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A Study on Science Achievement and Motivation Using Computer-based Simulations Compared to Traditional Hands-on Manipulation

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Abstract

This study was conducted to investigate whether or not computer-based simulations had a greater impact on science achievement compared to traditional hands-on methods for middle school students in an on-level science course. The study also sought to determine if either method had an impact on retention as well as motivation. The participants in the study were 6th grade students attending a public middle school in suburban metro-Atlanta. A variety of statistical analyses were utilized to measure science achievement, retention, and motivation. Results indicated that there was no significant difference on science achievement between the traditional hands-on method and the computer-based simulation method. While the control group and the experimental group both had academic gains, the control group experienced a statistically significant difference in gains on the density concept. There was no significant difference for the greenhouse effect concept in academic gains. Results further indicated statistically significant correlations between self-efficacy and science learning value, self-efficacy and active learning strategies, self-efficacy and achievement goal, and self-efficacy and performance goal.

Keywords

computer simulations, traditional hands-on, middle school, science achievement, motivation, technology

Educators are continuously looking for improved teaching strategies to help students learn. Years of research conducted on learning indicates that students learn best when assuming an active role in constructing knowledge through experiences and interpretation (Roschelle, Pea, Hoadley, Gordin, & Means, 2001). Therefore, the goal in education should be to actively engage students to help promote learning. Even with decades of research, there is debate over how to promote scientific literacy and inquiry (Kelly, Bradley, Gratch, & Maninger, 2007). Textbooks do not bring the necessary dynamics on their own to the interdisciplinary nature of science. Many times students grow frustrated in their quest to make sense of science phenomenon. Over time, this frustration continues and students may become more and more alienated from the field. In the traditional role of science education, students were passive learners while teachers lectured on various topics and theories. Inquiry and problem-solving are aspects of learning that move the students into an active learner mode. To move to a more active approach, students must go beyond the written word in textbooks as these do not offer the ability to manipulate or investigate. The utilization of technology is one way for educators to accomplish this and offer a method that many students may not normally access. Many educators believe there exists great potential for computer technology to enhance learning in the classroom (Kelly et al., 2007; Roschelle et al., 2001).

Advantages and Benefits of Simulations in Science Classrooms

In 2001, research was still being conducted on the benefits of technology in the classroom and many saw only marginal benefits (Roschelle et al., 2001). Students need to be able to apply their learning to real-world situations. The application of scientific concepts is important to scientific learning. In traditional classroom teaching methods, this is usually lacking. For students to gain this necessary life skill, they need to have situations to transfer their knowledge to real-world situations. Computer-based technology affords students this opportunity by allowing instruction to become more student-centered (Foti & Ring, 2008). As technology develops, teachers need to incorporate simulations into the classroom to effectively demonstrate what students will be doing in real-world scenarios. These alternative approaches to teaching in the classroom need to better replicate the future careers of students to best prepare them.

Computer simulation was initially used as an additional tool to help students understand after being taught the theoretical concept by the teacher (Bowen & DeLuca, 2015). In many classrooms it is still used this way today. The simulations used in classrooms are conceptual simulations that involve students performing experiments. Conceptual simulations promote critical thinking by students and lead to learning. In conceptual simulations, students are able to alter variables to see what happens, thereby deepening their understanding as they continue to manipulate the variables. Computer-based simulations give the student practical experience to apply their knowledge and increase critical thinking skills and higher order thinking (de Jong, 2006). Dynamic and interactive computer simulations that allow the student to interact and become immersed, as opposed to text and static pictures, have an equal or greater effect on the outcome of learning (Chen, Chang, Lai, & Tsai, 2014; Kim, 2006; Roschelle et al., 2001; Trey & Khan, 2008). There are many benefits to computer-based simulations in the science classroom: (1) the accessibility of simulations to students; (2) the use of beneficial constraints; (3) the use of constructive and immediate feedback; (4) the teaching of abstract concepts; and (5) the potential increase in retention of the concept.

