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Computer Simulations with Developing and Using Models in the NGSS Curriculum

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Abstract

Since 2013 the Next Generation Science Standards (NGSS) have been implemented in order to increase the scientific literacy of students (NGSS Leads, 2013). In order to bring the NGSS curriculum into the 21st century, technology should be incorporated along with the Science and Engineering Practices (SEP) to allow students to understand and explain phenomena (Gouvea, & Passmore, 2017; Harris, Sithole, & Kibirige, 2017). The purpose of this study was to investigate the effectiveness of integrating computer simulations in the NGSS science and engineering practice of developing and using models. This study used quantitative nonequivalent groups pretest - posttest quasi-experimental design. Both the control group and treatment group took an eight question pretest. The treatment group received computer simulations to understand an overall phenomena, while the control group received traditional learning methods (e.g., notes or lectures). At the end of the three week study, both groups took the same eight question posttest with the order randomized. After analysis of the data using independent and paired t-tests, both groups had statistically increased their understanding of scientific content. However, there was no statistically significant difference between the control and treatment group. This study shows that computer simulations may not impact student understanding more; however, it does suggest that computer simulations can be just as effective as more traditional teaching methods. Future studies should measure engagement or perception to see if students would enjoy the content more with computer simulations.

Keywords: Computer Simulations, Next Generation Science Standards, Developing and Using Models, Science and Engineering Practices, 5 E Model of Instruction

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Literature Review

Science education has been slowly changing with the development and implementation of the Next Generation Science Standards (NGSS). California has been using the same science standards since 1998, but recently started to make the switch to more rigorous standards (i.e., NGSS). The shift in science standards was related to the changing economic trends and employment in fields such as science, technology, engineering, and mathematics (STEM). Businesses and industries need students who have an advanced scientific understanding and are able to use engineering processes (NGSS Leads, 2013). This need is attributed to recent scientific advances and an increase emphasis on STEM related fields of employment; thus, NGSS was developed to meet the updated needs of society (McKenzie & Ritter, 2014).

The NGSS states that only one-third of college graduates are able to perform analytical tasks such as reading and interpreting a data table (2013). These results indicated a downfall in the previous education requirements, which emphasized of memorization of scientific content without a fundamental understanding of the processes. Since interpreting a data table requires students to utilize skills beyond rote memorization, the previous science standards did not prepare students for these types of tasks. Dewey (1910) warned of the limitations to science education if it was taught as a collection of final knowledge rather than an inquiry based process to be discovered. Over 100 years passed before science education started to see a change from memorization to inquiry based processes, which occurred through the development of the NGSS. Furthermore, this shift has increased the focus on the need for scientific literacy for all students.

Changing the Science Standards

In order to increase the scientific literacy for students, the way that science is taught should be changed in order to best support students. This change is particularly important to middle school students since they are able to start thinking more abstractly than in lower grades (Wadsworth, 1996). This allows more inquiry based learning to be involved in science education in middle school, since student have the cognitive development to process more abstract thinking. The increased rigor or difficultly gives students an opportunity to continuously work through the process that Duckworth, Peterson, Matthews, and Kelly (2007) refer to as grit. Grit is defined as perseverance and passion for long-term goals (Duckworth et al., 2007), which would include the understanding of a scientific process to increase their scientific literacy. This is also a trait that helps prepare students to be college and career ready by allowing them to work towards an understanding on their own without giving up. The NGSS was developed to provide a challenge to students through an inquiry based process, this process not only allows students to learn the content but also develop skills (e.g., grit) in context with curriculum. These skills developed with the NGSS can help students develop scientific literacy which can be applied to real world situations outside of school and in the public domain.

There is a need for a better understanding of scientific literacy in the public domain as well. For example, scientific issues are often presented and voted on by the public. If ordinary citizens developed foundational scientific literacy, they would be able to make informed choices for these votes and understand the consequences of their decisions. However, if science is continuously taught as a collection of facts that students must memorize to graduate, ordinary citizens will not understand how the scientific process works or how systems interconnect with each other (Harris, Sithole, & Kibirige, 2017). Without understanding these connections, citizens cannot make informed decisions that could fundamentally change how they live their daily lives. Harris and colleges (2017) discuss the need for a more progressive science curriculum and development of a new method of teaching and learning science to better prepare students for future technology-dependent careers. NGSS was created to address this need.

Next Generation Science Standards. Through the creation and implementation of the NGSS in science classrooms across the United States, students are learning how the scientific process is used in the real world (e.g., planning and carrying out investigations, asking questions, developing and using models, or engineering solutions). When students learn how to use science in the real world they are much more likely to make connections to science they may not have otherwise. These standards help to ensure that students are developing an understanding of how all aspects of science are interconnected (NGSS Lead States, 2013). Further, Gouvea and Passmore (2017) explain that the NGSS framework blends content and the process of science together, and allows students to develop knowledge through practice and inquiry. Students are able to develop a deeper understanding of the content when they are able to learn it in context through an inquiry bases process, such as a lab investigation where they can develop their own models to represent their thinking.

