USE OF COMPUTER SIMULATIONS IN PHYSICS:

COMPARISON OF SIMULATION IMPLEMENTATION AS INTRODUCTORY OR REINFORCEMENT TOOLS

by

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of the requirement for the degree

of

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in

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STATEMENT OF PERMISSION TO USE

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ABSTRACT

This study investigated whether online simulations are more effective as introduction activities or concept reinforcements in the physics classroom. The effectiveness of simulations based on student preference and performance was analyzed using the topics of energy, force, the law of gravitation and thermal physics. The study showed students preferred and had greater conceptual understanding when computer simulations were used as a reinforcement tool in the physics classroom.

INTRODUCTION AND BACKGROUND

Flathead High School in Kalispell, Montana offers students the unique and challenging opportunity to complete a two-year International Baccalaureate (IB) course in physics. The IB program as a whole is designed to allow for students to complete demanding courses and test in those subject areas for college credit. The IB courses also encourage international-mindedness and aim at helping student develop the skills and a positive attitude toward learning that will prepare them for higher education (retrieved from www.ib.org).

Flathead High School is located in the northwest part of Montana, close to Glacier National Park. There are just over 1,400 students in Flathead High School (FHS). The economic status of these students ranges from very low to very high. Twenty-seven percent of students at FHS qualify for free/reduced lunch. That same spectrum exists in the physics classes, students come from a wide range of backgrounds and experiences. At Flathead High School, 96% of students reported their ethnicity was white, and this class was no exception as they were predominantly Caucasian students.

The IB physics classes academic ability is above average. In order to be admitted to the course, students must have completed an Algebra 2 course with a C or higher. Additionally, they must have their current science teacher sign to admit them into the class. However, there are still many who struggle with material, specifically abstract concepts, and some with complex algebraic processes. As a whole, this class is a good representation of the students at Flathead High School (retrieved from http://public-schools.findthebest.com/l/54350/Flathead-High-School).

The IB physics program at Flathead spans two years and is an elective course taken by juniors and seniors. The final exam for the class is taken in the spring semester of the student's senior year with the possibility of replacing a college course if the student chooses to pursue higher education. The students learn core physics topics such as kinematics, thermal physics, waves and oscillations, and nuclear physics. Each class also selects additional options ranging from relativity to optics. One critical aspect of the program is that students must truly understand the conceptual ideas of the course and be able to apply them to challenging and open-ended questions.

One of the most difficult aspects of teaching this course is that students are unable to grasp some of the abstract concepts necessary to master the necessary complex topics in IB physics. Students often struggle with relatively simple concepts that they are unable to visualize. Many of the topics and ideas in this physics course can be explored in a laboratory setting. However, for other topics, the concepts may be too difficult to replicate or produce in the lab. For these abstract topics computer simulations may help students work through their ideas and misconceptions.

The use of these simulations in class prompted me to look further at the effectiveness of simulations. Some of the computer simulations available online are powerful resources and allow for students to see those topics that cannot be replicated in our limited laboratory facilities. I want to be able to more effectively use these simulations to maximize student understanding of concepts. In the past, I have used simulations to introduce a topic and had students complete an inquiry activity to explore physics concepts. I have also used the simulations to reinforce concepts the students have already discussed in class. I was interested in seeing which method worked the best.

The focus of this study was to explore how to effectively use simulations to teach abstract physics concepts. My focus question was, *Are computer simulations more effective as an introductory activity or as a reinforcement tool?*

From this research question, three research sub-questions were identified and addressed in this study:

- How can I create a way to measure student progress when using these simulations under different conditions?
- How can I create activities that will allow the same depth of learning in two very different ways of using the simulations?
- As class material varies in each unit, will the amount of progress within the two criteria vary?

CONCEPTUAL FRAMEWORK

In 2009, President Barack Obama stated, “I’m committed to moving our country from the middle to the top of the pack in science and math education over the next decade.” The President was speaking about “Educate to Innovate,” a campaign aimed at improving the participation and performance of students in science, technology, engineering, and mathematics ("Educate to Innovate", 2014). This campaign was designed to help American students learn deeply and think critically in the STEM disciplines.

President Obama’s “Educate to Innovate” and other educational initiatives are centered on the need for students to develop 21st century skills in order to be successful in today's world (Rotherham & Willingham, 2009). Many campaigns discuss how essential it has become that students master the STEM subject areas for economic growth in our country (Fulton & Britton, 2011). These skills can be taught to students in variety of ways. As teachers change their educational goals, they often change their methods.

Technology has become a major aspect of classroom teaching and is a fundamental piece of teaching the STEM curriculum. Through current science initiatives, teachers are encouraged to incorporate technology as a major feature of their teaching methods. The use of technology, coupled with an appropriate teaching strategy, can be effective in facilitating and enhancing instruction in the STEM fields.

As technology is implemented in science classrooms it is changing how teacher education courses are preparing their students (Kumar, 2007). More advanced technology has become increasingly available to teachers. As teachers are trained in how to teach students, a major part of teacher development is making are sure that teachers can use and incorporate technology into their classrooms. In the science fields, technology is an educational tool as well as a curricular topic in many subject areas (Flick & Bell, 2000). Teachers choose their instructional tools and strategies based on preferences, experience, and past successes.

