

Gizmos. (2019). Online simulations that power inquiry and understanding. Retrieved from https://www.explorelearning.com/

Gliem, J. A., and Gliem, R. R. (2003). *Calculating, Interpreting, and Reporting Cronbach's Alpha Reliability Coefficient for Likert-Type Scales.* Retrieved from https://scholarworks.iupui.edu/bitstream/handle/1805/344/Gliem+&+Gliem.pdf?sequence=1

Glynn, S.M., & Koballa, T.R. Jr., (2006). *Motivation to learn in college science*. In J.J. Mintzes & W.H. Leonard (Eds.), Handbook of college science teaching (pp. 25–32). Arlington, VA: National Science Teachers Association Press.

Glynn, S. M., Taasoobshirazi, G., & Brickman, P. (2009). Science motivation questionnaire: Construct validation with nonscience majors. *Journal of Research in Science Teaching, 46*(2), 127-146. https://onlinelibrary.wiley.com/doi/pdf/10.1002/tea.20267 Retrieved from https://pdfs.semanticscholar.org/eb7b/40a696b582f58af411bbeef38f567b448645.pdf

Gonzalez-Cruz, J., Rodriguez-Sotres, R., & Rodriguez-Penagos, M. (2003). On the convenience of using a computer simulation to teach enzyme kinetics to undergraduate students with biological chemistry-related curricula. *Biochemistry and Molecular Biology Education*, *31*(2), 93-101. Retrieved from https://iubmb.onlinelibrary.wiley.com/doi/full/10.1002/bmb.2003.494031020193

Grbich, C. (2013). *Qualitative data analysis* (2nd ed.). The Flinders University of South Australia: SAGE Publications Ltd. Available from https://uk.sagepub.com/en-gb/eur/qualitative-data-analysis/book236861

Guest, G., MacQueen, K. M., & Namey, E. E. (2012). *Applied thematic analysis* (p. 11). Thousand Oaks, California: SAGE Publications, Inc. Available from https://us.sagepub.com/en-us/nam/applied-thematic-analysis/book233379

Guido, M. (2016). 5 advantages and disadvantages of problem-based learning [+ activity design steps]. Retrieved from https://www.prodigygame.com/blog/advantages-disadvantages-problem-based-learning/

Hasanbegovic, J. (2006). *Learning strategy*. IGIP Course materials, Module 5 - Tutoring and Collaboration.

Hay, I. (2005). *Qualitative research methods in human geography*. (2nd ed.). Oxford: Oxford University Press. Available from https://www.tandfonline.com/doi/abs/10.1080/00221340802206303

Honey, M. A., & Hilton, M. (2011). *Learning science through computer games and simulations*. Washington, DC: The National Academies Press. Retrieved from https://www.ics.uci.edu/~wscacchi/GameLab/Recommended%20Readings/LearningScience-Games-2011.pdf

Horton, P., McCarthy, T., Werwa, E., & Dinah, Z. (2008). *Density*. The Nature of Matter. New York: McGraw-Hill.

Hung, W. (2011). Theory to reality: A few issues in implementing problem-based learning. *Educational Technology Research and Development*. *59*(4): 529–552. doi:10.1007/s11423-011-9198-1. https://doi.org/10.1007/s11423-011-9198-1 Retrieved from https://link.springer.com/article/10.1007/s11423-011-9198-1

Ioannidou, A., Repenning, A., Webb, D., Keyser, D., Luhn, L., & Daetwyler, C. (2010). Mr. Vetro: A collective simulation for teaching health science. *International Journal of Computer-Supported Collaborative Learning*, *5*(2), 141-166. Retrieved from https://link.springer.com/article/10.1007/s11412-010-9082-8

Johnstone, A. H., (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning*, *7*(2), 75-83. http://dx.doi.org/10.1111/j.1365-2729.1991.tb00230.x Available from https://eric.ed.gov/?id=EJ430257 & https://psycnet.apa.org/record/1991-34607-001 & https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2729.1991.tb00230.x

Joyce, C. (2006). Predict, observe, explain (POE). *Assessment Resource Banks*. Retrieved from https://arbs.nzcer.org.nz/predict-observe-explain-poe

Justi, R. & Gilbert, J. K. (2002). Science teachers' knowledge about and attitudes towards the use of models and modelling in learning science. *International Journal of Science Education*, *24*(12), 1273–1292. doi:10.1080/09500690210163198. Available from https://www.tandfonline.com/doi/abs/10.1080/09500690210163198 & https://www.researchgate.net/publication/252510582_Science_teachers'_knowledge_about_and_attitudes_towards_the_use_of_models_and_modeling_in_learning_science

Karplus R., & Thier, H. D. (1967). *A new look at elementary school science, new trends in curriculum and instruction series*. Chicago: Rand McNally. ERIC Number: ED017447. Available from https://eric.ed.gov/?id=ED017447

Khan, S. (2011). New pedagogies on teaching science with computer simulations. *Journal of Science Education and Technology*, *20*(3), 215-232. Available from https://www.learntechlib.org/p/52553/

Kiboss, J. K., Ndirangu, M., & Wekesa, E. W. (2004). Effectiveness of a computer-mediated simulations program in school biology on pupils' learning outcomes in cell theory. *Journal of Science Education and Technology*, *13*(2), 207-213. Available from https://link.springer.com/article/10.1023/B:JOST.0000031259.76872.f1 Retrieved from https://link.springer.com/content/pdf/10.1023%2FB%3AJOST.0000031259.76872.f1.pdf

Kiboss, J., Wekesa, E., & Ndirangu, M. (2006). Improving students' understanding and perception of cell theory in school biology using a computer-based instruction simulation program. *Journal of Educational Multimedia and Hypermedia*, *15*(4), 397-410. Available from https://eric.ed.gov/?id=EJ742381

Latham, L. G. II., & Scully, E. P. (2008). Critters! A realistic simulation for teaching evolutionary biology. *The American Biology Teacher*, *70*(1), 30-34. Retrieved from https://bioone.org/journals/The-American-Biology-Teacher/volume-70/issue-1/0002-7685(2008)70[30:CARSFT]2.0.CO;2/Critters-A-Realistic-Simulation-for- Teaching-Evolutionary-Biology/10.1662/0002-7685(2008)70[30:CARSFT]2.0.CO;2.full