The focus of the NGSS is to integrate three main aspects: The Disciplinary Core Ideas (DCI), which serve as the content of scientific information to understand; the Science and Engineering Practices (SEP), which are process that scientists do to understand the information they learn from observations or experiments; and the Cross Cutting Concepts (XCC), which are skills that can be transferred to any subject (NGSS Lead States, 2013). Focusing on all three aspects allows students to understand the process scientists use to make sense of the world around them, rather than just memorizing scientific concepts. By students using all three dimensions of NGSS they are able to make deeper connections and have a greater ability to solve problems and explain phenomena (Krajcik, Codere, Dahsah, Bayer, & Mun, 2017). The part of the NGSS that is being emphasized in middle school is the SEP, since it allows students to participate in science and develop an understanding of the processes that scientists use in the real world. One of the main SEPs being emphasized in middle school is having students 'Develop and Use a Model' (NGSS Lead States, 2013). This is an important principle because students are able to analyze and interact with the content in a way that is unique to them. This allows students not only an opportunity to understand the information but it gives them a chance to understand the thought process that scientists use when presented with new information.

Models in Science

Developing and using models is a process that scientists use to organize their thoughts, as well as synthesize new information about a particular phenomenon being studied (Gouvea & Passmore, 2017). In order for scientists to understand complex systems and how they can: function, respond to stimuli, adapt, or organize; scientists may develop a model to show how these processes work (Schwarz et al., 2009; Yoon et al., 2017). A model that scientists use can vary, often times it is a drawing that is changed or extended upon as new information is developed but it could also be a three dimensional representation made by hand or by computer (Schwarz et al., 2009). For example, most textbooks often have a drawing of a cell with the different organelles labeled with notes explaining the function of each organelle or it could be a three dimensional diagram with those same organelles labeled. By educating middle school students in this process of developing models they are able to take ownership of the information learned and develop a deeper understanding of the system or phenomena being taught (Gouvea & Passmore, 2017; Yoon et al., 2017). Instead of just learning about science, by creating models students are acting like scientists and engaging in the scientific process. In order to bring this process into the classrooms, educators must change how models are presented and used in the classroom.

Changing the definition of a model. Incorporating model development in the science classroom has been occurring for several years; long before the NGSS was developed (Gouvea & Passmore, 2017; NGSS Lead States, 2017). Having middle school students create and use models is a powerful tool, especially when it comes to phenomena that are difficult to observe in the typical classroom setting due to scale, time, safety, or budget limitations (D'Angelo et al., 2014; Yoon et al., 2017). Most students are exposed to common modeling activities such as building a solar system or constructing a DNA strand. Although it is important to know the structure of phenomena, the process of how these models were developed is not shown or taught to students.

Most times in science classes students are given a final scientific model that scientists have spent years developing; yet, little time to no time is spent showing them the evidence for the model or allowing them develop their own model that will explain the phenomena (Krajcik & Merritt, 2012). By having students develop their own models they will be able to synthesize the content in a way that unique to their thought process this is important because the students will be able to develop a better understanding of the content by actually thinking through the information rather than memorize facts relating to the content. The SEP of developing and using a model moves away from having students replicate an already developed model to a process of constructing the model themselves with the given evidence. In order for science education to change how models are used, educators need to change the definition of what a model is.

Although models have been used in classrooms for years, the new definition of a model can be confusing and vague. The NGSS defines models as a simplified representation of a system to help explain and make predictions regarding a particular phenomenon (Schwarz et al., 2009). The ambiguity of the definition is not the problem, but the understanding of what is expected by students can be detrimental to learning. Models that are treated in the old definition, are less able to support students' learning in science because they tend to treat models as representations of what is known rather than as tools to be used in generating new knowledge (Gouvea & Passmore, 2017).

The traditional definition of the term *model* in science class is typically a lesson where students are given supplies and they build a three-dimensional representation of something that cannot be observed in the classroom to understand the structure of it. A model in the NGSS classroom has a focus on the process of developing a representation with evidence. Models are used to make sense of the information gained with the emphasis on how they are developed and used in science as tools that support inquiry and exploration (Gouvea & Passmore, 2017; Schwarz et al., 2009). Having middle school students use NGSS models would mean a shift from building a three-dimensional representation to a deep understanding of the system and its relationships to serve a learning purpose (Gouvea & Passmore, 2017). This shift means a change in the way that middle school students are expected to learn in a science class; moving from researcher developed models to students developed models.