One form of technology used in classrooms are computer simulations. According to Bell and Smetana (2007), “Computer simulations are computer-generated dynamic models that present theoretical or simplified models of real-world components, phenomena, or processes” (p.23). Simulations allow students to observe and explore topics and concepts that otherwise would be too complex, time-consuming, or difficult to produce in a normal lab setting. Simulations have been in use since the early days of computers and researchers have been assessing effectiveness and student learning since they were introduced. Simulations are often used to supplement content and deepen understanding of a topic. Kulik (2002) reported that students gained understanding and achievement in general process skills and across subject areas when using computer simulations.

Students who have the opportunity to use individual computers for simulations, such as supplements to traditional instruction, showed an increase in content knowledge (Bayraktar, 2002). Additionally, students have greater success when they feel comfortable using the computer program and have a clear understanding of the goal of the simulation (Jackson, 1997). Simulations model in a way that will allow students to apply a scientific concept to a real-world situation, which is the goal of many science initiatives that educators focus on today.

In addition to the use of technology and simulations in classrooms, inquiry-based learning is also an important aspect of science education. The National Research Council of the National Academy of Sciences stated in its Framework for K-12 Science Education that, "One of the principal goals of science education has been to cultivate students scientific habits of mind, develop their capability to engage in scientific inquiry, and teach them how to reason in a scientific context" (Framework, 2012, p. 41). With this goal in mind, the Next Generation Science standards (NGSS) expect inquiry to be used in classrooms to help students develop knowledge and understanding about how scientists work and study the world around them (Framework). NGSS has created a set of standards that are aimed at transitioning science courses away from traditional direct instruction and toward inquiry-based teaching. Inquiry-based classrooms encourage student engagement and critical thinking skills.

The fusing of simulation and inquiry-based instruction in science classes has recently been researched in some depth. When simulations are used as an inquiry method in science classes it has a “significant effect” on students learning of conceptual knowledge and adequately allows students to transfer acquired knowledge into new lessons. (Kumar, 2007)

One study of simulation use in a science classroom was conducted by Richards, Bowary, and Levin in 1992 and involved two separate student experiences. The first aspect of this study contains insight into student response to inquiry-based simulation learning as a stand-alone method. Their study involved students using a constructivist approach instead of a passive reception of information and included no teacher directed instruction. This method allowed students to build upon existing scientific knowledge and construct new ideas through the experience of student run simulations.

Students participating in this study used simulations based on physics concepts, such as simplifying complex mathematical concepts by investigating physical phenomena and researching open-ended questions. The researchers found that the computer simulations provided a “bridge” between scientific and mathematical theory and experience (Richards, p. 71). They found that the students successfully explored their understanding and constructed new conceptual scientific knowledge.

The second part of the research conducted by Richards, Barowy, and Levin (1992) indicated that computer simulations used as concept reinforcement were successful teaching tools. Their research was based on the premise that teaching science by telling students about scientific theory is inadequate, as it fails to engage students in reflecting about their thinking. The study showed that through computer simulations students were able to rebuild concepts to reinforce ideas already established. Evidence shown in conjunction with traditional teaching methods, such as lecture and student work, simulations effectively encouraged students to support ideas and modify misconceptions.

A separate study centered on chemistry concepts was largely based on student experiences with virtual lab experiences compared to the traditional hands-on approach (Pyatt & Sims, 2012). The students completed both online virtual labs as well as labs in a more traditional setting. The assessment data for these classes were based on student performance paired with attitude. Attitude about the experience was collected through the use of surveys. The study found that students greatly favored the online experiences to the hands-on approach. Students also indicated that they felt the virtual experiences are easy to use and effective.

METHODOLOGY

The treatment of this study included the use of simulations and direct instruction followed by conceptual assessments of understanding. Additionally, the 42 physics students participating in this study completed surveys and student interviews indicating their confidence and perception of learning through the use of computer simulation. This study was conducted in two classes of IB Physics at Flathead High School. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A).

Data collection began during the fall of 2013 with students completing the Anonymous Pre-Survey asking whether they believed simulations were more effective as an introduction to or reinforcement of new material (Appendix B). The students were also asked whether they believed simulations helped them better understand the concepts they were learning. The survey utilized two methods to analyze student preferences. This first part of the survey utilized a scale from one to five with one being *not confident* and five being *totally confident*. Students were asked to rate each task according to how they currently felt. The second aspect of the survey used the Likert scale rating of *strongly agree* (SA), *agree* (A), *neutral* (N), *disagree* (D), and *strongly disagree* (SD). The questions were related to previous student experiences during their first year of physics.

After the pre-survey students were separated by class into two groups. The first period class was given direct instruction over the topic of force, while the second class performed the simulation over the same topic. The next day, the classes reversed experiences, period one completing the simulation as a reinforcement tool and the second receiving direct instruction over the topic.

Once the students had received both instruction and used the simulation, the students completed the conceptual quiz on their understanding of the topic of force (Appendix C). The quiz identified whether students understood the major conceptual goals of the introductory concepts in the simulation and instruction. The questions on the quiz stemmed from what the students had done in class instruction and simulation.

The data from these conceptual quizzes and surveys was then used to assess student understanding and preference. The individual questions and the quiz as a whole was averaged, graphed, and analyzed for students understanding of the topic. This data was then compared between the two classes and evaluated based on whether the students has participated in the simulation or instruction first.