Merriam-Webster, Incorporated. (n.d.). Retrieved from https://www.merriam-webster.com/dictionary/dependent%20variable

Merriam-Webster, Incorporated. (n.d.). Retrieved from https://www.merriam-webster.com/dictionary/effective

Merriam-Webster, Incorporated. (n.d.). Retrieved from https://www.merriam-webster.com/dictionary/independent%20variable

Merriam-Webster, Incorporated. (n.d.). Retrieved from https://www.merriam-webster.com/dictionary/strong

Mohanty, S. D., & Cantu, S. (2011). Teaching introductory undergraduate physics using commercial video games. *Physics Education*, *46*(5), 570-577. doi:10.1088/0031-9120/46/5/009. Available from https://arxiv.org/abs/1107.5298 Retrieved from https://iopscience.iop.org/article/10.1088/0031-9120/46/5/009/pdf & https://www.researchgate.net/publication/51918710_Teaching_introductory_undergraduate_Physics_using_commercial_video_games

Murphy, M. (2005). *The history and philosophy of education: Voices of educational pioneers*. Upper Saddle River: Prentice Hall PTR. ISBN 0130955507. ISBN-13: 9780130955500. ISBN-10: 0130955507. Available from https://www.campusbookrentals.com/textbook/the-history-and-philosophy-of-education-murphy/9780130955500

National Institute for Health. (2005). *Doing science: The process of science inquiry*. Colorado Springs, CO: BSCS. Retrieved from http://www.uwyo.edu/scienceposse/resources/nih_doing-science.pdf

National Research Council. (1996). *National Science Education Standards*. Washington, DC: The National Academies Press. https://doi.org/10.17226/4962 Available from https://www.nap.edu/catalog/4962/national-science-education-standards Retrieved from https://www.csun.edu/science/ref/curriculum/reforms/nses/nses-complete.pdf

National Research Council (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. Washington, DC: The National Academies Press. https://doi.org/10.17226/9596 Available from https://www.nap.edu/catalog/9596/inquiry-and-the-national-science-education-standards-a-guide-for & https://trove.nla.gov.au/work/33910363?q&versionId=46667856 Retrieved from https://www.nap.edu/read/9596/chapter/1

Oil Gas Glossary (2014). Density Definition. Retrieved from http://oilgasglossary.com/density.html

Oxford University Press. (n.d.). Retrieved from https://en.oxforddictionaries.com/definition/effective

Oxford University Press. (n.d.). Retrieved from https://www.lexico.com/en/definition/strong

Rands, S. A. (2012). Using physical and computer simulations of collective behaviour as an introduction to modelling concepts for applied biologists. *Bioscience Education*, *19*(1), 1-10. doi:10.11120/beej.2012.19000005. Retrieved from https://www.tandfonline.com/doi/full/10.11120/beej.2012.19000005

Renkl, A., Atkinson, R. K., Maier, U. H., & Staley, R. (2002). From example study to problem solving: smooth transitions help learning. *Journal of Experimental Education*, *70*(4), 293–315. Available from https://asu.pure.elsevier.com/en/publications/from-example-study-to-problem-solving-smooth-transitions-help-lea & https://www.researchgate.net/publication/298585531_From_example_study_to_problem_solving_Smooth_transitions_help_learning

Ryan, G. & Bernard, H. R. (2003). Techniques to identify themes. *Field Methods*, *15*(1), 85-109.

https://doi.org/10.1177/1525822X02239569 Available from https://journals.sagepub.com/doi/10.1177/1525822X02239569 Retrieved from https://pdfs.semanticscholar.org/a31e/c3652f3f1b6df31423883a1fc7fbf8509ce4.pdf

Saldaña, J. (2015). *The coding manual for qualitative researchers* (3rd ed.). Thousand Oaks: SAGE Publications Ltd. Available from https://books.google.com/books?hl=en&lr=&id=ZhxiCgAAQBAJ&oi=fnd&pg=PP1&dq=Salda%C3%B1a,+J.+(2015).+The+coding+manual+for+qualitative+researchers+(3rd+ed.).+SAGE+Publications+Ltd.&ots=yIWc1zQWeP&sig=CrZYQFfKKTKoc9WXEupJP6z9mP0#v=onepage&q&f=false

Sarıa, U., Hassanb, A. H., Kutalmış Güvena, K., & Şena, Ö. F. (2017). Effects of the 5E teaching model using interactive simulation on achievement and attitude in physics education. *International Journal of Innovation in Science and Mathematics Education*, *25*(3), 20-35. Retrieved from https://openjournals.library.sydney.edu.au/index.php/CAL/article/view/11383/11418

Schmidt, H. G., Rotgans, J. I., &; Yew, E. H. (2011). The process of problem-based learning: what works and why. *Medical Education*. *45*(8): 792–806. doi:10.1111/j.1365-2923.2011.04035.x Available from https://www.ncbi.nlm.nih.gov/pubmed/21752076 Retrieved from https://onlinelibrary.wiley.com/doi/full/10.1111/j.1365-2923.2011.04035.x & https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1365-2923.2011.04035.x

Schwab, J. J. (1962). The teaching of science as inquiry. *Bulletin of the Atomic Scientists*, *14*(9), 374-379. https://doi.org/10.1080/00963402.1958.11453895 Available from https://www.tandfonline.com/doi/abs/10.1080/00963402.1958.11453895 &

https://www.scirp.org/(S(vtj3fa45qm1ean45vvffcz55))/reference/ReferencesPapers.aspx?ReferenceID=741795

Schwarz, N., & Bohner, G. (2001). The construction of attitudes. In A. Tesser & N. Schwarz (Eds.), *Intrapersonal Processes (Blackwell Handbook of Social Psychology)* (pp. 436-457). Oxford, UK: Blackwell. Retrieved from https://pdfs.semanticscholar.org/0887/7666eb361ad712ed565d0b0f2cf7e7a3490d.pdf

