THE EFFECTS OF THE APPLICATION OF THE NEXT GENERATION SCIENCE STANDARDS SCIENCE AND ENGINEERING PRACTICES ON STUDENT ACHIEVEMENT

by

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DEDICATION

To Seth, Luke, and Stephanie, I love you more than coffee, tacos, and sunshine!

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ABSTRACT

The Next Generation Science Standards were developed as a pathway for student success in science. The Science and Engineering Practices encourage students to take active roles in constructing knowledge by engaging in authentic learning experiences as real scientists and engineers. This study examines the effect of science and engineering practices on student motivation, and ultimately, achievement in ninth grade introduction to physics and earth science. The data used in this study was collected from pre- and post-exams, pre- and post-surveys, engagement timelines, and student interviews. The results of the study indicate that students participating in science and engineering practices learning opportunities are more interested and engaged in the content than when participating in traditional lecture and take notes learning opportunities. The apparent increase in interest and engagement motivated students to more actively participate and an increase in achievement was determined.

INTRODUCTION AND BACKGROUND

Woodland Junior/Senior High School is located on the eastern border of the United States in Baileyville, Maine. Approximately 170 students, grades 7 through 12, attend the school. The student body is comprised of Baileyville residents, as well as students from 16 surrounding towns. Ninety-one percent of students are Caucasian, and 96.1% qualify for either free or reduced lunch (Woodland Jr-Sr High School).

Baileyville, known to locals as the Village of Woodland, is located in Washington County and has a population of 1,521 (Washington County, 2011; Baileyville/Woodland, n.d.). Washington County is Maine’s easternmost county and contains only 2.5% Maine’s total population. Baileyville is home to the county’s largest employer and taxpayer, Woodland Pulp, LLC and St. Croix Tissue, Inc. The annual payroll for the mill’s employees is $30,000,000. Considering the dire economic climate for pulp and paper mills in Maine, the Baileyville plant is unique. Instead of shutting down and laying off workers, it has invested $120,000,000 into building two tissue machines, and it has hired 70 new employees (Welcome to Woodland, 2015).

St. Croix Paper opened a paper mill in Baileyville in 1905, and it has continued to be an integral part of the community ever since (Washington County, 2011). Over the years, many Woodland Jr./Sr. High School students have aspired to go to college and move out of Maine, but others sought employment at the mill. My grandfather worked at the mill for 47 years, my father was an electrician at the mill for 40 years, and my brother continues to work there after 16 years. Ten years ago the mill shut down, laid off most of the workers, and sold the paper machine. The entire county was affected. At that time, I told my students that graduating from high school and getting hired for a job at the mill was no longer an option. I encouraged my students to push themselves to take college-prep classes in an effort to increase their options after graduation. Our region's outlook was bleak, similar to J. D. Vance's outlook as described by Rothman (2016), "I grew up poor, in the Rust Belt, in an Ohio steel town that has been hemorrhaging jobs and hope for as long as I can remember." Fortunately, the market improved and the mill started producing pulp again, and we were all cautiously optimistic about the future of the mill.

For over 100 years the Baileyville mill has provided many people the financial security necessary to raise families. My grandfather quit high school in the tenth grade to work at the mill peeling logs to help support his family. At that time, the only requirements were to show up and work hard. Although attendance and work ethic are important today, they are not enough to secure and maintain a job at the mill. My grandfather could not have imagined the skill set necessary to run the computer operated automated systems used to control the machines at the mill today. Many of my students are not planning to go to college and/or move away. They want to stay in the area, and recognize that the mill is potentially a well-paying option for them. But according to Whittle (2016), the paper industry in Maine is dying, "Maine's paper manufacturing industry employed nearly 13,000 people as recently as the early 2000s, but now only employs 6,150."

Introduction to Physics and Earth Science (IPES) is a heterogeneously grouped ninth grade science course that all students are required to pass. IPES meets one period every day for 45 minutes. Students learn about physics, earth science, and astronomy. Forty percent of students have either an Individual Education Plan (IEP) or a Section 504 Accommodation Plan. The broad range of student abilities within the classroom usually leads to complications. Many students have classroom modifications, and it doesn't take very long for students not receiving modifications to perceive an injustice and demand the modifications as well. Rick Wormeli (2005), in his book Fair Isn't Always Equal, describes differentiation of instruction as a way to maximize student learning and says that it "requires us to do different things for different students." Regardless of how modifications are justified, and necessary under the law, a caste system develops and resentment builds between students.