First, computer-based technology can bring science to students in ways they would not otherwise experience due to financial or geographical constraints (Roschelle et al., 2001). In earth science, it is not possible for teachers to create a lab using greenhouse gases allowing students to increase or decrease the amounts of those gases in the atmosphere to hypothesize and then experiment with outcomes. However, computer simulations can do this. Likewise, hands-on laboratories may require a high cost expenditure for schools. Finstein, Darrah and Humbert (2013) found that in a general physics high school setting, students performed similarly well on virtual labs and hands-on labs. Since one delivery method was not more or less effective than another, schools could bring scientific concepts to students virtually when they do not have the funds to outfit a traditional lab.

Second, computer-based simulations put constraints on students in productive ways (Finkelstein et al., 2005). These purposeful constraints filter complexities that might otherwise distract students in their inquiry (Perkins, Loeblein, & Dessau, 2010). Beneficial constraints are ones that reduce demands on students and free their time to become immersed in the simulation. For example, allowing choice to only increase or decrease those gases which contribute to the greenhouse gas effect as opposed to all gases in the atmosphere would be a beneficial constraint. However, one caveat to working in simulations is that the simulation must provide the same amount, or level, of information as the traditional laboratory (van Joolingen, de Jong, & Dimitrakopoulou, 2007). Additional benefits are seen when support is incorporated into the simulation.

Third, students assume more responsibility for their learning in simulations because they view it as a source of constructive feedback (Ronen & Eliahu, 1999). Simulations allow for quicker response times than in traditional lab experiences where it might take two to three days for the teacher to provide feedback (Kelly et al., 2007). One paramount question exists when using simulations and that is whether students are learning *about* science or actually learning how to *do* science. Simply clicking buttons in a computer simulation does not indicate that the student has grasped how their choices are related to the scientific concept. Many simulations have multiple entry points in that the participant may maneuver through the simulation in a varied procedure as opposed to traditional labs where the steps depend on each other. Science has a systematic approach that may be lost in computer simulations if they are seen more as a game than a scientific experiment.

Fourth, computer-based applications have been shown to be effective in teaching abstract concepts and the extremes of these concepts (Chen et al., 2014). For example, in one study using simulation to help students understand the particulate nature of matter, students in the control group still had a naïve concept of particle movement as their traditional hands-on laboratory did not effectively show how particles are in constant motion (Stern, Barnea, & Shauli, 2008). The experimental group was able to more clearly understand that particles are constantly moving as this was explicitly shown and reinforced in the simulation.

Fifth, simulations offer the chance for students to repeat their experiments multiple times, which might increase retention levels of the concept (Lalley, Piotrowski, Battaglia, Brophy, & Chugh, 2010). Teachers should allocate additional time in instruction for repeated

experimentation, allowing students to go deeper into the subject matter as additional trials are run. In research conducted by Renken and Nunez (2013) using a PhET pendulum lab simulation, they found that students were more likely to run repeated trials in the simulation experiment since it was easy for students to reset the simulation.

Disadvantages and Limitations of Simulations in Science Classrooms

With all the benefits of simulations, there remain limitations: (1) no physical manipulation of variables; (2) no measurement errors; (3) potential problems for students with lower computer literacy skills; and (4) scientific concepts may be lost if not provided proper guidance by an educator (Kelly et al., 2007). A disadvantage of computer simulations is that they do not allow users to physically manipulate lab equipment as a hands-on laboratory would (de Jong, Linn, & Zacharia, 2013). As technology develops, simulated tools and apparatuses are incorporated in hopes that this disadvantage will lessen.

Additionally, simulations do not factor in measurement errors or other unanticipated events like a traditional experiment would (de Jong et al., 2013). Students often trust technology unrealistically believing that all data received to be precise (Chen et al., 2014). Thus they lack a critical view of computer-generated results. With scientific investigation, the student needs to be skeptical of the data in order to properly evaluate and analyze it. Simulation-based environments need to provide real-world data, and not ideal conditions, to ensure students are getting the most out of the simulation.

Also, using computer-based simulations can pose difficulties for students with lower computer literacy skills (Carvin, 2000). This digital divide can have disadvantages for some students who might understand the scientific concept but falter on manipulating the simulation properly (Wecker, Kohnle, & Fischer, 2007). Many computer-based simulations offer students many modalities (text, pictures, videos) to help them in forming hypotheses, collecting data, inferring results and drawing conclusions. Students who are more comfortable and confident in using computers have the opportunity to acquire more knowledge when they are being used in a computer-based simulation since they more easily navigate the simulation. However, those students who are not as comfortable with computers have a disadvantage. The result may be lower knowledge acquisition.