Shirley, V. N. (2011). Teacher education in Canada. *Journal of Education for Teaching, 37*(4), 409-421. doi:10.1080/02607476.2011.611222. https://doi.org/10.1080/02607476.2011.611222 Retrieved from http://education.eng.macam.ac.il/article/2992

Springer Nature Limited. (n.d.). Retrieved from https://www.macmillandictionary.com/us/dictionary/american/effective

Stafford, R., Goodenough, A. E., & Davies, M. S. (2010). Assessing the effectiveness of a computer simulation for teaching ecological experimental design. *Bioscience Education, 15*(1), 1-9. Available from https://www.tandfonline.com/doi/full/10.3108/beej.15.1 Retrieved from https://www.tandfonline.com/doi/full/10.3108/beej.15.1#aHR0cHM6Ly93d3cudGFuZGZvbmxpbmUuY29tL2RvaS9wZGYvMTAuMzEwOC9iZWVqLjE1LjE/bmVlZEFjY2Vzcz10cnVlQEBAMA==

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education, 2,* 53–55. doi:10.5116/ijme.4dfb.8dfd. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4205511/

The Glossary of Education Reform. (2016). Content Knowledge. Retrieved from https://www.edglossary.org/content-knowledge/

Trey, L., & Khan, S. (2008). How science students can learn about unobservable phenomena using computer-based analogies. *Computers & Education*, *51*(2), 519-529. Retrieved from https://www.sciencedirect.com/science/article/pii/S036013150700070X?via%3Dihub & https://www.sciencedirect.com/science/article/pii/S036013150700070X/pdfft?md5=8ab1842bac7c63b93d64c3cf63c802c7&pid=1-s2.0-S036013150700070X-main.pdf

Tshewang, N. & Khajornsak, B. (2017). The development of simulation and game in 5E earning cycle to teach photoelectric effect for grade 12 students. *Asia-Pacific Forum on Science Learning and Teaching*, *18*(2), 1-30. Retrieved from https://www.eduhk.hk/apfslt/download/v18_issue2_files/buaraphan.pdf

UKEssays. (2017). Why science is difficult to learn. Retrieved from https://www.ukessays.com/essays/education/why-can-science-be-difficult-to-learn-education-essay.php?vref=1

University of Colorado Boulder (2019). Interactive simulations for science and math. Retrieved from https://phet.colorado.edu/mr/Vocabulary.com. (n.d.). Retrieved from https://www.vocabulary.com/dictionary/effective

Wehmeyer, M., & Schwartz, M. (1998). The relationship between self-determination and quality of life for adults with mental retardation. *Education and Training in Mental Retardation and Developmental Disabilities*, *33*(1), 3-12. Available from: https://kuscholarworks.ku.edu/handle/1808/6237 Retrieved from http://supporteddecisionmaking.org/sites/default/files/relationship_between_self-determination_quality_of_life.pdf

Windschitl, M., Thompson, J. & Braaten, M. (2008). Beyond the scientific method: model-based inquiry as a new paradigm of preference for school science investigations. *Science Education*, *92*(5), 941–967. Available from https://onlinelibrary.wiley.com/doi/abs/10.1002/sce.20259 Retrieved from https://onlinelibrary.wiley.com/doi/epdf/10.1002/sce.20259

Winn, W., Stahr, F., Sarason, C., Fruland, R., Oppenheimer, P., & Lee, Y. (2006). Learning oceanography from a computer simulation compared with direct experience at sea. *Journal of Research in Science Teaching*, *43*(1), 25-42. Retrieved from https://onlinelibrary.wiley.com/doi/epdf/10.1002/tea.20097

Wood, D. F. (2003) ABC of learning and teaching in medicine: Problem based learning. *British Medical Journal (BMJ)*, *326*(7384), 328–330. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1125189/

Wood, W. (2000). Attitude change: Persuasion and social influence. *Annual Review of Psychology*, *51*, 539–570. doi:10.1146/annurev.psych.51.1.539. PMID 10751980. Available from https://europepmc.org/abstract/med/10751980 Retrieved from https://www.annualreviews.org/doi/full/10.1146/annurev.psych.51.1.539

Zacharia, Z. C. (2005). The impact of interactive computer simulations on the nature and quality of postgraduate science teachers' explanations in physics. *International Journal of Science Education*, *27*(14), 1741–1767. doi:10.1080/09500690500239664 Retrieved from https://www.tandfonline.com/doi/full/10.1080/09500690500239664

APPENDIX A

PRE-TEST

PRE-TEST for Density (5E and POE)
(-ENGAGEMENT (PRE-TEST: For 5E Model))
(-Instructions: Either Fill in the Blank or Circle Your Answer)
(Edinformatics (1999), and Content Knowledge Questions, adapted from
http://www.edinformatics.com/math_science/mvd_quiz.htm)

Name: ____ Date_____________________

1. Fill in the blank: The greater the amount of matter that is packed into a given space,

the greater the ______________________.

- **A.** mass
- **B.** density
- **C.** volume
- **D.** temperature

2. Why does oil float on water? (Circle Your Answer)

- **A.** Because oil does not dissolve in water
- **B.** Because oil is less dense than water
- **C.** Because water weighs more than oil (or is heavier than oil)
- **D.** Because oil does not dissolve in water and oil is also is less dense than water

3. The amount of matter that an object has is called its _______________
(Circle Your Answer)

- **A.** Volume
- **B.** Mass
- **C.** Weight
- **D.** Density

4. **What property is being measured in the image below? (<u>Circle Your Answer</u>)**

A. mass

B. density

C. volume

D. weight

5. **If the units of gram (or g) is used to measure mass and the units of milliliters (or mL) are used to measure volume, then what will the resulting units for density be? (<u>Circle Your Answer</u>)**

A. mL

B. grams

C. g - mL

D. g/mL

6. **A ball has a mass of 30 grams and a volume of 15 milliliters (or mL). What is its density? (<u>Circle Your Answer</u>)**