I want my students to be successful, whatever career path they choose to pursue: working at the mill, going to college, or leaving the State. Engaged students are motivated learners and are better able to achieve, and hopefully achievement will lead to success. John Holt (1984) claimed that learning is not the product of teaching, but that it was the product of the activity of the learners. Generally, students are engaged if they perceive the learning opportunity to be interesting, relevant, or worthy of study. Students are also more engaged if the learning opportunity is authentic, has a purpose, and deemphasizes differences in ability (Slavich and Zimbardo, 2012). Although the State of Maine Legislature has not adopted the Next Generation Science Standards (NGSS) as State standards, students should be exposed to Science and Engineering Practices that are contained in the NGSS (NGSS Lead States, 2013). These practices help learners understand how science works and makes the information they learn more meaningful.

They provide insight into the work of engineers and how to make sense of the world in which we live.

I want my students to be engaged in authentic, relevant, and beneficial learning experiences. I want the learning experiences to be beneficial in class, right now, by increasing content knowledge. I also want the learning experiences to influence students' thinking for the rest of their lives, regardless of their career path. The Science and Engineering Practices provide the learning experiences that I want students to experience (NGSS Lead States, 2013). I think that the Practices can help level the playing field for students with learning disabilities and prepare students for whatever their future holds. This led me to my focus statement: *What effects do the Next Generation Science Standards Science and Engineering Practices have on student achievement in ninth grade introduction to physics and earth science?* In addition, the following sub-questions were researched. 1. *What is the effect science and engineering practices on student interest?* 2. *What is the effect of science and engineering practices on student engagement?*

CONCEPTUAL FRAMEWORK

All students have the potential to experience success in science. Educators can ensure that their students are successful by incorporating the NGSS science and engineering practices into their science classrooms. The Framework for K-12 Science Education (2012) states that, "students cannot fully understand scientific and engineering ideas without engaging in the practices of inquiry and the discourses by which such ideas are developed and refined. At the same time, they cannot learn or show competence in practices except in the context of specific content."

Student Success

Teachers want students to experience academic success (Davis, Summer, & Miller, 2012). Every educator remembers a time when their students were actively engaged in learning and there was no doubt that learning was occurring and students were experiencing success (Stephens, 2015). Saeed and Zyngier (2012) claim that student academic success depends on engagement and motivation. The National Research Council and Institute of Medicine (2004) agrees with Saeed and Zyngier's (2012) claim, but qualifies it by maintaining that while student engagement issues are universal across all races and socio-economic levels, student disengagement consequences are more severe depending on race and socio-economic status. Rodriguez (2015) is sensitive to the diversity of students and creates socio-culturally relevant learning experiences that tie into everyday life and strengthen student engagement.

Schlechty (2002) propounds that schools do not offer enough opportunities for students to develop, apply, and hone academic skills and knowledge. When students are not able to conform to what the school can offer and there is not an alternative pathway to learning, student engagement suffers (Schlechty, 2002). He further explains that student engagement is an active process of being attentively committed to a task that provides something of inherent value to the learner (Schlechty, 2002). Dewey (1916) believes that learning naturally occurs when students are given something to do that requires thinking and replicates what interests and engages in ordinary life. Stephens (2015) contends that students are enticed and distracted by a world of technology at their fingertips and attempts to nurture high levels of engagement in the classroom have never been more challenging. Kuh (2009) describes student engagement as a combination of the degree of effort and the extent of involvement employed during learning experiences. The more meaningful interactions that a student has with the content the better he or she will understand it (Kuh, 2009). The practices provide students with meaningful learning opportunities that improve engagement and motivation.

Student Engagement

Fredricks, Blumenfeld, and Paris (2004) identify three types of engagement: behavioral, cognitive, and emotional. They explain that behavioral engagement relates to students following rules and doing work, cognitive engagement deals with motivation and effort, and emotional engagement includes interests and values. Davis et al., (2012) agree that engagement encompasses behavioral and cognitive dimensions, but argue that in the past emotional engagement may actually have been referring to relational engagement. Davis et al., (2012) contend that previous researchers misdefined emotional engagement and that the term for a student's perceived fit at school is relational engagement. Relationally engaged students tend to be optimally engaged in the learning.

Hunter (2014) claims that student interest in science begins with a hook or a positive curiosity-piquing experience that will lead to student engagement. Blumenfeld, Kempler, and Krajcik (2006) state that motivation is a factor that increases engagement and therefore leads to enhanced achievement. Motivation and engagement are important factors contributing to student learning outcomes (Schlechty, 2001). Fredricks et al.