Student Developed Models

Changing the definition of developing and using models helps to increase scientific understanding in middle school students. This process allows students to think like a scientist and collaborate with others. This creates a shared culture in the classroom environment of scientific inquiry by collectively developing and monitoring shared learning targets or goals (Gouvea & Passmore, 2017). Having middle school students engage in the process of developing and using models collaboratively or independently allows for students to become familiar with the scientific process as they discover a particular phenomenon and revise that model as evidence is collected (Krajcik & Merritt, 2012). Through this collection of new evidence students are able to understand not only the structure of the phenomenon but also why a phenomenon is happening. This change is beneficial to students developing a deeper understanding of scientific content which is emphasized with the NGSS.

The focus of models has shifted from being able to see a structure that normally cannot be seen, to using the known information to construct a representation of what is happening with a particular phenomenon. The Biological Sciences Curriculum Study (2016) provides an example lesson that shows this shift in what a model is. The example lesson focuses on students developing an understanding of what causes seasons on Earth. Students first analyze a variety of sources (e.g., maps, graphs, world data) to understand the temperature patterns present, then they use a three dimensional representation in order to physically see how the sun and Earth revolve (Biological Sciences Curriculum Study, 2016). Students engage in a reading to gather the necessary background information for this phenomenon, lastly they create a pictorial representation (i.e., a model) using all the information from the previous lessons (Biological Sciences Curriculum Study, 2016). This process allows students to gain a deeper understanding of the content, as well as the process scientists use to make sense of naturally occurring phenomena. With new technologies, readily available in the classroom, this process can be expanded upon and brought into the 21st century.

Using computers to create models. Having middle school students use 21st century skills in the process of developing and using models can help increase the understanding of the phenomena or interdependence of the phenomena or systems being modeled (Gouvea & Passmore, 2017; Harris et al., 2017). These 21st century skills are defined as Collaboration, Critical Thinking, Communication, and Creativity; or the 4Cs (Trilling & Fadel, 2013). The emphasis is to use technology to not only reach students, but enhance their understanding of these skills. Using computer simulations in the NGSS process of developing and using models allows for students to reach the 4Cs while helping them develop a deeper understanding of their models. Furthermore, simulations are a key way that students can interact with models (D'Angelo et al., 2014). Simulations are tools which can help students to organize their knowledge of a system, or phenomena, and allow them to reevaluate their ideas with new information (Gouvea & Passmore, 2017; Schwartz et al., 2009). Thus, computer simulations can be used to enhance the process of developing and creating models.

Computer simulations allow middle school students to see how a phenomenon or system would change in a way that may not be possible in the physical classroom space. Using computer simulations in the classroom allows middle school students to test previous knowledge or revise any previous models and to ensure consistency with new evidence gained during the simulation (Krajcik & Merritt, 2012). Adding computer simulations alone will not serve as an automatic enhancement to the process, students must be guided on how to use these simulations to make sense of the phenomena or system being understood. Computer simulations provide learning opportunities that may help increase student understanding (Gouvea & Passmore, 2017; Yoon et al., 2017). If used properly, computer simulations integrated in the process of developing and using models, has the potential to enhance student understanding of scientific phenomena and systems. Therefore, using computer simulations in the classroom would help increase the understanding of scientific content.

Outcome of computers and models. Computer simulations have already shown to increase the understanding of science content with middle school students (Gouvea & Passmore, 2017; Yoon et al., 2017). A two-year study of middle school students using a computer-based program to develop simulations of different phenomena demonstrated students' scores increased when computers were used in the learning sequence (Yoon et al., 2017). These results indicate that students were able to gain a greater understanding of the content when using computer simulations. By incorporating these simulations in the process of developing and using models, students understanding may be enhanced. However, D’Angelo and colleagues (2014) found that access to a simulation was not enough. More specifically, D’Angelo and colleagues (2014) compared student performance on simulations. One group was left to work on the simulation independently and the other was given specific guidance and scaffolds from the researcher. The students who received scaffolded instruction that was tailored to their learning needs received a higher t score (D'Angelo et al., 2014). This means that students are able to develop a deeper understanding of the material with correctly scaffolded models; thus teachers must incorporate both the use of computer simulations and scaffolded instruction to fully support student understanding.

In order for simulations to have a positive learning effect and supplement instruction, two aspects should be built into the learning activities. The first aspect is to have high quality scaffolds (Yoon et al., 2017). The second aspect is an opportunity for students to experience cognitive dissonance; having two beliefs that conflict with each other (i.e., thinking seasons are caused by the Earth getting closer to the Sun, and learning that seasons are caused by the tilt of the Earth on its axis; Yoon et al., 2017). The use of technology can increase the opportunities for cognitive dissonance since students are able to see a process that they cannot see in the real world (e.g., seeing the Earth revolve around the Sun). Using this information, it can be determined that there is a need to integrate technology into the process of developing and using models with the NGSS. Research in the integration of technology is very limited but some current studies have investigated the use of technology in understanding complex system for middle school curriculum.