Finally, as computers become more available in schools and more simulations become available, teachers need to ensure effective application of the technology (Roschelle et al., 2001). Renken and Nunez (2013) found that when computer simulation is unsupported, it is not the best method for experimentation. They found that conceptual understanding was not positively affected when guidance was not provided with the simulation. Thus, computer simulations should be used with caution.

Thus far there have been mixed results on the effectiveness of computer technology in the classroom to improve learning (Roschelle et al., 2001). There is also a distinction between the types of computer-based simulations on the market. Programs that seek to improve repetitive skills have shown to be less effective than those programs prompting students to think deeply and reason.

Science Motivation and Attitudes in Laboratories

Research shows that students participating in computer-based learning demonstrate higher levels of motivation as well as more willingness to think about difficult questions and a deeper understanding of the concepts (Roschelle et al., 2001). In a study conducted on V-Frog$^©$ simulations, student responses indicated that simulations were the way they liked to learn, that learning was more fun, and that the lesson was easy to understand (Lalley et al., 2010). In another study when students used the University of Colorado Physics Education Technology (PhET) simulations, students found themselves exploring the concept in a fun way, which prompted them to discover new scientific ideas they did not previously know (Wieman, Adams, & Perkins, 2008). Additionally, this allowed students to become self-driven in their investigation much like real-world scientists. Students were not afraid of breaking equipment or hurting themselves either, giving them more confidence in performing the experiment.

The University of Colorado Physics Education Technology Project

With so many instructional strategies for teachers to use, teachers are left with making the decision of what would be best for their particular concept and their students. Time is a limitation in the classroom and teachers need to incorporate the optimal strategy for learning. Many computer simulations exist out there. One such simulation is from the University of Colorado. The University of Colorado Physics Education Technology (PhET) project has simulations for physics, chemistry, earth science, biology and math. When designing these simulations, particular attention was paid to the user interface to encourage users to engage and explore difficult concepts (Finkelstein et al., 2005). PhET simulations were designed to enhance a robust curriculum and to be used with guidance from a teacher (Perkins et al., 2010). By invoking students' familiar thinking and intriguing their interests, PhET simulations are meant to connect to the real world.

Current Study

The purpose of this study was to measure science achievement in middle school students when using a computer-based simulation compared to traditional hands-on manipulation to determine if computer-based simulations increase achievement. This study also measured students' motivation and efficacy in both traditional hands-on manipulation and computer-based simulations to ascertain if there is a difference. The achievement in lower-performing students was evaluated to determine if they had higher achievement levels with the computer-based simulation or the traditional hands-on manipulation. Lastly, retention was analyzed. The goal of any instruction is for students to retain the information. Thus, this study attempted to determine if either computer-based simulations or traditional hands-on manipulation had a greater impact on retention. Therefore, the research questions for this study were:

1. Do computer-based simulations increase science achievement more than traditional hands-on manipulation?
2. Is there an increase in motivation and efficacy when using computer-based simulations in comparison to traditional hands-on manipulation?

3. What is the impact on science achievement in lower performing students when using computer-based simulations compared to traditional hands-on manipulation?
4. Is there a difference in retention using computer-based simulations or traditional hands-on manipulation?

An increase in science achievement was expected to emerge between the control group (traditional hands-on manipulation) and the experimental group (computer-based simulation). In addition, higher levels of motivation and efficacy in the experimental group were expected as the computer-based simulation provides real-world application of the earth science concepts. Since computer-based simulations make abstract principles more visual, it was expected that lower performing students would benefit from this to a greater degree than hands-on manipulation. Retention was hypothesized to increase when using computer-based simulations as students were able to conduct multiple experiments within the laboratory and evaluated variables in a range of real-world situations.

Method

Participants

This study was conducted at a small suburban public middle school in a metro-Atlanta county in Georgia. The county is an affluent county in Georgia with a median household income of $87,657 (Census Bureau, 2014). The middle school where the study was conducted is located in the southwestern part of the county where the median household income is $42,414 (Census Bureau, 2014). The student population consists of students from working class and lower middle class socioeconomic backgrounds. The demographics are predominately Hispanic, Asian, and Caucasian with the following breakdown: 37% Caucasian, 28% Hispanic/Latino, 24% Asian and 7% African American.