(2004) and Lawson and Masyn (2015) point out that a deeper level of student engagement is correlated with higher educational achievement outcomes. However, Lawson and Masyn (2015) assert that determining ways to improve student engagement at the high school level is not complete and continues to be a work in progress. Rodriguez (2015) believes that more research is needed to discover how the implementation of engineering practices affects student engagement and achievement in science. Schlechty (2001) suggests that students must believe the work they are asked to complete is worthy of doing; they must see its importance and relevance. Newmann (1989) proposes that student engagement will increase when students perceive that academic achievement leads to rewards that they value. The students must also believe that their diligence will result in academic achievement. Beesley, Barker, Germeroth, and Apthorp (2010) claim that engaging students in interesting, challenging, and developmentally appropriate topics will elicit a high level of motivation. Schwarz, Passmore, and Reiser (2017) indicate that becoming a full participant in the practices goes beyond the learning of new science content, it involves new ways of thinking, interpreting, communicating, and acting. Students become more engaged in science class when involved with science and engineering practices learning opportunities.

Techniques for Improving Achievement

The Center for Comprehensive School Reform and Improvement (CCSRI) (2007) suggest several possible ways to increase positive student engagement: creating a culture of achievement, developing lessons that are relevant and interactive, and being encouraging and supportive to the learner in all ways (CCSRI, 2007). They claim that students will be more engaged when presented with high expectations, challenging instruction, and a safe environment to ask questions (CCSRI, 2007). Furthermore, lessons and activities need to draw from students' backgrounds, experiences, interests, and academic needs, as well as a need for parental involvement, extracurricular activities, and consistent and continual efforts during the entire educational experience (CCSRI, 2007). Brewster and Fager (2000) and Christenson, Reshly, and Wylie (2012) agree that parental involvement plays a major role in student motivation, and that educators also impart a significant effect on student engagement.

Student achievement depends on how committed the student is to building knowledge and utilizing deeper learning strategies (Blumenfeld et al., 2006). Newmann (1989) contends that high school students are unable to meet the cognitive rigor of secondary education by passive listening and reading. Hunter (2014) identifies the science and engineering practices and inquiry as powerful tools to engage students in learning experiences. He maintains that success can be realized when the student is an active willing participant in the learning process (Hunter, 2014). Brown (2014) grabs students' attention by using a paper airplane project with an inquiry based learning method where students engage in design discussions, explore designs, explain design results, and evaluate their findings. Cunningham and Carlsen (2014) suggest that a student's understanding of scientific concepts can be strengthened by precollege engineering design. They also contend that students engaged in engineering projects learn scientific concepts better (Cunningham and Carlsen, 2014). Van Haneghan, Pruet, Neal-Waltman, and Harlan (2013) describe a constructivist approach to learning with student centered engineering design challenges that provide a learning opportunity for students to think creatively, test models, work collaboratively, and apply math and science. Bishop and Anderson, Jensen and Finley, and Rudolph and Stewart (as cited in Bouwma-Gearhart & Bouwma, 2015) claim that modeling allows students to create models that help resolve deeply held misconceptions. Building accurate conceptual models to describe scientific phenomena is also a way to elicit student engagement (NGSS Lead States, 2013). Bouwma-Gearhart and Bouwma (2015) determined that students gain content knowledge, competence, and empowerment from modeling-based inquiry. Models also encourage students to participate in scientific argument using reasoning and evidence.

Student success depends on engagement. Engagement depends on motivation. Student motivation and engagement is enhanced when topics of study are interesting, relevant, and deemed worthy of study by the learner. Students can be encouraged to do well by teachers, parents and peers, but it depends on them to exert the force and put forth the effort to achieve. Student achievement levels will increase when students are engaged in learning opportunities that are grounded in and supported by the science and engineering practices.

METHODOLOGY

The main purpose of study this was to determine the effect of the application of the science and engineering practices on student achievement in ninth grade science. To minimize any unforeseen impact of this study on students, the intervention was applied after the regular unit of study had been completed.

Several instruments were used to determine the effect of the intervention on student achievement, as well as, gauge the effect that the application of the practices had on student interest and engagement. The Data Collection Matrix displays the cross verification of the instruments used in this study (Table 1). Pre and post Interest and Engagement Surveys were used to compare student opinions of science before and after the intervention was applied (Appendix A and Appendix B, respectively). The pre and post Interpreting Graphs Exams were also analyzed to compare skills before and after the intervention (Appendix C). The Student Engagement Timeline Chart recorded what students were doing in classes leading up to the intervention and then what students were doing in classes during the intervention (Appendix D). All students were asked to participate in the Student Interview (Appendix E). They had the choice of being interviewed individually, in pairs, or not at all. The Institutional Review Board exempted the research project from review on November 22, 2016 (Appendix F).