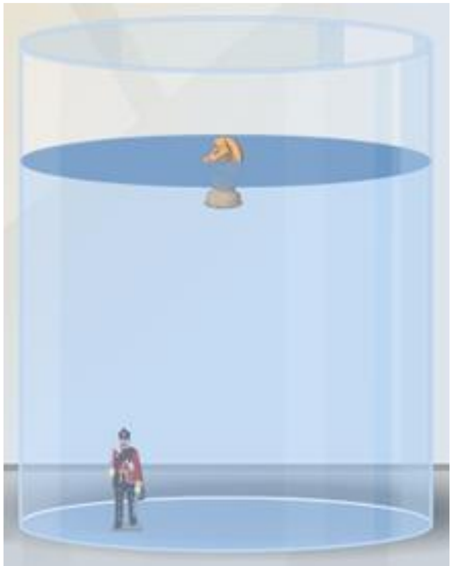
A. 0.50 g/mL

B. 2.0 g/mL

C. 15 g/mL

D. 450 g/mL

7. According to the picture, which of the two items is less dense? (<u>Circle Your Answer</u>)



A. the chess piece

B. the toy soldier

C. the liquid in the container

D. There is no way to tell.

8. Fill in the blank: An object is most likely to sink in water if ________________.

A. it has a larger mass

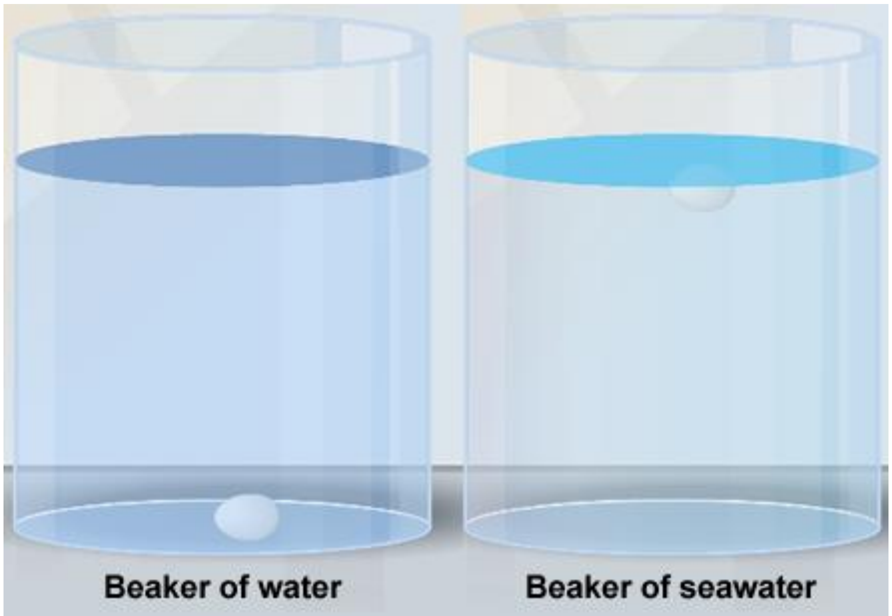
B. it has a larger volume

C. it has a larger density

D. it has a smaller density

9. The image below shows the same egg in plain water (on the left) and in seawater (on the right).

What must be true about these two liquids? (<u>Circle Your Answer</u>)



A. The seawater is less dense than the plain water.

B. The seawater is more dense than the plain water.

C. The plain water and the seawater have equal densities.

D. It is impossible to tell which liquid is denser.

APPENDIX B

POST-TEST

<u>POST-TEST</u> for Density (5E and POE)
(EVALUATION (<u>POST-TEST</u> For 5E Model))
(-Instructions: <u>Either Fill in the Blank or Circle Your Answer)</u>
(Edinformatics (1999), and Content Knowledge Questions, adapted from
http://www.edinformatics.com/math_science/mvd_quiz.htm)

Name: ____ Date_____________________

1. **<u>Fill in the blank</u>: The greater the amount of matter that is packed into a given space, the greater the ______________________.**

   A. volume

   B. temperature

   C. density

   D. mass

2. **Why does oil float on water? (<u>Circle Your Answer</u>)**

   A. Because water weighs more than oil (or is heavier than oil)

   B. Because oil does not dissolve in water

   C. Because oil is less dense than water

   D. Because oil does not dissolve in water and oil is also is less dense than water

3. **The amount of matter that an object has is called its _______________ (<u>Circle Your Answer</u>)**

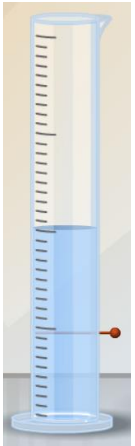
   A. Weight

   B. Density

   C. Mass

   D. Volume

4. What property does a graduated cylinder (shown below) measure? (<u>Circle Your Answer</u>)



A. Mass

B. Volume

C. Weight

D. Density

5. If the units of milliliters (or mL) are used to measure volume, and the units of gram (or g) is used to measure mass, then what will the resulting units for density be? (<u>Circle Your Answer</u>)

A. grams

B. mL

C. g/mL

D. g - mL

6. What is the density of a block that has a mass of 36 grams (or g) and a volume of 9 milliliters (or mL)? (<u>Circle Your Answer</u>)