Purpose of the Current Study

Previous research has already concentrated on developing middle school students' understanding of complex systems, yet few studies have focused on identifying supports that will help teachers provide instruction on these systems (Yoon et al., 2017). Using the process of developing and using models will allow for guidance of teachers in providing the appropriate scaffold to teach students how to make sense of the systems and phenomena. Using computer simulations alone will not allow for deepening student understanding, they should be used in context of modeling to have a larger learning impact (Gouvea & Passmore, 2017). The purpose of the study is to incorporate technology into the NGSS. Specifically, this study was designed to determine if using computer simulations with the processes of developing and using models will increase middle school student scientific literacy.

Methods

Research Question

The research question for this study was: Does using computer simulations in the NGSS process of developing and using models increase scientific literacy in middle school students?

Hypothesis

Based off the research of Yoon and colleagues (2017) the hypothesis for the study was that using computer simulations would increase the scientific literacy of middle school students by allowing them to see how phenomena interact in the real world which may not be possible in a classroom setting. Creating models is a useful tool that allows students to evaluate their ideas and organize what they have learned (Gouvea & Passmore, 2017). Incorporating computer simulations in science education would help students to make meaning in more significant ways (Yoon et al., 2017). This hypothesis was tested by selecting students from two different classes in a middle school using nonequivalent group design.

Research Design

This design of this research is a quantitative nonequivalent groups pretest - posttest quasi-experimental design. Both the control and treatment classes took an eight question pretest to determine what content they already knew. The control class went through the same learning sequence following the 5E lesson development design: engage, explore, explain, elaborate, and evaluate (Biological Sciences Curriculum Study, 2016) as the treatment class. On the elaborate phase the treatment class used computer simulations to develop a model to explain the content. The control class did not use computers, but instead used the resources already given to them from labs and readings to design the model. The end of the sequence students took a multi question posttest with the same questions as the pretest, but in random order to ensure students did not memorize the answers. The change in the test scores were measured to examine the effectiveness of the intervention.

Independent variable. The independent variable in this study was the development of the NGSS three dimensional models within the learning sequence, which was through the use of computer simulations in the learning sequence (NGSS Lead States, 2013).

Dependent variable. The dependent variable in this study was the gains in scientific literacy. This was defined conceptually as the knowledge and understanding of scientific concepts and processes required for decision making (National Research Council, 1996). To measure the gains in scientific literacy students took an NGSS aligned test of multiple choice and short answer questions (Accelerate Learning Inc, 2018). The difference in pretest and posttest scores were analyzed.

Setting and Participants

The setting for this study was a middle school in Central California which was made of primarily low income families and a predominantly Latino population. The school was a 7th and 8th grade only middle school. Further, 92.7% of students were English language learners or have been recently reclassified as English language proficient, 98% of students were Latino, and 90.3% of students were on the free and reduced lunch program (Education Data Partnership, 2018). The sample for this research was a purposeful convenience sample as participants are readily accessible to the researcher, however they represent the target population. This opportunistic sampling was used throughout this process to gain insights in the difference between modeling with and without computer simulations, all will be participating in the study. For this research, all students of the most diverse two classes were selected to be the control and treatment groups.

Treatment group. The treatment group consisted of 30 students. The treatment group consisted of 43% female to 57% male, all students are age 13-14. The ethnicity of the treatment group is 96% Latino and 4% Asian. The educational subgroups are 13% English Language Learner, 16% enrolled in the Gifted and Talented Education (GATE) program, and 10% have an Individualized Education Plan (IEP).

Control group. The control group consisted of 25 students. The control group consisted of 36% female to 64% male, all students are age 13-14. The ethnicity of the control group is 100% Latino. The education subgroups are 23% English Language Learner, 23% of students are enrolled in the GATE program, and 8% have an IEP.

Measures

To measure growth in scientific literacy, an NGSS aligned test was taken by both the control and treatment groups. The NGSS aligned test was an eight item test to assess knowledge of three dimensional aspects of the NGSS (DCI, SEP, and XCC) using district approved questions through STEMscope.com (Accelerate Learning Inc, 2018). The test contained one short answer question, six multiple choice questions, and one claim-evidence-reasoning question (see Appendix A) which was graded using a Claims-Evidence-Reasoning (CER) rubric (see Appendix B). Both control and treatment group took the test electronically. The test was designed to take approximately 20 minutes of class time. The multiple-choice questions were self-grading upon submission, the short answer and CER questions were graded by the researcher and trained teacher utilizing the CER rubric. This district approved questions ensured validity with standards.