Intervention

For this project, the intervention was a learning opportunity that utilized many of NGSS science and engineering practices. The intervention was used to remediate specific content areas where students had performed poorly, as identified by the pre Interpreting Graphs Exam (Appendix C). The exam probed student understanding of the content, specifically, interpretation of graphs of motion with respect to position, velocity, acceleration, and time. The intervention was applied after the students had received instruction, participated in practice, asked questions, and taken the end of unit exam. The intervention was in addition to regular instructional practices typically used in this unit, not to supplant nor replace any part of it.

Table 1
Data Triangulation Matrix

Research Question	Data Source 1	Data Source 2	Data Source 3
Focus Question What is the effect of the science and engineering practices on student achievement?	Pre- and Post-Interest and Engagement Surveys	Student Interview	Pre- and Post-Test
Sub-Question 1 How is interest affected?	Pre- and Post-Interest and Engagement Surveys	Student Interview	Pre- and Post-Test
Sub-Question 2 How is motivation affected?	Pre- and Post-Interest and Engagement Surveys	Student Interview	Pre- and Post-Test

The intervention encouraged students to engage in science and engineering practices to solve a fictitious problem with potentially dire consequences. Students pretended that they were working for the Maine Emergency Management Agency, and they had to find a way to get insulin to five residents on a small island off the coast of Maine after it had been cut-off from the mainland as a result of a severe winter storm. Students had to employ the NGSS practices to be able to solve the problem, they started by asking questions and defining the problem. In doing so, the context and confines of the problem were established by the students. In this particular case, the only viable option was to deliver the insulin by air. The insulin had to be air dropped from the plane, and therefore, had to be protected from damage. Each group researched and then designed both a parachute to slow the insulin's descent from the plane and a cargo container to keep the insulin protected. Students developed and used models, as well as, planned and carried out their investigations. Students used motion detectors to graph the motion of their parachutes as they deployed and slowed the cargo of a single raw egg, which served as a substitute for the insulin. The graphs were printed and used to develop a better understanding or, in some instances, reinforce current understandings of the motion of objects with respect to position, velocity, acceleration, and time. Students compared their results with other groups as they constructed explanations and made improvements to their parachutes and cargo containers. As students tested, researched, and shared, they were asked to evaluate the information and results found, and at times, asked to communicate their findings to other groups. After the intervention, students were given the Interpreting Graphs Exam (Appendix C) again, asked to complete the Post Interest and Engagement Survey (Appendix B), and, in pairs, asked the questions from the Student Interview (Appendix E)

Instruments

The Interpreting Graphs Exam was administered to all introduction to physics and earth science students to determine a baseline from which the effects of the intervention could then be examined and compared (Appendix C). The test was comprised of twenty multiple choice questions investigating students' ability to interpret an object's motion from graphs of position vs. time, velocity vs. time, and acceleration vs. time. The Interpreting Graphs Exam was also administered to students after the application of the intervention (Appendix C). Normalized gains, described by Hake (1998) "as a comparative measure of course effectiveness," were calculated and displayed for each student, and box and whisker plots compare the pre and post exam scores (Figure 8).

Students completed the Pre Interest and Engagement Survey before the application of the intervention to expose their attitude about science (Appendix A). The survey contained five statements. Students were asked to indicate their level of agreement with being good at science, interested in science, and engagement by the topics covered in science class. The Likert-type scale for the survey included four options: agree, tend to agree, tend to disagree, and disagree. Students were asked to complete a Post Interest and Engagement Survey after the intervention to determine the effect of the intervention (Appendix B). Students responded to the same five questions that were on the Pre Interest and Engagement Survey, but two additional questions queried students about their interest and engagement during the application of the intervention (Appendix A). As with the Pre Interest and Engagement Survey, students selected one of four choices: agree, tend to agree, tend to disagree, or disagree (Appendix A).