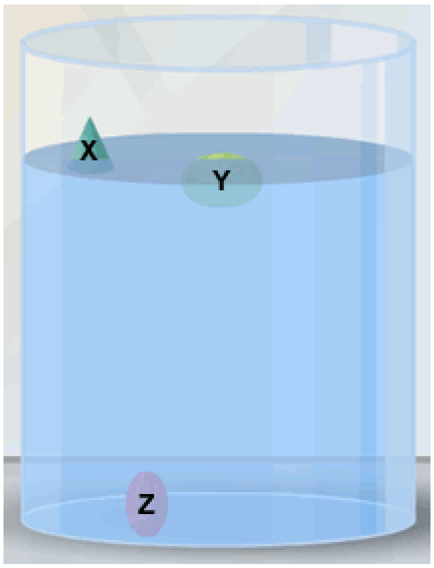
A. 45 g/mL

B. 27 g/mL

C. 4 g/mL

D. 0.25 g/mL

7. Based on the diagram below, rank the three objects from least dense to most dense. (<u>Circle Your Answer</u>)



A. Object X, object Z, object Y.

B. Object Z, object Y, object X.

C. Object X, object Y, object Z.

D. Object Y, object Z, object X.

8. Fill in the blank: An object is most likely to sink in water if ________________.

A. the object has a larger mass than water

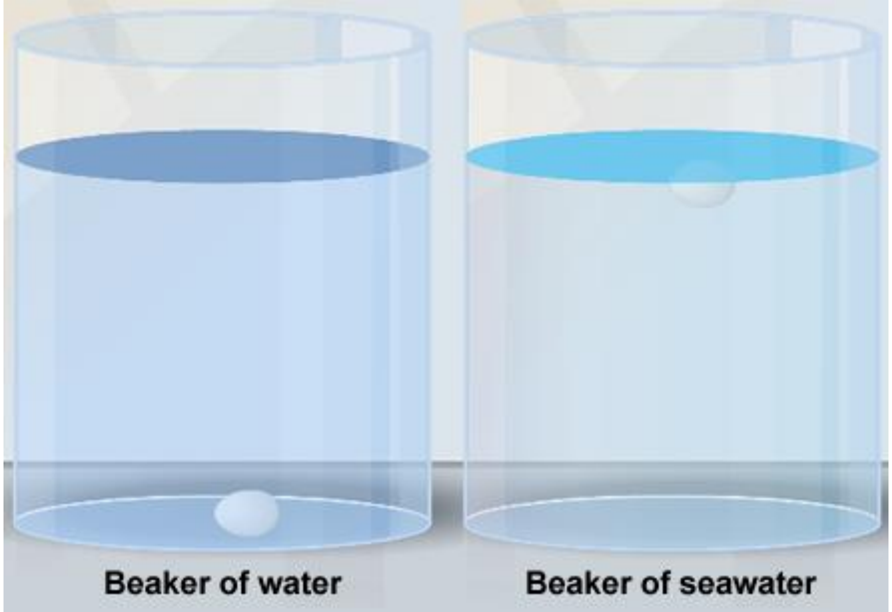
B. the object has a larger density than water

C. the object has a larger volume than water

D. the object has a smaller density than water

9. The image below shows the same egg in plain water (on the left) and in seawater (on the right).

What must be true about these liquids? (<u>Circle Your Answer</u>)



A. The seawater is less dense than the plain water.

B. It is impossible to tell which liquid is denser.

C. The seawater is more dense than the plain water.

D. The plain water and the seawater have equal densities.

APPENDIX C

THE POE ACTIVITY WORKSHEET

Activity Worksheet: Computer Simulation on Density

Name: ____ **Date**____________________

Overall Description of this Density Simulation Activity:

* In this activity, measure the mass and volume of a variety of objects,
* then place them into a beaker of liquid (water) to see if they float or sink.
* By comparing the density of each object with the density of the liquid in the beaker (water),
* learn to predict whether objects will float or sink in water based on the object's mass and volume and calculated densities.

Learning Objectives

* State the SI units used for mass (in grams, or g) and volume (in milliliters, or mL).
* Measure the volumes of irregular objects using water displacement.
* Discover that density can be measured.
* Calculate the densities of irregular objects.
* Predict whether an object will float or sink in water by measuring the object's mass and volume and by comparing the object's density to the density of water.
* Water has a density of 1.0 g/mL (or 1.0 grams per milliliters).
*Define the relationship among mass, volume, and density.

Vocabulary to Watch For

*density, mass, matter, volume, flotation

Accessing the density computer simulation:

1. Go to website, **explorelearning.com**
2. Go to Login:

Username: density1
Password: density

3. Scroll down to the section titled "**Elementary School Science Samples**"
4. and click the section titled "**Density**."

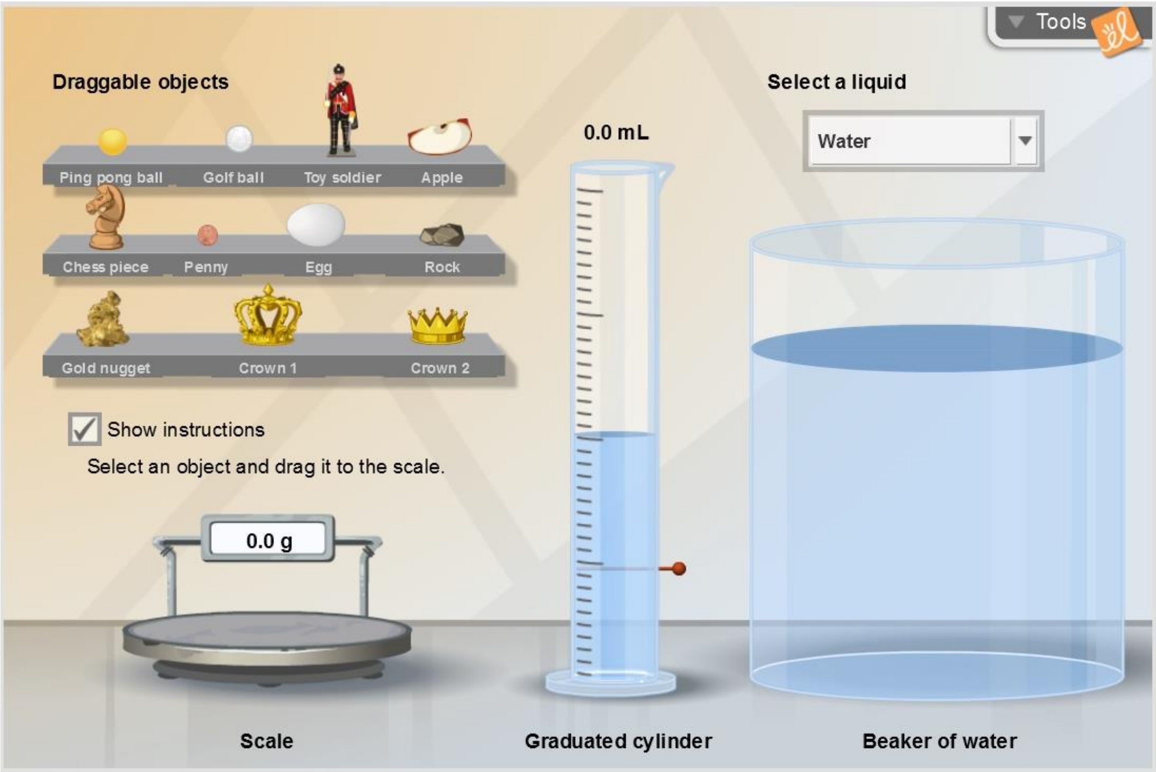
Or, use this second option to find the density computer simulation:

3. Click "Browse Gizmos" (located at the bottom of the page)
4. Click: "**Gizmos by Grade & Topic**"
5. Click: "**Grade 3-5**"
6. Click "**Physical Science**"
7. Scroll all the way down on the "**Physical Science**" menu

8. and Click: "**All Physical Science Subtopics**"
9. Click: "**Density**"

Form the hypothesis:

- Compare the density of each object with the density of water to determine whether each object will float in water or sink in water.
- Water has a density of 1.0 g/mL (or 1.0 grams per milliliters).
- If an object has a density that is lower than the density of water, then the object will float in water.
-If an object has a density that is higher than the density of water, then the object will sink in water.
-Determine if each object will float or sink in liquid water by comparing the density of the object with the density of water.



Step 1: Obtain the weight of each object (weight in grams (or g)) by placing each object on the scale (picture of scale shown above) and record the weight of each object in the table below.

Name of Each Object	Measure **Weight** (grams or g)	Measure **Volume** (milliliters or mL)	Calculate **Density** (g/mL)	**Predict** Will the Object **Float** or **Sink** in Water? (**Circle Your Answer**)		**Observe** Does the Object **Float** or **Sink** in Water? (**Circle Your Answer**)		**Explain** Does the Object have a **Higher** or **Lower** Density than Water? (**Circle Your Answer**)	
Ping Pong Ball				Float	Sink	Float	Sink	Higher	Lower
Golf Ball				Float	Sink	Float	Sink	Higher	Lower
Toy Soldier				Float	Sink	Float	Sink	Higher	Lower
Apple				Float	Sink	Float	Sink	Higher	Lower
Chess Piece				Float	Sink	Float	Sink	Higher	Lower
Penny				Float	Sink	Float	Sink	Higher	Lower
Egg				Float	Sink	Float	Sink	Higher	Lower
Rock				Float	Sink	Float	Sink	Higher	Lower
Gold Nugget				Float	Sink	Float	Sink	Higher	Lower
Crown 1				Float	Sink	Float	Sink	Higher	Lower
Crown 2				Float	Sink	Float	Sink	Higher	Lower

Step 2: Obtain the volume of each object (volume in milliliters (or mL)) by placing each object in the liquid in the graduated cylinder (picture of graduated cylinder shown above) and record the volume of each object in the table above.

Step 3: Calculate the density of each object and record the densities in the table above.

Predict

Step 4: Based on the density of each object, predict whether each object will float or sink in liquid water by circling your answer in the table above as either float or sink under the column listed as "Predict" (liquid water has a density of 1.0 g/mL (or 1.0 grams per milliliters)).

Observe

Step 5: (Now to compare the density of each object with the density of water); Place each object in the water located in the container (picture of container shown above) and indicate whether each object FLOATED in water or SANK in water (circle your answer as either Float OR Sink in the table)

Explain

Step 6: Indicate in the table whether each object had a HIGHER density than water or a LOWER density than water (circle your answer): (density units are in grams per milliliters (or g/mL)) and water has a density of 1.0 g/mL (or 1.0 grams per milliliters)).

Step 7: Use the information in the table above to answer the following questions:

A1. Which items floated in liquid water? ____

____

____

A2. How do the density of these items compare to that of liquid water? Is each density higher or lower than the density of water? Water has a density of 1.0 g/mL (or 1.0 grams per milliliters)).

____

____

A3. Which items sank in liquid water? ____

____

____

A4. How do the density of these items compare to that of liquid water? Is each density higher or lower than the density of water? Water has a density of 1.0 g/mL (or 1.0 grams per milliliters)).

____

____

A5. If an item has a density less than the density of liquid water, will the item float or sink in liquid water? (Circle your answer)

A6. If an item has a density greater than the density of liquid water, will the item float or sink in liquid water? (Circle your answer)

B1. Why does oil float on water? (Circle Your Answer)

- **A.** Because oil does not dissolve in water
- **B.** Because oil is less dense than water
- **C.** Because water weighs more than oil (or is heavier than oil)
- **D.** Because oil does not dissolve in water and oil is also is less dense than water

B2. The amount of matter that an object has is called its _______________ (Circle Your Answer)

A. Volume **B.** Mass **C.** Weight **D.** Density

B3. What property does a graduated cylinder (shown above) measure? (Circle Your Answer)

A. Mass **B.** Volume **C.** Weight **D.** Density

B4. If the units of milliliters (or mL) are used to measure volume, and the units of gram (or g) is used to measure mass, then what will the resulting units for density be? (Circle Your Answer)

A. grams **B.** mL **C.** g/mL **D.** g - mL

B5. Why is liquid water more-dense than ice? ________________________________

____

____

APPENDIX D

THE 5E ACTIVITY WORKSHEET

Activity Worksheet: <u>Computer Simulation</u> on <u>Density</u>

Name: ____ Date_____________________

<u>Overall Description of this Density Simulation Activity:</u>

* In this activity, measure the mass and volume of a variety of objects,
* then place them into a beaker of liquid (water) to see if they float or sink.
* By comparing the density of each object with the density of the liquid in the beaker (water),
* learn to predict whether objects will float or sink in water based on the object's mass and volume and calculated densities.