For the second unit, the classes reversed the order in which they experienced the simulation for the topic of energy. The first class completed the simulation and then received direct instruction over the topic. The second class received instruction first followed by a simulation to reinforce the topic. After the experience students completed the Energy Conceptual Quiz over the topic of energy (Appendix C). The students also completed computer simulations and conceptual quizzes for the Law of Gravitation and thermal physics (Appendices E & F).

Data collection came to an end in the Spring of 2014 when students completed the Anonymous Post-Survey asking whether they believe that simulations were more effective as a introductory or reinforcement tools (Appendix G). Additionally, they were asked whether they believed simulations helped them understand the concepts they learned. The survey was the same as the one used in the pre-survey so that they responses could be compared directly.

In addition to the questions in the Post-Survey, students were also given an opportunity to write comments about their experiences in this study. The goal of this aspect of the study was to allow students to elaborate on their personal experience with the simulations and instruction. They were encouraged to elaborate on their answers to the Post-survey responses.

Several students were selected to interview after the process of data collection was completed. This interview was voluntary and students met with me during class to reflect on the process of learning with the aid of simulations of physics (Appendix H). Comments from these student interviews helped to determine methods students preferred in their learning process. Effectiveness of using computer simulations in class was assessed using these interviews, the student surveys, and conceptual quizzes.

Table 1
Data Triangulation Matrix

	Data Source		
	1	2	3
Student Preference of Simulation Timing in unit	Pre- and Post-Survey	Written Comments	Student Interview
Student Knowledge	Concept Quizzes	Student Interview	Written Comments

DATA AND ANALYSIS

The Anonymous Post-Survey administered in two Flathead High School physics classes indicated that 95.2% of students believe that computer simulations help them learn physics concepts (*N*=42). One student commented, " Using simulations allows me change the variables more quickly and get better results than in the lab." Another stated that "simulations help me see things better than reading or hearing about something."

While the students indicated that simulations help them learn physics concepts, only 29% felt that simulations are best used to introduce material that is new to them. When used as a tool to reinforce material learned through direct instruction, 78% felt that simulations are effective as a learning tool (Figure 1).

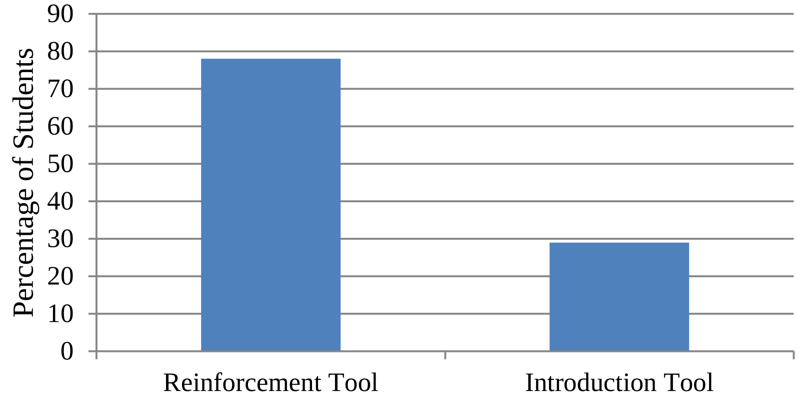

Figure 1. Students response to best practice of simulation use, (*N*=42).

The trends indicated above were mirrored in the Anonymous Pre-Survey prior to treatment (Figure 2). In the pre-survey 74% of student felt that simulations would be best used as a reinforcement tool, compared to the 78% in the post-treatment survey. Three percent of students were undecided. Twenty-three percent felt that simulations would be best used to introduce new material. One student commented, "when I think of simulations, I think of an experiment, used to build upon what I learned in class."

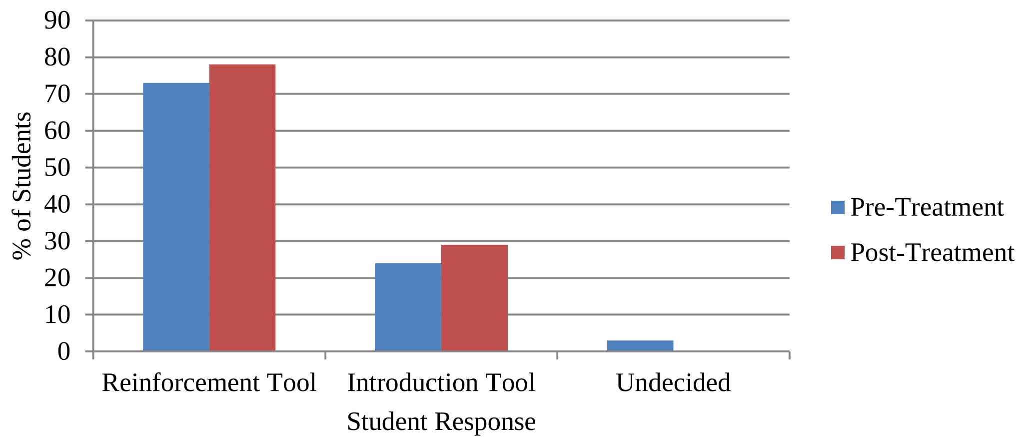

Figure 2. Pre- and Post- treatment Comparison, Students Response to Best Practice of Simulation Use, (*N*=42*).*

When students were asked whether they gain most of their conceptual understanding from the use of computer simulation, the results were mixed (Figure 3). Twenty-four percent of students *strongly agreed* or *agreed* that they gain most understanding from simulations, while 34% *strongly disagreed* or *disagreed*. The remaining 42% reported neither. One student stated, "Simulations help me to dig deeper, but not to understand the concept itself." While another said, "Simulations help me see content, without them I would not be able to get the big picture."