Validity. To ensure validity the test measured growth in scientific literacy and was aligned to the NGSS performance expectations. The test questions were developed by STEMscope and aligned to the NGSS standards to prepare students for the California Science

Test (CAST) state test. This ensured formative validity to determine students understanding of scientific content.

Reliability. To ensure reliability the test was aligned to the NGSS (NGSS Lead States, 2017) for Newton's three law of motion. It was graded against a rubric to ensure it has a high test-retest reliability. In order to ensure that this test had a high reliability it was graded by the researcher and one other science teacher, who graded 20% of the short answer and 20% of the CER question against a rubric after a calibration training conducted by the researcher. Multiple questions were asked to address the same standards to ensure mastery of the content and provide internal reliability. Through a study conducted by Rice University Center for Digital Learning and Scholarship (RDLS; n.d.) resulted indicated a statistically significant relationship ($p < .05$) between the use of STEMscope, and its tests, with an increase performance in NGSS aligned state test.

Intervention

The intervention used in this study is based of the work of Yoon and colleagues (2017). Students received two lessons with computers to determine a change in oral vocabulary use, this study found that using computers in the process increased vocabulary usage. Additional research from D'Angelo and colleagues (2014) suggests that having computer based simulations could increase students understanding of content. Based on these two research papers the intervention for this study was developed. The intervention was focused on using computer simulations in the NGSS process of developing and using models. The intervention started with a pretest, then went through a learning sequence for each of Newton's three laws of motion with a focus on creating and developing a model for each law using computer simulations, then the treatment group took the same test as a posttest with the question order being randomized.

Procedures

Both treatment and control groups began with an eight item test that was aligned to the NGSS to determine baseline knowledge of subject (Accelerate Learning Inc, 2018). Each of the three learning sequences in this study followed the 5E (i.e., engage, explore, explain, elaborate, evaluate) model of instruction (Biological Sciences Curriculum Study, 2016). This model of instruction started by having an engaging lesson to introduce the material (e.g., a card sort, engineering activity, or looking at real world phenomena); the second lesson in the sequence was an inquiry based lab to have students develop an understanding of the content; the third lesson explained the content to the student (e.g., article, notes, or lecture); the fourth lesson allowed subjects to elaborate on the information learned (e.g., developing and using a model); at the end of the sequence the subjects were evaluated using a posttest. This study lasted three weeks using Newton's three laws of motion, each week was dedicated to a different law of motion. Each week followed the 5E model of instruction, the treatment group received three computer simulations as part of the sequences before developing their models. The evaluation lesson occurred only at the end with the eight item posttest. The difference in pretest and posttest scores were analyzed to determine scientific literacy.

Fidelity. To ensure fidelity of this research, a second science teacher observed three days of the learning sequences for the control group, and another teacher observed three days of the learning sequence for the treatment group. The teachers observed the three treatment days where computer simulations are used, one simulation for each of newton's three laws of motion, and completed a fidelity checklist (see Appendix C). The additional science teachers also graded pre and posttests after calibration and observation of these sequences. This ensured the teachers have an understanding of the process and what students were expected to learn.

Ethical Considerations

In order to ensure this study follows the three core principles in educational research of Respect for persons, Beneficence, and Justice the following steps were taken. This study ensured no harm came to the students, they still gained an understanding of the required standards with both types of learning sequences. All student information remained anonymous and confidential throughout the course of this study. This study provided very low risk since it involved normal educational practices. Treatment effects were taken into account and during the review lessons for the CAST, students in the control group were given the opportunity to engage in an abbreviated sequence of the intervention.

Validity threats. One extraneous variable that could affect the validity of this study would be the way the learning sequences were taught. Since both sequences were taught by one teacher, the manner in which the information was delivered was the same. However during the three computer simulation lessons for the treatment group, the control group received lessons that have been used in previous years. This ensured that subjects were learning the same content that met the NGSS performance expectations. Furthermore, both learning sequences followed the 5E model of inquiry based instruction: engage, explore, explain, elaborate, evaluate (Biological Sciences Curriculum Study, 2016). Similar classes were chosen to control for extraneous variables such as amount of EL, SPED, and GATE students. The school site for this study has a rotating schedule, ensuring that both treatment and control groups would be taught during different times each day. Since little research is known about the effects of using computer simulations with developing models, the researcher does not have preconceived ideas about the benefits of the intervention. To ensure this study was conducted with fidelity, a second teacher observed the intervention and control lessons (see Appendix C).