<u>Learning Objectives</u>

* State the SI units used for <u>mass</u> (in grams, or <u>g</u>) and <u>volume</u> (in milliliters, or <u>mL</u>).
* Measure the volumes of irregular objects using water displacement.
* Discover that density can be measured.
* Calculate the densities of irregular objects.
* Predict whether an object will float or sink in water by measuring the object's mass and volume and by comparing the object's density to the density of water.
* <u>Water</u> has a <u>density</u> of <u>1.0 g/mL</u> (or 1.0 grams per milliliters).
*Define the relationship among mass, volume, and density.

<u>Vocabulary to Watch For</u>

*density, mass, matter, volume, flotation

<u>Accessing the density computer simulation:</u>

1. Go to website, **explorelearning.com**
2. Go to Login:

Username: <u>density1</u>
Password: <u>density</u>

3. Scroll down to the section titled "**<u>Elementary School Science Samples</u>**"
4. and click the section titled "**<u>Density</u>**."

<u>Or, use this second option to find the density computer simulation:</u>

3. Click "Browse Gizmos" (located at the bottom of the page)
4. Click: "**Gizmos by Grade & Topic**"
5. Click: "**Grade 3-5**"
6. Click "**Physical Science**"
7. Scroll all the way down on the "**Physical Science**" menu

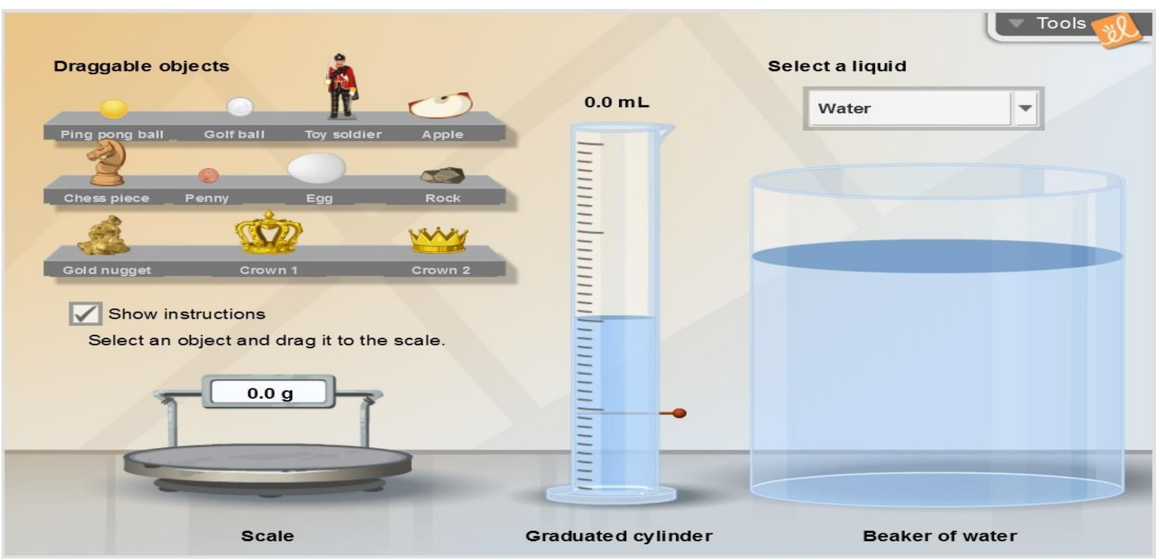
8. and Click: “**All Physical Science Subtopics**”
9. Click: “**<u>Density</u>**”

<u>Engage</u>

<u>Form the hypothesis:</u>

- Compare the density of each object with the density of water to determine whether each object will float in water or sink in water.
- Water has a density of 1.0 g/mL (or 1.0 grams per milliliters).
- If an object has a density that is lower than the density of water, then the object will float In water.
-If an object has a density that is higher than the density of water, then the object will sink In water.
-Determine if each object will float or sink in liquid water by comparing the density of the object with the density of water.

<u>Explore</u>



<u>Step 1</u>: Obtain the weight of each object (weight in grams (or g)) by placing each object on the scale (picture of scale shown above) and record the weight of each object in the table below.

Name of Each Object	**Measure Weight (grams or g)**	**Measure Volume (milliliters or mL)**	**Calculate Density (g/mL)**	**Does the Object Float or Sink in Water? (Circle Your Answer)**		**Does the Object have a Higher or Lower Density than Water? (Circle Your Answer)**	
Ping Pong Ball				Float	Sink	Higher	Lower
Golf Ball				Float	Sink	Higher	Lower
Toy Soldier				Float	Sink	Higher	Lower
Apple				Float	Sink	Higher	Lower
Chess Piece				Float	Sink	Higher	Lower
Penny				Float	Sink	Higher	Lower
Egg				Float	Sink	Higher	Lower
Rock				Float	Sink	Higher	Lower
Gold Nugget				Float	Sink	Higher	Lower
Crown 1				Float	Sink	Higher	Lower
Crown 2				Float	Sink	Higher	Lower

Step 2: Obtain the volume of each object (volume in milliliters (or mL)) by placing each object in the liquid in the graduated cylinder (picture of graduated cylinder shown above) and record the volume of each object in the table above.

Step 3: Calculate the density of each object and record the densities in the table above.

Step 4: Indicate in the table whether each object had a HIGHER density than water or a LOWER density than water (circle your answer): (density units are in grams per milliliters (or g/mL)) and water has a density of 1.0 g/mL (or 1.0 grams per milliliters)).

Step 5: (Now to compare the density of each object with the density of water); Place each object in the water located in the container (picture of container shown above) and indicate whether each object FLOATED in water or SANK in water (circle your answer as either Float OR Sink in the table)

Explain

Step 6: Use the information in the table above to answer the following questions:

A1. Which items floated in liquid water? ____

____

____

A2. How do the density of these items compare to that of liquid water? Is each density higher or lower than the density of water? Water has a density of 1.0 g/mL (or 1.0 grams per milliliters)).

____

____

A3. Which items sank in liquid water? ____

____

____

A4. How do the density of these items compare to that of liquid water? Is each density higher or lower than the density of water? Water has a density of 1.0 g/mL (or 1.0 grams per milliliters)).