The participants were students enrolled in 6th grade on-level earth science. Earth science in 6th grade includes geology, hydrology, meteorology and astronomy. The focus of this research utilized simulations for density and the greenhouse effect in two different units of study. All students were between 11 and 13 years old. Three teachers and 10 classes took part in this study. There were 176 students ($N = 176$) who were randomly placed into classes based on the county's scheduling system. These classes included special education, ESOL, and gifted students. The racial demographics of the study were: 20.7% Hispanic, 36.0% Caucasian, 11.9% African American and 31.4% Asian. 43.3% of the students were female.

Two groups of 6th grade on-level earth science students from 10 different classes were included in this study with three teachers providing instruction. Due to schedules, one teacher taught one control group ($n = 8$) and one experimental group ($n = 12$), the second teacher taught two control groups ($n = 51$) and two experimental groups ($n = 52$), and the third teacher taught two control groups ($n = 28$) and two experimental groups ($n = 25$). The total sample size for the control group was 87 students ($n = 87$) and the total sample size for the experimental group was 89 students ($n = 89$). Table 1 shows the control group and the experimental group academic demographics.

Table 1
Control Group and Experimental Group Academic Demographics

Group	Gen. Ed. (%)	Gifted (%)	Sp. Ed. (%)	ESOL (%)
Control	77	14	8	1
Experimental	71	27	2	0

Students were randomly assigned to the classes by the county's scheduling system. Teachers identified the control groups and experimental groups at the start of the semester by random selection.

Materials/Measures

Materials. The 6th grade textbook for Georgia Earth Science (Prentice Hall Science Explorer (eds.) 2009) was used during instruction as well as various activities and lectures performed by each teacher. The textbook included beginner-level information on density and the greenhouse effect as well as information on Earth's processes as taught in the 6th grade earth science classroom. One of the independent variables in the research was the computer-based simulation. The study used the University of Colorado's PhET simulations for density and the greenhouse effect for the experimental group. Details of the simulation are explained in the procedures section. The traditional hands-on manipulation laboratory varied for each concept.

Measures. In order to measure science achievement in students, a pre-, post- and delayed posttest were administered. The pre-test was given to provide a baseline for existing knowledge, while the post-test provided data on science achievement. The delayed post-test was administered to measure retention. The assessment for density was from the American Chemical Society's test bank. The American Chemical Society's mission is to advance science. One of the ways they do this is through advocacy programs that support science education. As such, they have a test bank of questions for teachers to use on various chemistry-related topics.

The multiple choice questions for the greenhouse effect test were from The National Center for Atmospheric Research (sponsored by the National Science Foundation), BBC Science, and Southern Nevada Regional Professional Development Program. Each of these organizations publish sample assessment questions for educators on the greenhouse effect in their mission to educate the public. A compilation of the test questions was used for the study assessment.

Assessments specific to density and the greenhouse effect were given before and after each unit of study. The density test consisted of 15 multiple choice questions, and the greenhouse effect test contained 10 multiple choice questions. Both were administered on paper.

Student motivation was measured by the SMTSL Questionnaire (Tuan, Chin, & Shieh, 2005). The Students' Motivation Towards Science Learning (SMTSL) Questionnaire consisted of 35 questions (Cronbach alpha = 0.89) measuring six factors of motivation. These six motivation factors were self-efficacy, active learning strategies, science learning value,

performance goal, achievement goal and learning environment stimulation. The questionnaire was a Likert-scale format with ratings from one (strongly disagree) to five (strongly agree).

Procedures

The research was conducted during the spring semester of 6th grade when Oceanography (density) and Atmosphere and Weather (the greenhouse effect) were taught. Class periods were held daily for approximately 50 minutes of science instruction. Two treatments occurred over the course of the spring semester. Oceanography covered a three week period, while Atmosphere and Weather lasted for four weeks. The curriculum map and pacing guides incorporated by all three teachers were the same and the teachers met weekly to collaborate on instruction being provided as well as to determine the pacing and inclusion of labs. All teachers used the same textbook (Prentice Hall Science Explorer (eds.) 2009) during instruction as well as similar instructional materials (presentations, notes, worksheets, activities, etc.). Additionally, the lab handouts for the computer simulation labs and the hands-on manipulation labs were as similar as possible given the parameters of the labs. In addition, the procedures for the simulated labs included details about how to operate the simulation.