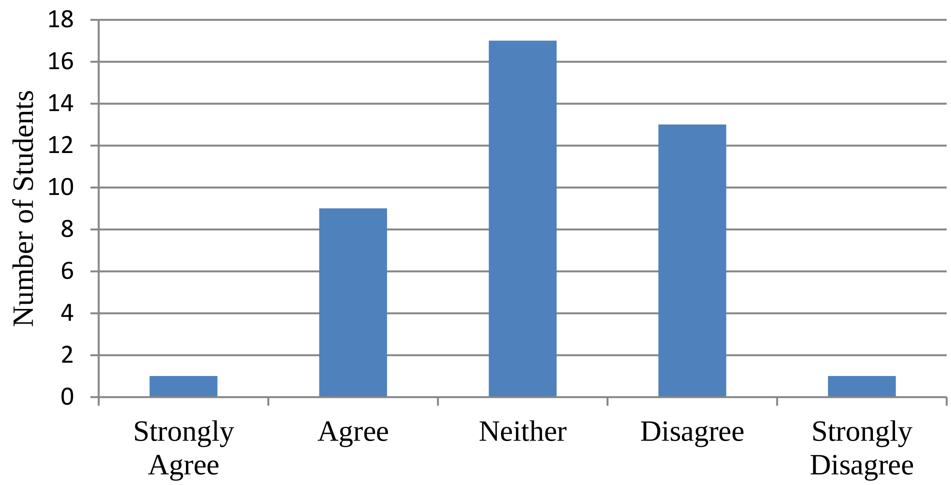

Figure 3. Students Responses to Survey Question About Whether They Gained Most of Their Conceptual Physics Knowledge From Simulation Use, (*N*=42).

In a series of three questions, students were asked to indicate their confidence about learning physics through simulations, direct instruction, or both. The survey indicated that 20% of students felt *very confident* about learning physics through direct instruction alone and 24% of students felt *very confident* about learning physics through simulations alone (Figure 4). Thirty-four percent of students felt *very confident* about using a combination of direct instruction and computer simulations to learn physics concepts. One student commented on this matter by saying, "I like both, I get different things out of each."

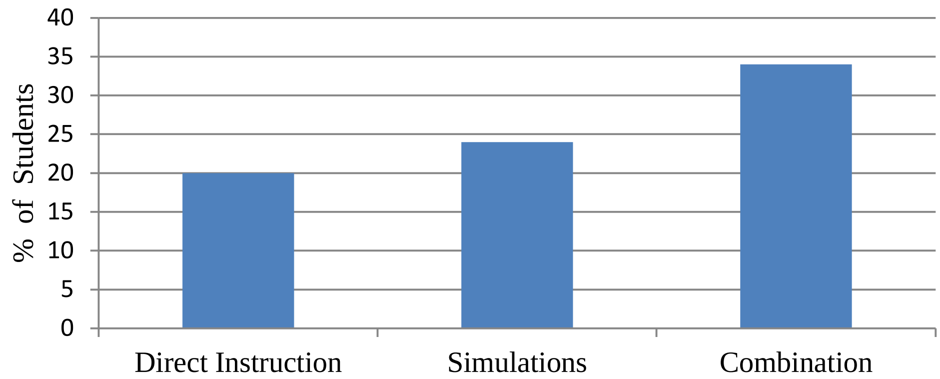

Figure 4. Percentage of Students Very Confident About Their Ability to Learn Physics Through Various Classroom Methods, (*N*=42*)*.

In the concept quizzes administered throughout the treatment, students who participated in the simulation after direct instruction consistently scored higher on quizzes. In the quiz that followed the direct instruction and simulation on the Law of Gravitation, students who were given direct instruction before the simulation scored 4% higher than their peers (Figure 5). On average, those students answered four of the five questions correctly more often than their classmates. On one question from the law of gravitation quiz, the simulation-first students scored higher, this was a calculation problem that asked students to calculate a value based on the Law of Gravitation formula. In the same quiz, students were asked content questions that were about the formula but pattern-based not calculation based, students who participated in the simulation activity after instruction scored higher on both.