____

____

A5. If an item has a density less than the density of liquid water, will the item float or sink in liquid water? (circle your answer)

A6. If an item has a density greater than the density of liquid water, will the item float or sink in liquid water? (circle your answer)

Elaborate, Evaluate

B1. Why does oil float on water? (Circle Your Answer)

- **A.** Because oil does not dissolve in water
- **B.** Because oil is less dense than water
- **C.** Because water weighs more than oil (or is heavier than oil)
- **D.** Because oil does not dissolve in water and oil is also is less dense than water

B2. The amount of matter that an object has is called its _______________ (Circle Your Answer)

A. Volume **B.** Mass **C.** Weight **D.** Density

B3. What property does a graduated cylinder (shown above) measure? (Circle Your Answer)

A. Mass **B.** Volume **C.** Weight **D.** Density

B4. If the units of milliliters (or mL) are used to measure volume, and the units of gram (or g) is used to measure mass, then what will the resulting units for density be? (Circle Your Answer)

A. grams **B.** mL **C.** g/mL **D.** g - mL

B5. Why is liquid water more-dense than ice? __________________________________

____

____

APPENDIX E

ATTITUDE SURVEY QUESTIONS

This is the Document That Contains the Attitude Survey Questions

ATTITUDE SURVEY OF THE DENSITY SIMULATION
(Science Motivation Questionnaire II; Glynn & Koballa (2006); Glynn, et. al (2009). Retrieved from http://www.coe.uga.edu/smq/ located in file: SMQ.pdf)
(**Instructions:** Choose and/or Fill in the blank of the appropriate answer.)

Name: ____ **Date**______________________

1. After this lesson, I am confident about using computer simulations in teaching the topic of density. (attitudes about teaching density)

(1)=strongly disagree	(2)=disagree	(3)=uncertain	(4)=agree	(5)=strongly agree
O	O	O	O	O

2. Computer simulations are valuable for teaching. (value of the simulation)

(1)=strongly disagree	(2)=disagree	(3)=uncertain	(4)=agree	(5)=strongly agree
O	O	O	O	O

3. Computer simulations seem useful in learning about density; simulations are useful in teaching science concepts (expected use of simulation)

(1)=strongly disagree	(2)=disagree	(3)=uncertain	(4)=agree	(5)=strongly agree
O	O	O	O	O

4. I feel confident about using computer simulations to help teach the topic of density in the future (confidence in using the simulation to teach density)

(1)=strongly disagree	(2)=disagree	(3)=uncertain	(4)=agree	(5)=strongly agree
O	O	O	O	O

Page 1 (Turn Page)

5. In what ways did the density computer simulation help you understand the topic of density?

6. How did the density computer simulation help you understand the relationship between mass (or weight) and volume?

Page 2 (Turn Page)

7. After using the density computer simulation, are you able to explain why objects that have a lower density than the density of liquid water float on water, while objects that have a higher density than liquid water sink in water?

8. What were the strengths of the density computer simulation?

Page 3 (Turn Page)

9. What were the weaknesses of the density computer simulation?

APPENDIX F

CONSENT FORM

This is the Document That Contains the Consent Form

CONSENT FORM

My name is _Rasheta Fateen_. I am a graduate student/faculty member at Southern Illinois University-Carbondale.

I am asking you to participate in my research study. The purpose of my study is the following: _

This study has two purposes: (1) to compare the learning effectiveness of two established inquiry-based strategies (POE and 5E) for implementing computer simulation-based instruction, and (2) to compare participants' attitude of the computer simulation used based on which inquiry-based strategy was used.

Participation is voluntary. If you choose to participate in the study, it will take approximately ___90___ minutes of your time. You will _Complete the pretest, the posttest, the activity worksheets, and the survey questionnaire_ .

All your responses will be kept confidential within reasonable limits. Only those directly involved with this project will have access to the data.

If you have any questions about the study, please contact me,
Rasheta Fateen (773-354-4939; rfsiuc@siu.edu),

or my advisor,

Peter J. Fadde, Ph.D.
Professor and Coordinator, Learning Systems Design and Technology
Department of Curriculum and Instruction
Southern Illinois University
Phone: (618) 453-4019
Email: fadde@siu.edu
Office: Wham 323J
625 Wham Drive, Mail Code: 4610
Southern Illinois University
Carbondale, Illinois 62901

Thank you for taking the time to assist me in this research.

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Participant Signature and Date

This project has been reviewed and approved by the SIUC Human Subjects Committee. Questions concerning your rights as a participant in this research may be addressed to the Committee Chairperson, Office of Sponsored Projects Administration, SIUC, Carbondale, IL 62901-4709. Phone (618) 453-4533. E-mail: siuhsc@siu.edu

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Dissertation Paper Title:

Comparing Inquiry-Based Teaching Strategies for Improving and Implementing Computer Simulation-Based Instruction of Science Concepts

Major Professors: Dr. Harvey Henson and Dr. Peter Fadde

Publications:

Journal Articles

1. Chabalengula, V., Fateen, R., Mumba, F. & Ochs, L.K. (2016). Effect of Inquiry-Based Computer Simulation Modeling on Pre-service Teachers' Understanding of Homeostasis and their Perceptions of Design Features. *Journal of Computers in Mathematics and Science Teaching*, *35*(3), 225-248. Waynesville, NC USA: Association for the Advancement of Computing in Education (AACE). Available from https://www.learntechlib.org/p/150938/

2. Vermeulen, L. A., Fateen, R. Z., & Robinson, P. D. (2002). Single Crystal Structure Determination of a New Zirconium *N*-Ethylpyridinium Phosphonate: $Zr(O_3PCH_2CH_2NC_5H_5)(F^-)_3$. *Inorganic Chemistry*, *41* (9), 2310-2312. doi: 10.1021/ic015614z. Retrieved from https://pubs.acs.org/doi/10.1021/ic015614z

Conference Proceedings, Transations and Abstracts

1. Fateen, Rasheta, Henson, Harvey & Fadde, Peter (2017). “Comparing Inquiry-Based Teaching Strategies for Improving and Implementing Computer Simulation-Based Instruction of Science Concepts”, Presented at the National STEM Education Research and Practice Summit, West Lafayette, IN, October 16-17, 2017.