The Student Engagement Timeline Chart was used to record what students were doing in class before the intervention was applied (Appendix D). A record of student engagement was also kept during the intervention: the learning opportunity that applied the science and engineering practices. The Student Engagement Timeline Chart included a column for recording times and a column for recording what students were doing at that time (Appendix D). There were four categories used to indicate what each student was doing: talking, listening, working, or disengaged. A student was considered disengaged if they were doing something other than talking, listening , or working. The talking and listening had to be grounded in the context of the learning opportunity or directly related to the topic of study. To be considered working, students had to be physically employed in a task that was directly related to the lesson. A comparison was made, of what students were doing during class, between the two Student Engagement Timeline Charts (Figure 6).

After the intervention, students participated in the Student Interview (Appendix E). Students were interviewed in pairs and were asked the same set of seven questions. One of the interview questions offered an opportunity for students to explain and/or clarify a previous response on the Pre and Post Interest and Engagement Survey (Appendix A and Appendix B, respectively) about whether or not they like science. Another question asked, “Do you prefer traditional lecture and take notes learning opportunities or learning opportunities that make use of the science and engineering practices? Why?” The responses to the interview questions were written and then read back to the students to ensure the accuracy of the notes. The qualitative data produced from the interview underwent thematic analysis, it was grouped by question number and then categorized by the similarity of the response.

DATA AND ANALYSIS

The results of the Pre-Interest and Engagement Survey (Appendix A) indicate that 65% (*N*=23) of respondents agreed or tended to agree that they like science (Figure 1). One student said, “I don’t like science if we are just sitting around taking notes.” Another said, “science is interesting and I like it.” The results of the Post-Interest and Engagement Survey (Appendix B) indicate that 77% (*N*=17) of respondents agreed or tended to agree that they like science (Figure 1). One student said, “science is boring if we just sit around.” Another student said, “I liked the project, but not the other stuff.”

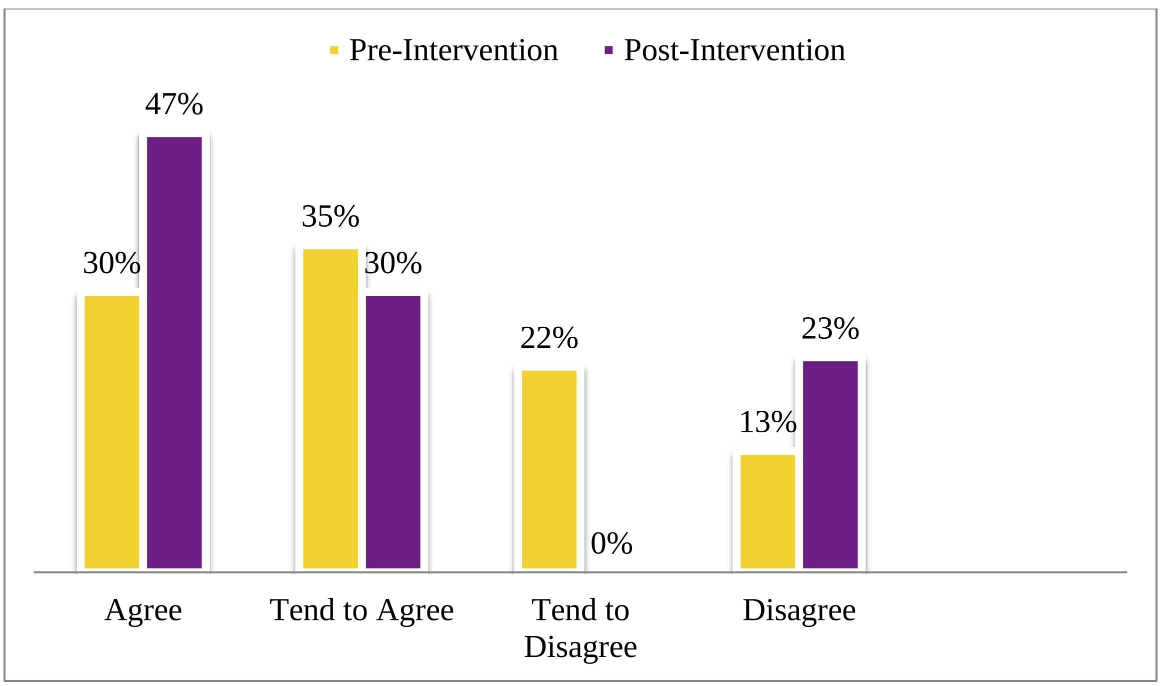

Figure 1. Student responses to Pre- and Post-Interest and Engagement Survey question “I like science”, (*N*=23).