Both the control group and the experimental group were administered the Students' Motivation Toward Science Learning (SMTSL) Questionnaire pretest to provide a baseline for students' motivation in learning science. In addition, a content pretest was given at the start of each unit containing a treatment (units were oceanography [density] and atmosphere and weather [the greenhouse effect]). Following the pretest, teachers provided instruction on the unit (key vocabulary, processes, scientific concepts, etc.). In the middle of the unit, where appropriate for each of the focus concepts, students explored the key concepts with either a hands-on manipulation lab (control group) or a PhET computer-based simulation lab (experimental group). A description of the laboratory procedure for the control groups and the experimental groups is described in subsequent paragraphs. At the end of the unit, students took a posttest. Three weeks following the posttest, a delayed posttest was administered to all students to determine retention of the concepts.

Control group. The control group utilized hands-on manipulation during the laboratory portion of the unit. For the density hands-on manipulation lab, students performed an experiment with one-inch density cubes. This lab was conducted during one class period. First, background knowledge was accessed (from earlier instruction in the unit) on what density is and the relationship between mass and volume. In addition, the property of sinking or floating, and how that relates to density, was discussed as a whole class. The teacher and students then reviewed the lab handout – materials and procedures – before the students conducted the lab with their partner.

Each lab set-up contained five materials. The assortment of one-inch cubes was random for each set-up. Students first predicted which of the materials would float and which would sink. The teacher explained that all of the cubes were one inch and, therefore, all of the cubes were the same volume. A brief discussion on how to calculate volume was provided. The volumes were pre-recorded in the data table. Students then weighed each of the cubes on a digital scale and recorded the mass in a data table. Next, students calculated the density of each

material and recorded that information in the data table. Finally, students were able to place the cube into a 300mL beaker of water and observe whether the material floated or sunk and recorded it in the data table. At the conclusion of the lab, students answered post-lab questions regarding density. They used the data collected during the experiment to analyze how the densities changed for each of the materials and how the masses were different for each material but the volumes remained constant. At the conclusion of the lab, the teachers held a whole class discussion about observations made during the lab and about how the density of a material is a property that does not change.

The Greenhouse Effect was investigated in a lab modeling the Earth with two containers. Students worked with their lab partner during one class period. Both containers held dark soil in their bases and thermometers were attached to the outside of the containers. One container was covered with plastic wrap, while the other container was open. Both containers were placed under a sunlamp and the temperature in each system was recorded every minute for 15 minutes. Following data collection, students analyzed their data by graphing it. Using their graphed data and observations during the lab, students answered questions regarding the reason one container heated up more rapidly than the other container; if materials other than plastic wrap were used to close the container, would the results be the same; what was happening to the gases in the closed system (i.e., which gas (or gases) built up in the closed system); and what was happening to the gases in the open system. Finally, the students had to analyze the lab and explain how the model was similar to and different from Earth's greenhouse effect and the links to global warming.

Experimental group. The experimental group used the University of Colorado's PhET Simulations. The simulations were conducted on the school-provided desktops in one of the computer labs. These are computer-based simulations on various topics.

The density simulation had students investigating density, volume and mass with blocks comprised of five different materials. Students, with their lab partner, manipulated variables (mass of the block, volume of the block, density of the block) to see their interrelationships. As in the hands-on lab, the lab was conducted during one class period. Background knowledge was accessed from previous instruction on density and the relationship between mass and volume. There was a whole-class discussion on how whether an object will sink or float is related to its density. Students then reviewed the lab handout with the teacher. The teacher provided direction on how the simulation worked and how students would navigate through the simulation.