Data Analyses

All data were entered into the Statistical Package for the Social Sciences® (SPSS®) for Windows, version 24.0.0 (SPSS, 2016). No names or identifying information were included in the data analysis. Before analyses, all data were cleaned to ensure no outliers were present (Dimitrov, 2012). During data collection, one student from the treatment group was absent for the half the intervention as well as the posttest, they were dropped from the study. After cleaning the data, independent and paired samples t-tests were conducted to determine the significant difference in the NGSS aligned test between the two means of the (pretest and posttest) scores. Levene's Homogeneity of Variance was tested to determine is the assumption of equivalence has been violated (Levene, 1960). If variances are equal data were interpreted for the assumption of equivalence; however, if the variances were not equal across groups the corrected output was used for interpretation.

Results

Two independent samples t-tests were conducted on the whole sample ($n = 56$) for both pre and posttest scores. Results for the pretest were: Levene's Homogeneity of Variance was not violated ($p > .05$), meaning the variance between groups was not statistically different and no correction was needed, and the t-test showed non-significant differences between the mean scores on the pretests between the two group $t(54) = .38$, $p > .05$. This means both the control and treatment group had similar knowledge or lacked similar about of knowledge of the content before instruction (see Table 1). Therefore, the two groups were statistically similar when the study began, so scores could be compared without issues. Results for the posttest were: Levene's Homogeneity of Variance was not violated ($p > .05$), meaning the variance between groups was not statistically different and no correlation was needed, and the t-test showed non-significant differences between the mean scores on the posttest between the two groups $t(54) = .72$, $p > .05$. This means that the treatment group gained similar amount of content knowledge through the intervention as the control group who did not receive the intervention (see Table 1). Both the control and treatment group increased their mean scores on the posttest while also decreasing their standard deviation; indicating both groups learned the content and the scores were closer to the average in the posttest. The intervention was not overly successful since both the control and treatment groups improved their posttest scores.

Table 1

Results on Independent Samples T-Tests

	Mean	SD
Pretest		
Treatment	4.17	1.85
Control	4.35	1.70
Posttest		
Treatment	9.03	2.86
Control	9.54	2.35

Note. SD = Standard Deviation.

After determining the differences between pre and posttest scores between groups, two paired t-test were run for both groups (i.e., treatment and control) to determine if participants mean scores from pre to post were significantly different within each group (see Table 2). Results for each group were as follows: treatment group, $t(29) = -9.69$, $p < .001$; control group, $t(25) = -9.09$, $p < .001$. This means that both the control group and the treatment group made statistically significant growth in their content knowledge from pre to posttest. The negative t value also indicates an increase in scores from pre to posttest. This further supports that participants gained content knowledge during this study; however, since the independent t-tests did not report significant differences on the posttest, this increase in knowledge cannot be solely attributed to the intervention.

Table 2

Results on Paired T-Tests

	Mean	SD
Treatment Group*		
Pre	4.17	1.70
Post	9.03	2.85
Control group*		
Pre	4.35	1.86
Post	9.54	2.35

Note. SD = Standard Deviation. *= $p < .001$.

Discussion

Over the years the way in which science is taught in education has changed in order to keep up with an ever demanding need for a scientific literate society. The NGSS was created in order to address this need by not only teaching facts about how the world works, but also the skills and practices scientists engage in during their research (Krajcik et al., 2017; NGSS Leads, 2013). One of the most important practices that scientist use is the ability to develop and use models with given information discovered through inquiry based research (Gouvea & Passmore, 2017). By having students develop and use models, they are able to gain a deeper understanding of the phenomena being examined (Gouvea & Passmore, 2017; Harris et al., 2017). Not only are students expected to become more scientifically literate, but they are also expected to develop 21st century skills (i.e., communication, collaboration, critical thinking, and creativity) using technology. By integrating computer simulations in the NGSS process of developing and using models, students are able to increase their scientific literacy while learning the 4Cs of 21st century skills (Gouvea & Passmore, 2017; Harris et al., 2017; Trilling & Fadel, 2013; Yoon et al., 2017). The purpose of this study was to investigate if integrating computer simulations would increase scientific literacy.

This study was conducted to determine if using computer simulations in the NGSS process of developing and using models would increase scientific literacy in middle school students. Based on previous research by Yoon and colleagues (2017) the hypothesis for the study was that using computer simulations would increase the scientific literacy of middle school students since they would be able to interact in ways not possible in a classroom setting (e.g., seeing how forces increase and decrease when acceleration is changed). Both groups received the same pretest of eight questions at the start of the study. The control received traditional methods of teaching (e.g., lecture and notes) before developing models. The treatment group received the intervention of using computer simulations before developing models in order to gain a deeper understanding of the content. At the end of the three week study both groups received the same posttest, which consisted of the same eight questions with the order randomized.