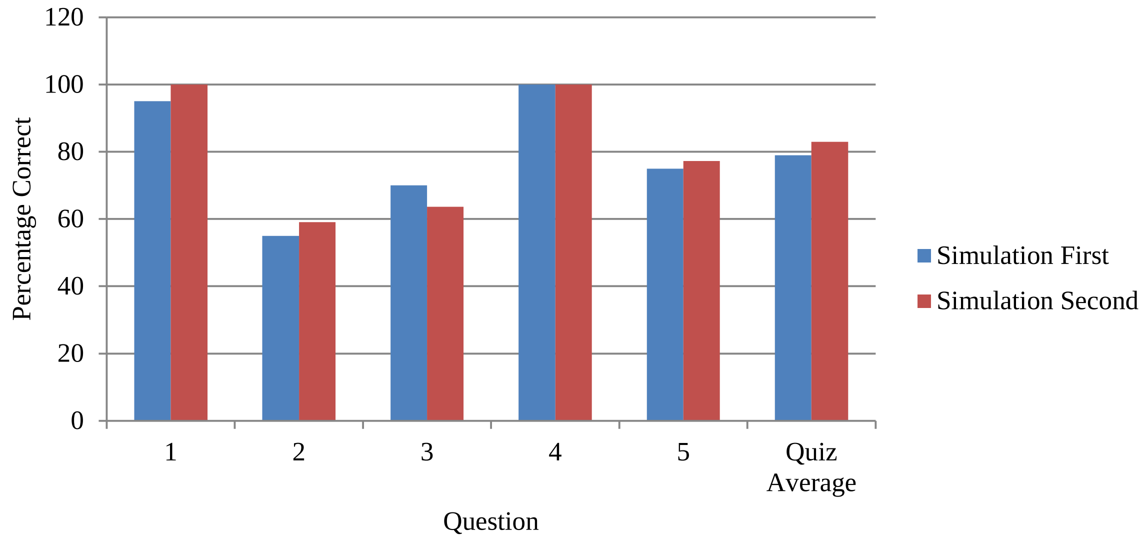

Figure 5. Percentage of Students Who Correctly Answered Questions on the Law of Gravitation Concept Quiz, (*N*=42*)*. Key: Question 1: What would happen to the gravitational force between two objects if the objects both increased their masses by two times? Question 2: Two bowling balls each have a mass of 6.3 kg. They are located next to each other with their centers 16.5 cm apart. What gravitational force do they exert on each other? Question 3: Two objects have their centers 3.0m apart. One object has a mass of 2.7 kg. The other has a mass of 4.5kg. What gravitational force do they exert on each other? Question 4: The attractive force that exists between all objects is known as________________. Question 5: If earth began to shrink but it's mass remained the same, what would happen to the value of g on Earth's surface?

On the introduction to thermal quiz, students who had direct instruction first, followed by a simulation, scored higher than students with the situation reversed on every question (Figure 6). On average, those students participating in the simulation second scored 11.2% higher than their peers.

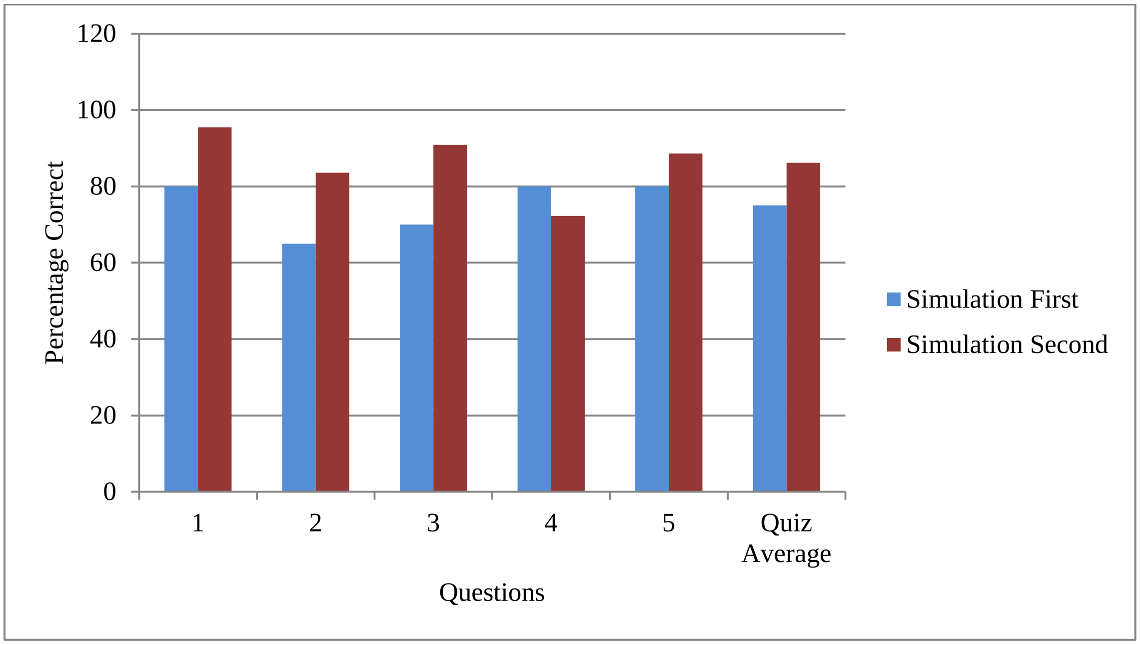

Figure 6. Percentage of Students Who Correctly Answered Questions on the Introduction to Thermal Physics Concept Quiz, (*N*=42). Key: Question 1: What is the difference between heat and temperature? Question 2: If you increase the temperature in a closed container, what happens to the pressure? Question 3: If you increase the number of molecules in a closed container, what would happen to the pressure? Question 4: Sketch a graph of Kinetic Energy vs. Temperature. Question 5: How the molecules in a solid, liquid and gas compare to each other.