Students first predicted which of the five materials would float and which would sink. For the simulation, the students selected "same volume" for the blocks. The teacher explained that all of the cubes were one inch and, therefore, all of the cubes were the same volume. A brief discussion on how to calculate volume was provided. Volume was pre-recorded in the data table on the lab handout. As students toggled through the materials of the blocks, they recorded the masses of the cubes in the data table. Students then calculated the density of each material cube once volume and mass were known and recorded the density in the data table. Students were then able to virtually "drop" the cube into the container of water and observe whether the material floated or sunk. This observation was recorded in the data table.

At the conclusion of the lab, students answered post-lab questions regarding density. They used the data collected during the experiment to analyze how the densities changed for each of the materials and how the masses were different for each material but the volumes remained constant. With the simulation, students were able to explore how materials of the same mass, but different volumes, would behave in the simulation. Students were also asked to play with the masses and volumes of the cubes to determine if they could make a less dense object ever sink or a more dense object ever float. At the conclusion of the lab, the teachers held a whole class discussion about observations made during the lab and about how the density of a material is a property that does not change.

The second treatment explored the Greenhouse Gas effect during the Atmosphere and Weather unit. Students worked with their lab partner on the PhET simulation for Greenhouse Effect. In this simulation, students began by simply observing what the greenhouse effect is by clicking the "run now" button once in the Greenhouse Effect simulation. In the exploration phase, students navigated through the simulation to observe the interactions between the various greenhouse gas components. They then changed variables to analyze the relationship between the gases and the atmosphere when these variables are altered.

During the second phase of the simulation, students observed what happened in the atmosphere with infrared photons and visible photons as glass layers were added (0, 1, 2, and 3 glass layers). Students were able to see that, as more glass layers were added, the number of photons absorbed near the Earth's surface increased and fewer photons were emitted back into space. Students then applied this information to how the Earth's temperatures changed from the Ice Age to the 1750s to today.

At the conclusion of the simulation, students verbally explained the effect greenhouse gases have on our climate citing evidence from the simulation and variables presented. The simulation provided an extension activity relating the greenhouse effect to global warming. The final step in the lab was to conclude what can be done to slow down or stop the rate of global warming based on the supporting evidence from the lab.

Results

In order to determine if computer-based simulations increase science achievement more than traditional hands-on manipulation, the posttest scores for the control group and the experimental group were compared. An ANCOVA analysis was performed. All analyses were conducted with a 95% confidence level for significance. For density, the dependent variable was the density posttest and the covariate was the density pretest. The mean pretest scores for density were similar between the control group ($M = 49.33$) and the experimental group ($M = 52.33$) indicating that the two groups had similar background knowledge with which to begin. Following the treatment, both the control group and the experimental group increased their knowledge on density ($M = 60.27$ and $M = 56.71$, respectively) on the posttest. However, the two groups were not significantly different ($p = .064$).

The dependent variable for the ANCOVA analysis on the greenhouse effect was the greenhouse effect posttest and the covariate was the greenhouse effect pretest. For greenhouse

effect, the control group ($M = 35.42$) and the experimental group ($M = 32.24$) were, again, similar in their background knowledge to start. While both groups improved on the posttest, the difference was not significant ($p = .496$, control $M = 47.67$, experimental $M = 48.27$). This study was not able to analyze performance by lower performing students as the sample sizes were too small for comparison in that category.

An independent samples t-test was conducted to compare the gains in science achievement for the traditional hands-on manipulation (control group) and the computer-based simulation (experimental group). There was a significant difference ($p = .045$, $t(147) = 2.02$) in the achievement gains between the control group and the experimental group with the control group showing significantly greater gains (Table 2). These results suggest that the traditional hands-on manipulation lab had a greater impact on learning the concepts of density than the computer-simulated lab. For greenhouse effect, there was not a significant difference ($p = .203$) in achievement gains between the control group and the experimental group (Table 2). These results suggest that neither the traditional hands-on manipulation lab nor the computer-based simulation lab had a greater impact on achievement for this particular topic.