Based on the research of Yoon and colleagues (2017) it was expected from this study that the treatment group would have had a higher mean score on the posttest because they received the intervention with computer simulations in lieu of traditional learning assignment (e.g., notes, lecture, and articles). However during this study it was determined that there was no statistically significant difference between the control and treatment group on the posttest (see Table 1). This means the both the control and treatment group learned approximately the same amount of content knowledge during the study. This differs from that previous research has found. Previous studies have found that when scaffolded computer simulations are integrated into the curriculum, students develop a deeper understanding of scientific content (D’Angelo et al., 2014; Yoon et al., 2017). Although these results were not the expected outcome, a conclusion can be drawn the computer simulations can be just as effective as less interactive traditional learning assignments.

Integrating computer simulations into the NGSS process of developing and using models is a powerful tool for student learning. Previous research has already shown that using computer simulations can increase the understanding of scientific content with middle school students (Gouvea & Passmore, 2017; Yoon et al., 2017). This study showed that students can learn almost as effectively with computer simulations as with note taking and lectures since both the treatment and control group received very similar posttest scores. Students were able to develop and revise their models using the computer simulations to explore how their models would change if the given parameters (e.g., amount of force) were changed, this allowed students to understand the phenomena being examined. Previous studies have concluded that students who have time to interact with phenomena on the computers are able to develop a better understanding of that phenomena (Gouvea & Passmore, 2017; Harris et al., 2017). This research showed that students may not have gained more content information using computer simulations, this does not mean that they did not develop a deeper understanding that cannot be captured in a multiple choice test. There could be other hidden limitations that effected student performance on the tests.

Limitations and Future Directions

Several hidden limitations could have affected the outcome of this study. The most major limitation is the time frame in which this study was conducted. Given the short time period allowed for the study, the intervention may not have run long enough to see more accurate results. A second limitation was the sampling of students. All participants in this study were selected as a convenience sample. The students sampled were also a small size, only 26 and 30 participants for the control and treatment groups. Although the sample size may be representative of the population at the school, it may not be a true representation of all middle school students. In order to determine effectiveness of intervention, further studies should be conducted. Further studies to investigate the effectiveness of computer simulation interventions should address the limitations of this study. Future studies should increase the time the intervention is conducted to allow students to investigate the computer simulations more to increase their understanding. Random samples should also be used to ensure they are representative of student population. The researcher also noted that students in the treatment group were excited when using computer simulations in class. Therefore further studies should include a measure to test student perception or motivation about the subject to see if students are more engaged with the material when using computer simulations.

Science education has been changing over the years to promote a more inquiry based learning to enable students to truly understand phenomena in our world. The NGSS has been developed to support students in this goal by focusing on not just the scientific content, but also the practices that scientist and engineers use to make sense of the world around them (Gouvea & Passmore, 2017; NGSS Leads, 2013). By utilizing technology in this process, students are able to develop 21st century skills and would be able to interact with phenomena in ways that are not possible in a traditional classroom setting (D’Angelo et al., 2014; Trilling & Fadel, 2013). This study suggest that using computer simulations can be just as effective to helping students to develop an understanding of the world around them. Through this inquiry process of the NGSS and computer simulations, students are able to think more abstractly and develop skills (e.g., SEP or grit) to increase their scientific literacy (Duckworth et al., 2007; Gouvea & Passmore, 2017). By increasing students’ scientific literacy, they would become more informed citizen and would be able to make more knowledgeable choices on scientific topics that are voted on by citizens.

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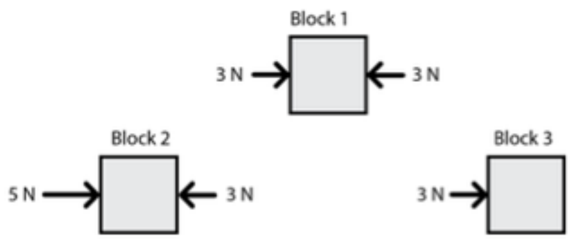
Appendix A

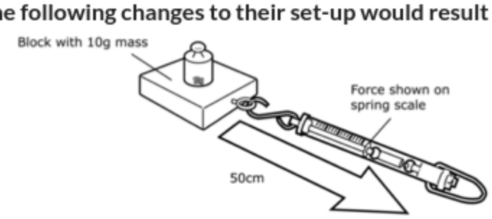
Newton's First Law

The illustration shows the forces in Newtons (N) acting on three different blocks. Which boxes will move under these conditions?



	A	Blocks 1 and 2
✓	B	Blocks 2 and 3
	C	Blocks 1 and 3
	D	Blocks 1, 2, and 3

Students are investigating how mass affects the force needed to move an object. They attached a wooden block to a spring scale and placed a 10 g mass on top of the block and pulled it 50 cm across the table. Which of the following changes to their set-up would result in a larger force reading on the spring scale?