The comparison of student scores on all concept quizzes is shown in Figure 7. Students who participated in the computer simulation after the direct instruction scored higher than students who experienced the simulation as an introduction to a new topic on three of the four quizzes. The first topic investigated was Force and both classes averaged an 83% on that concept quiz. On average, the class who participated in simulations post-instruction scored 4.7% higher than the other class.

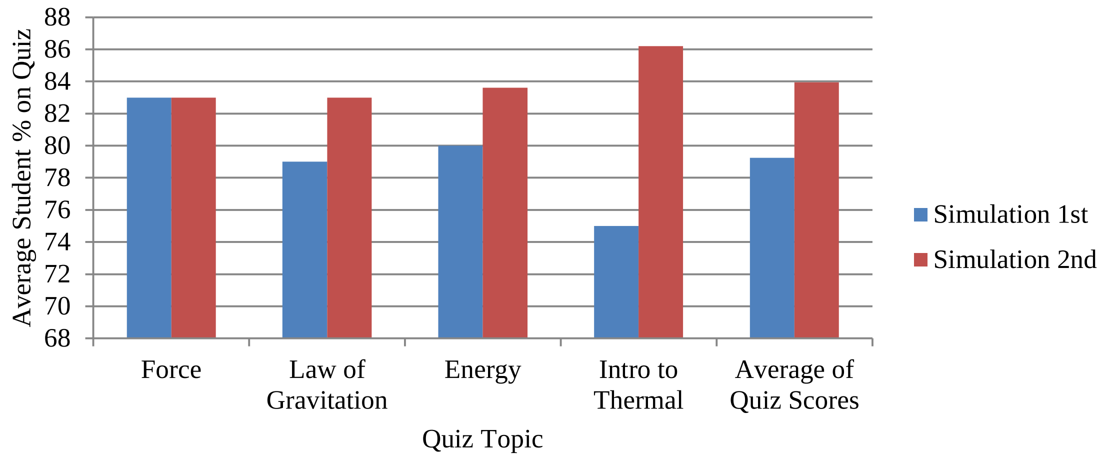

Figure 7. Quiz by Quiz Comparison of Average Student Scores on Concept-based Questions , (*N*=42).

In the post treatment interview process with the students (Appendix G), all students reported a positive experience with using computer simulations to student physics topics (*N*=10). Additionally, all students stated that simulations enhanced the learning experiences in the classroom. One student commented that "simulations are one more way that we can look at what we learned aside from experiments and demonstrations." Another said that simulations "a fun way to learn something new."

Of the ten students interviewed, eight stated that they preferred the simulations after direct instruction. One of those eight students said, “when I did the simulation first, I couldn't recognize what patterns I was supposed to be looking for. When simulations came after in class discussion, I understood what the point was and I could see patterns more clearly. " Another of the eight said, " when the sim was first, I could do the assignment, but the information didn't mean as much to me as when I knew what to look for." Two of ten student said that they preferred simulations before direct instruction. One said that "If we did the simulation before you taught us about it, I could use the simulation to visualize what we were learning. When we learned the concept first, I already knew what was going to happen when we set up the lab."

INTERPRETATION AND CONCLUSION

I felt that the study was conclusive in identifying which method of simulation use worked best for my students. In all the tools that I used to assess my research question, results indicated that students preferred and preformed better when computer simulations were used as a reinforcement tool. Students consistently commented that they believed simulations helped them learn physics material and after the treatment, more stated that they preferred the simulation activities after introduction to the concept in class. Although this increase was small, 74 to 78%, it indicates two things. The first, is that these students are very in tune with how they learn. In discussions with this class of high-achieving students, I have found they are aware of what they like and need to most effectively learn concepts in science. Prior to this research in class, these students had not used a computer simulation in my class before. And yet, the majority of them predicted what they felt it would be a successful learning strategy. Additionally, this small increase means that after truly evaluating their learning and seeing the results of various implementation strategies, they still felt that simulation conducted post-instruction were most effectively used.

Students had a strong sense of what they found effective and the data from the concept quizzes echoed that same result. The concept quizzes were a way for me to look at students success based on quantitative data of knowledge based results and not preference. I felt that by including this aspect into the research I could see a clear picture of what method worked best for the students. Although the data from the concept quizzes was similar to student preference in the surveys, it was not as apparent as I had anticipated or hoped. It was clear that students who had experienced the simulation as a reinforcement tool had done better on the quizzes, but not by the huge margin that would have been made the research more conclusive. The difference in the quiz scores from one class to the other was 4.7%. Although this number is not staggering, it is relatively consistent across the four concepts that we had evaluated using the computer simulation. Students never performed better as a class when they participated in the simulations before we discussed the topic as a class.

The pre-instruction simulation never outscored post-instruction, but students did score equally on one of the concept quizzes. In the first simulation experience with force, both classes averaged the same score on the quiz with an 83%. It was difficult to keep the experiences similar for both classes and as a teacher, was able to learn through this process as well. In the first simulation, I presented two very different discussions in class. In the first, before the simulation, I was very deliberate in explaining the concepts, formulas, and types of questions that could be asked about that topic. Whereas in the following lecture, I referenced the simulation often and tried to build off what they had already seen. This could be the reason the scores were more similar than in the last three topics. In the final three topics, I tried to make our in class time more comparable between the groups, whether or not they had experienced the simulation yet. I felt that strategy would more accurate data into what method was in fact more effective.