Table 2
Science Achievement Independent Samples t-test

Density			
Condition	Mean	Std. Deviation	*N*
Control	10.10	16.86	87
Experimental	4.09	19.29	89

Greenhouse Effect			
Condition	Mean	Std. Deviation	*N*
Control	11.37	20.43	87
Experimental	15.50	19.55	89

The next analysis was meant to determine if there was a difference in retention using computer-based simulation versus traditional hands-on manipulation. An ANCOVA analysis was conducted with the density delayed posttest as the dependent variable and the density pretest as the covariate. While the delayed posttest mean scores were higher than the pretest scores for density in both the control group ($M = 58.02$) and the experimental group ($M = 54.12$), the difference was not significant ($p = .111$). Additionally, for greenhouse effect, the delayed posttest scores were not significant ($p = .478$, control $M = 53.42$, experimental $M = 54.11$) with the delayed greenhouse effect as the dependent variable and the greenhouse effect pretest as the covariate in the ANCOVA analysis. The results indicate that traditional hands-on laboratories and computer-based simulations helped increase students' knowledge base and helped them retain this new information, but neither method was more beneficial than the other.

This study also analyzed motivation and efficacy when using computer-based simulations and traditional hands-on manipulation. There are many factors that motivate students to learn. The constructs in the SMTSL survey measured self-efficacy, active learning strategies, science learning value, performance goal, achievement goal, and learning environment simulation. An

ANCOVA analysis was done on each of these constructs with the post-survey as the dependent variable and the pre-survey as the covariate to control for initial levels. When examining the pre-survey and post-survey for each construct, there was not a significant difference in self-efficacy ($p = .608$), active learning strategy ($p = .937$), science learning value ($p = .844$), performance goal ($p = .669$), achievement goal ($p = .701$), or learning environment simulation ($p = .741$).

A Pearson correlation analysis was conducted with self-efficacy and each of the other constructs in the survey. When students have high self-efficacy, they are better able to perceive the value of science learning. This analysis showed a strong correlation between self-efficacy and science learning value ($p < .001$; $r = .834$). Additionally, there was a strong correlation between self-efficacy and active learning strategies ($p < .001$; $r = .856$). Students with high self-efficacy are more apt to find resources to understand concepts and take an active learning approach. Students who demonstrate a high achievement goal are intrinsically motivated. They are motivated to achieve their goal. As expected, the Pearson correlation analysis demonstrated a strong correlation between self-efficacy and achievement goal ($p < .001$; $r = .785$). The tendency to be motivated by a performance goal to perform better than peers or to impress teachers was correlated with self-efficacy ($p < .001$; $r = .531$).

Discussion

The focus of this study was to compare student achievement and motivation for computer-based simulations to traditional hands-on manipulation. An increase in science achievement was expected to emerge in the experimental group (computer-based simulation) compared to the control group (traditional hands-on manipulation), which was not evidenced in this study. Both groups scored higher on the posttest but neither method had a greater impact than the other on science achievement. Retention was hypothesized to increase when using computer-based simulations as students were able to conduct multiple experiments within the laboratory and evaluated variables in a range of real-world situations. The data suggests that this is not the case. Similar to science achievement, there was not a significant difference in retention between computer-based simulations and traditional hands-on manipulation. Both groups scored higher on the delayed posttests than the pretests but not at a significantly different level.

This study's findings are in contrast to Stern, Barnea, and Shauli (2008), who found that the experimental group was able to more clearly understand the particulate nature of matter when using computer-based simulations. However, this current study saw no significant difference in students' understanding of density or the greenhouse effect when using computer-based simulations compared to traditional hands-on labs. One exception must be noted. In the current study for the concept of density, the control group (traditional hands-on lab) showed significantly greater gains from pretest to posttest compared to the experimental group (computer-based simulation lab) indicating that the traditional hands-on lab had a greater impact on achievement in that particular topic. For science achievement, the experimental group did not demonstrate a significant difference compared to traditional hands-on manipulation from pretest to posttest in either density or the greenhouse effect. Delayed posttest results for density and the greenhouse effect were also not significantly different between the experimental group compared to the control group.

Many studies have concluded that labs with virtual manipulation are as effective as labs with physical (hands-on) manipulation (Chen, Chang, Lai, & Tsai, 2014; Finstein, Darrah, & Humbert, 2013; Roseman & Jones, 2013). In Chen, Chang, Lai, and Tsai's experiment, students collected, graphed, and analyzed data on Boyle's Law. In their findings, both groups had gains from pretest to posttest in learning achievement but no significant difference was found.