	A	Sliding the block 60 cm
	B	Attaching a larger spring scale
✓	C	Using a 20g mass
	D	Using a circular piece of wood

A boulder sits at rest on top of a mountain. What conclusion can be made about the forces acting on the boulder?

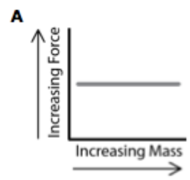
Answer

The forces acting on the boulder are balanced (net force equals zero).

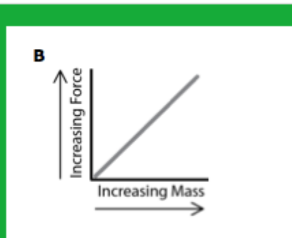
Newton's Second Law

Which of the following graphs shows how the mass of an object affects the amount of force needed to move it?

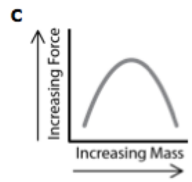
A



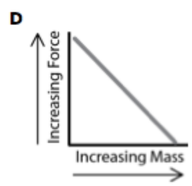
B



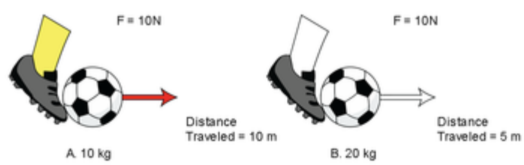
C



D



Argue: Claim-Evidence-Reasoning



Scenario: In professional sports, equipment such as balls have very specific size and weight requirements. Typically, only official balls are allowed to be used during competitions.

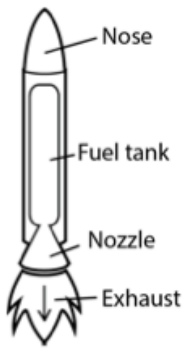
Prompt: Write a scientific explanation that describes the differences in motion of the Ball A and Ball B.

Newton's Third Law

A baseball bat hits a baseball with a force of 100 newtons. What is the force and its direction exerted by the ball on the bat?

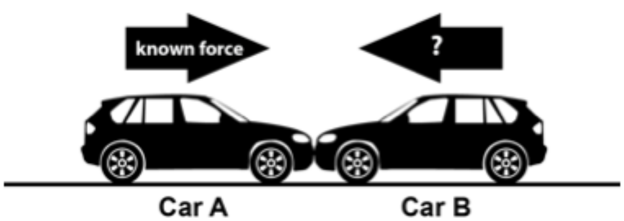
A	100 newtons, same direction
✓ B	100 newtons, opposite direction
C	200 newtons, same direction
D	200 newtons, opposite direction

The nozzle of a rocket is pointed downward so that, as fuel is ignited, the exhaust pushes downward. Why is this arrangement necessary for a rocket to function properly?



	A	The rocket is protected from the heat of the exhaust.
	B	Burned fuel can be collected on the ground.
✔	C	As exhaust pushes down, the rocket is pushed up.
	D	This allows the rocket to be steered properly.

Car A and Car B collide. The force that Car A exerts on Car B is known. The force that Car B exerts on Car A will be equal to the force Car A exerts on Car B –



	A	if Car B is moving at the same speed as Car A.
✔	B	if the product of Car B's mass and acceleration is equal to that of Car A.
	C	if Car B has the same mass as Car A.
	D	only if the cars are on a frictionless surface.

Appendix B

Component	Level		
	1	2	3
Claim – A statement or conclusion that answers the original question/problem.	Does not make a claim, or makes an inaccurate claim. Does not answer the question or answer is inaccurate	Makes an accurate but incomplete claim. Accurate but incomplete answer.	Makes an accurate and complete claim. Accurate and complete answer.
Evidence – Scientific data that supports the claim. The data needs to be appropriate and sufficient to support the claim.	Does not provide evidence, or only provides inappropriate evidence (Evidence that does not support claim or answer).	Provides appropriate, but insufficient evidence to support claim or answer. May include some inappropriate evidence.	Provides appropriate and sufficient evidence to support claim or answer.
Reasoning – A justification that links the claim and evidence. It shows why the data counts as evidence by using appropriate and sufficient scientific principles.	Does not provide reasoning, or only provides reasoning that does not link evidence to claim or answer.	Provides reasoning that links the claim/answer and evidence. May include some scientific principles, but not sufficient.	Provides reasoning that links evidence to claim or answer. Includes appropriate and sufficient scientific principles.

Appendix C

Fidelity Checklist			
Treatment Class Observer:		Control Class Observer:	
Date	**Time**	**Control/Treatment**	**Signature**
2/15/18	10:23 am	Control	
2/15/18	11:45am	Treatment	
3/1/18	2:07pm	Control	
3/1/18	3:11pm	Treatment	
3/6/18	9:26am	Control	
3/6/18	10:04am	Treatment	