VALUE

Throughout this process, I believe that students gained a better understanding of their own learning and the process of science. Students evaluated their learning both in terms of their confidence on topics and actual results of knowledge they had gained. Computer simulation gave them another tool that they have to study or review a topic that they are learning. I believe they realized that reviewing material with simulations helped them understand a topic and we discussed that simulations would be a great student tool outside of the class or assignment. Additionally, I believe that they recognized the importance of reflecting on your learning and adjusting based on what works for them.

An unexpected value of this study came from my discussion with the class about the research. It was great to see them interested in my research project, they wanted to know the results faster that I could process them and there was a real bu- in from the students in terms of fully participating and supporting this research process. Several of them commented that it was refreshing to see science in action, and as a class we discussed the action research process and compared that too many forms of scientific research that they will come across in our classroom and beyond.

As a teacher, this research reinforced what I had expected to find in the results. I have used simulations for the past few years and as unsure about how to implement them into class in a meaningful way. I am glad that I can be confident in this use of technology and know that I can use simulations in a way that is most conducive to student learning. In addition simulation use in my classroom, simulations are also supported by the Next Generation Science Standards as a way to incorporate technology and engineering in the science classroom. I try to use inquiry in my classroom and differentiate instruction enough to cover many learning styles for a topic we cover in class. What this research project allowed me to do was identify what works for physics students in terms of lesson timing and using simulations in class. I also recognize that this structure could be completely unique for my teaching strategy and could very well be a result of me and not of the technology.

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APPENDICES

APPENDIX A

IRB APPROVAL

INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
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MEMORANDUM

TO: Kaylee Shaw and John Graves

FROM: Mark Quinn, Chair *Mark Quinn CJ*

DATE: November 12, 2013

RE: *"Comparing the Effectiveness of Computer Simulations in Physics when Implemented as Reinforcement or Introductory Teaching Tool Comparing the Effectiveness of Computer Simulations in Physics when Implemented as Reinforcement or Introductory Teaching Tool"* [KS111213-EX]

The above research, described in your submission of November 12, 2013, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

_X_ (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

_X_ (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

____ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

____ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

____ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

____ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX B

ANONYMOUS PRE-SURVEY

Pre-Survey
Note: The information provided will remain anonymous. Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.
This questionnaire is optional, but filling it out will help me understand what helps students learn physics. Your participation is greatly appreciated. This part of the questionnaire investigates the confidence you have in using simulations to learn physics. Using the scale 1-5 with 1 being not confident and 5 being totally confident, rate each task according to how you currently feel.

1. Please indicate how confident you feel about learn physics concepts through direct instruction.
1 2 3 4 5

2. Please indicate how confident you feel about learning physics concepts through computer simulations.
1 2 3 4 5

3. Please indicate how confident you feel about learning physics through the combination of direct instruction and computer simulations.
1 2 3 4 5

This part of the questionnaire looks at your experiences during your first year physics class.
Using:
SA - Strongly Agree
A - Agree
N - Neither
D - Disagree
SD - Strongly Disagree
Please answer these questions considering all of your experiences during your first year physics class.

4. I gain most of my conceptual understanding of physics topics through direct instruction.
SA A N D SD

5. I gain most of my conceptual understanding of physics topics through the use of computer simulations.
SA A N D SD

6. I believe that computer simulations are best used to introduce new material that I have not seen before.

SA A N D SD

7. I believe that computer simulations are best used to reinforce material that I have only seen through direct instruction.

SA A N D SD

8. I find computer simulations enjoyable.

SA A N D SD

9. I believe computer simulations help me learn concepts in physics.

SA A N D SD

Additional Comments:

APPENDIX C

CONCEPTUAL QUIZ : FORCE

Force Concepts Quiz **Name:**

Your participation in this research is voluntary and participation or non-participation will not affect your grades or class standing in any way.

Directions: Read each question carefully and answer questions following instructions.

1. A person pushes an object with 30 N of force. Friction acts in the opposite direction with 10 N of force. What is the net force acting on the object?
A 10 N
B 30 N
C 20 N
D 60 N

2. What is the name of the force that pushes up on a surface to prevent an object from falling through a floor or table?
A tension
B gravity
C normal force
D friction

3. A man has a mass of 60 kg. He sits on a giant ice cube. He is pushed with a force of 30N. How quickly will he accelerate?
A 0.5 m/s/s
B 2 m/s/s
C 15 m/s/s
D 30 m/s/s

4. A karate chop delivers a force of 3000 N to a board that breaks. The force that the board exerts on the hand during this event is
A. less than 3000 N.
B. 3000 N.
C. greater than 3000 N.
D. Need more information.

5. Which of Newton's three laws does the following example illustrate? If you have a hockey puck sliding along a table, it will eventually come to a stop.
A Newton's First Law
B Newton's Second Law
C Newton's Third Law
D All of the above

6. Explain your answer in question 5.

APPENDIX D

CONCEPTUAL QUIZ : ENERGY

Energy Concepts Quiz Name:

Your participation in this research is voluntary and participation or non-participation will not affect your grades or class standing in any way.