Likewise, Finstein, Darrah and Humbert (2013) found that in a general physics high school setting, students performed similarly well on virtual labs and hands-on labs. Roseman and Jones (2013) determined that 8th grade students in a middle school setting showed gains in their knowledge on lunar phases, but there was not a significant difference between computer simulations and hands-on manipulations. The findings from this study would agree that the same was the case for this on-level 6th grade earth science middle school setting. In the current study, the experimental group did not demonstrate a significant difference in science achievement compared to traditional hands-on manipulation from pretest to posttest in either density or the greenhouse effect. Delayed posttest results were also not significantly different when the experimental group was compared to the control group. This study validates that one delivery method was not more or less effective than another. This being the case, schools could bring scientific concepts to students virtually when they do not have the funds to outfit a traditional lab as was one of the recommendations of Finstein, Darrah, and Humbert's (2013) research.

The results of this study did not find a significant difference in student motivation toward science learning between the control group and the experimental group as was the case for Roschelle et al. (2001) and Lalley et al. (2010). Roschelle et al. (2001) and Lalley et al. (2010) found that students using a computer-based simulation had higher levels of motivation. In the current study, student motivation stayed consistent between the control group and the experimental group indicating that one method (traditional hands-on manipulation or computer-based simulation) did not motivate students more than the other.

However, like Chen, Chang, Lai, and Tsai (2014), this study did find a correlation between various constructs in student motivation (self-efficacy and achievement goal as well as self-efficacy and science learning value). In Chen, Chang, Lai, and Tsai's (2014) study, they found that students enjoyed actively participating in the lab whether it was a computer-based simulation or a traditional hands-on manipulation, which were the results of this current study. Smart (2014) found that efficacy and student achievement goal were positively correlated in middle school 6th grade students. This study would agree with those findings as there was a strong positive correlation between self-efficacy and achievement goal. Those students with a high self-efficacy sought to achieve scientific knowledge for personal improvement. There is a positive correlation between self-efficacy and the value of science or science learning value (Smart, 2014; Williams, Kurtek, and Sampson, 2011). As was the case with this study, students who scored high on self-efficacy also scored high on science learning value, indicating that students who believe they can accomplish their goal no matter the challenge also believe there is value in learning science. That being the case, this research does not support using one method of laboratory over the other for science achievement or for student motivation.

Limitations

There are limitations to all action research and this study was no exception. This was a single study done in one location. The labs were conducted in one day. Conceptual information was taught before and after the lab; however, students were given one day working in the simulation or the hands-on lab. For some students, this may not have been enough time for them to manipulate the simulation or traditional lab and gain full understanding. In addition, students' time on task was not recorded. The current school schedule is tight with class time limited. Students who may normally spend time maneuvering through the variables in a laboratory may not have on these labs in order to complete all necessary tasks.

The students in this study live in a suburban area and have daily access to technology. This may not be the case in all locations, and thus some students' ability to gain access to the simulations may be limited. More structured guidance might be necessary in those populations where students do not have the same level of access to technology.

This study was not able to analyze lower performing students because the sample sizes were too low. The participants in this study were minors so parent permission was necessary to use the data. Many participants in the special education population did not sign the waiver for their data to be used in this study.

Future Research and Implications

Future research on this topic should include analysis of lower performing students. Do hands-on manipulations help lower performing students in science achievement more than computer-based simulations? Do computer-based simulations provide more opportunities to learn for lower performing students?

Future studies should also analyze whether the combination, and order used, of computer-based simulations and hands-on manipulations would have a significant effect on science achievement. Given the sample size for this study and the classes taught by the teachers, this was not an option. However, future research should add an experimental group that conducts both the computer-based simulations and the traditional hands-on manipulations. It would be interesting to research if the order in which the labs are conducted has an effect on achievement. Would students score higher on achievement if they were to conduct the laboratories in a specific pattern? For example, one group conducts the hands-on manipulation and then the computer-based simulation while the other group conducts the computer-based simulation and then the hands-on manipulation. While this study indicated that computer-based simulation was not more effective than traditional hands-on manipulation in increasing science achievement, combining both methods and varying the order in which they are administered might increase science achievement and, possibly, retention of science concepts.

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