Directions: Read each question carefully and answer questions following instructions.

1. A sphere falls from rest through the atmosphere (friction is present) gaining 10 J of Kinetic Energy. How much gravitational potential energy did it lose?

A 10 J.

B More than 10 J.

C Less than 10 J.

D It is impossible to tell.

2. Two identical arrows, one with twice the kinetic energy of the other, are fired into a hay bale. The faster arrow will penetrate _____.
A the same distance as the slower arrow
B twice as far as the slower arrow
C four times as far as the slower arrow.
D more than four times as far as the slower arrow

3. An object is raised above the ground gaining a certain amount of potential energy. If the same object is raised twice as high it gains ________.
A four times as much potential energy.
B twice as much potential energy.
C half as much potential energy
D neither of these.

4. An object that has kinetic energy must be _________________.
A moving.
B falling.
C at an elevated position.
D at rest.

5. Car A has a mass of 1000 kg and has a speed of 60 km/h and car B has a mass or 2000 kg and a speed of 30 km/hr. The kinetic energy of car A is ____________.
A half that of car B
B equal that of car B
C twice that of car B
D four times that of car B

APPENDIX E

CONCEPTUAL QUIZ : LAW OF GRAVITATION

Law of Gravitation Concepts Quiz **Name:**

Your participation in this research is voluntary and participation or non-participation will not affect your grades or class standing in any way.

Directions: Read each question carefully and answer questions following instructions.

1.) What would happen to the gravitational force between two objects if the objects both increased their masses by two times?

A. It would double
B. It would be halved
C. It would be increased by 4 times
D. It would be decreased by a quarter

2.) Two bowling balls has a mass of 6.3 kg. They are located next to each other with their centers 16.5 cm apart. What gravitational force do they exert on each other? G=6.67x10-11 Nm^2/kg^2

A. 9.7 x 10^{-8} N
B. 9.4 x 10^{-8} N
C. 3.1 x 10^{-7} N
D. 1.6 x 10^{-8} N

3. Two objects have their centers 3.0m apart. One object has a mass of 2.7 kg. The other has a mass of 4.5kg. What gravitational force do they exert on each other? G=6.67x10-11 Nm^2/kg^2

A. 1.3 x 10^{-11} N
B. 9.0 x 10^{-11} N
C. 9.0 x 10^{-10} N
D. 2.7 x 10^{-10} N

4. The attractive force that exists between all objects is known as________________.

A. Centripetal force
B. The normal force
C. Friction
D. Gravitational force

5. If earth began to shrink but it's mass remained the same, what would happen to the value of g on Earth's surface?

A. It would decrease
B. It would be halved
C. It would increase
D. It would stay the same

APPENDIX F

CONCEPTUAL QUIZ : INTRODUCTION TO THERMAL PHYSICS

Intro To Thermal Physics Concepts Quiz **Name:**

Your participation in this research is voluntary and participation or non-participation will not affect your grades or class standing in any way.

Directions: Read each question carefully and answer questions following instructions.

1. What is the difference between heat and temperature?

2. If you increase the temperature in a closed container, what happens to the pressure?
   A. It would decrease
   B. It would be halved
   C. It would increase
   D. It would stay the same

3. If you increase the number of molecules in a closed container, what would happen to the pressure?
   A. It would decrease
   B. It would be halved
   C. It would increase
   D. It would stay the same

4. Sketch a graph of Kinetic Energy vs. Temperature.

5. How the molecules in a solid, liquid and gas compare to each other.

APPENDIX G

ANONYMOUS POST-SURVEY

Post-Survey

Note: The information provided will remain anonymous. Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

This questionnaire is optional, but filling it out will help me understand what helps students learn physics. Your participation is greatly appreciated. This part of the questionnaire investigates the confidence you have in using simulations to learn physics.

Using the scale 1-5 with 1 being not confident and 5 being totally confident, rate each task according to how you currently feel.

1. Please indicate how confident you feel about learn physics concepts through direct instruction.

   1 2 3 4 5

2. Please indicate how confident you feel about learning physics concepts through computer simulations.

   1 2 3 4 5

3. Please indicate how confident you feel about learning physics through the combination of direct instruction and computer simulations.

   1 2 3 4 5

This part of the questionnaire looks at your experiences during your first year physics class.
Using:

SA - Strongly Agree
A - Agree
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Please answer these questions considering all of your experiences during your first year physics class.

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   SA A N D SD

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6. I believe that computer simulations are best used to introduce new material that I have not seen before.

SA A N D SD

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SA A N D SD

8. I find computer simulations enjoyable.

SA A N D SD

9. I believe computer simulations help me learn concepts in physics.

SA A N D SD

Additional Comments:

APPENDIX H

OUTLINE OF STUDENT INTERVIEW QUESTIONS

Name: ______________________________Date:_____ Per:____

Student-Teacher Interview Questions

1.) How was your overall experience using computer simulations in physics?

2.) Do you feel they enhance the learning experience in this class? Why of Why not?

3.) Reflect on how these simulations help you. Can you explain how they improved your understanding of a topic?

4.) Did you prefer direct instruction or simulation use first? Why?

5.) Which of the computer simulations did you enjoy the most?