Before the intervention, 65% of students claimed that they were not interested in the topic being studied in science class (Figure 2). After the intervention, responses to the

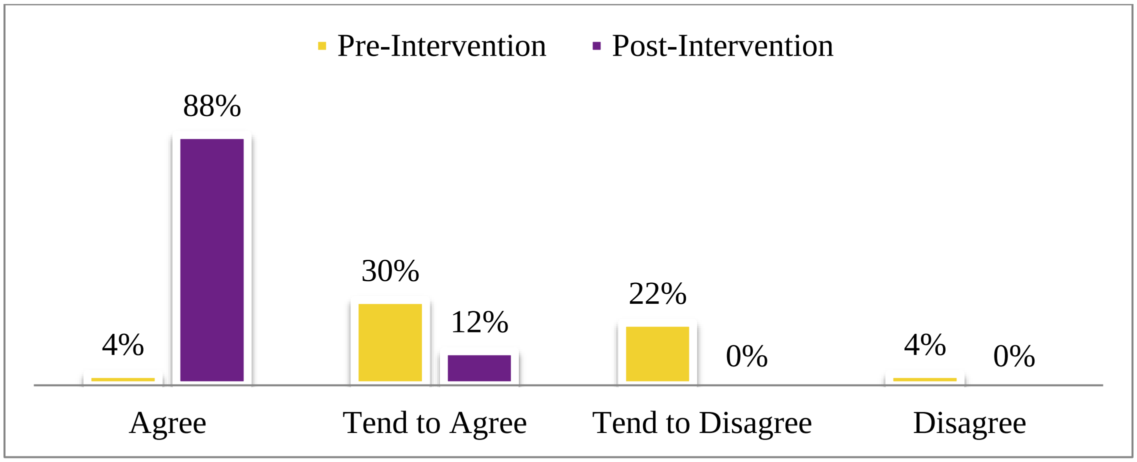

Figure 2. Student responses to Pre- and Post-Interest and Engagement Survey question "I am interested in what we have been studying in science class during the past three days", (*N*=23).

Post-Interest and Engagement Survey (Appendix B) indicated that 100% of students agreed or tended to agree that they were interested in what they had been studying during class during the past three days (Figure 2).

Seventy-three percent of students indicated that they were engaged in class before the intervention (Figure 3). A student claimed that "even though I don't like physics I do pay

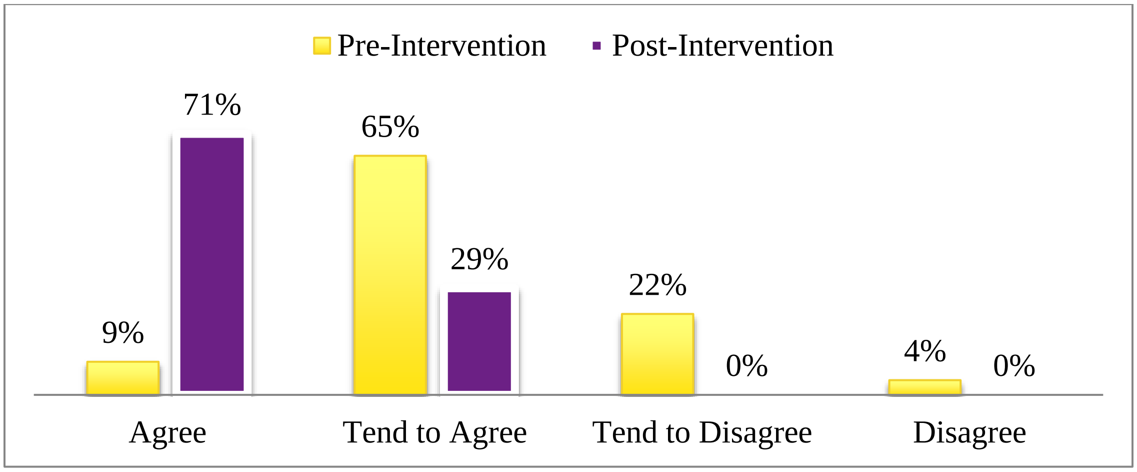

Figure 3. Student responses to Pre- and Post-Interest and Engagement Survey question "In science class, I have been engaged in the topic of study during the past three days", (*N*=23).

attention and do the work." After the intervention, 100% of respondents claimed that they were engaged in the topic of study during the past three days (Figure 3). One student said, "I prefer the practices, I get sucked in by what I'm doing."

When asked if they had discussed what they had been studying in class with someone from outside of class, in the past three days, only 17% indicated in the affirmative (Figure 4). One student reported, "I only tell my mom about the stuff that is exciting, not the

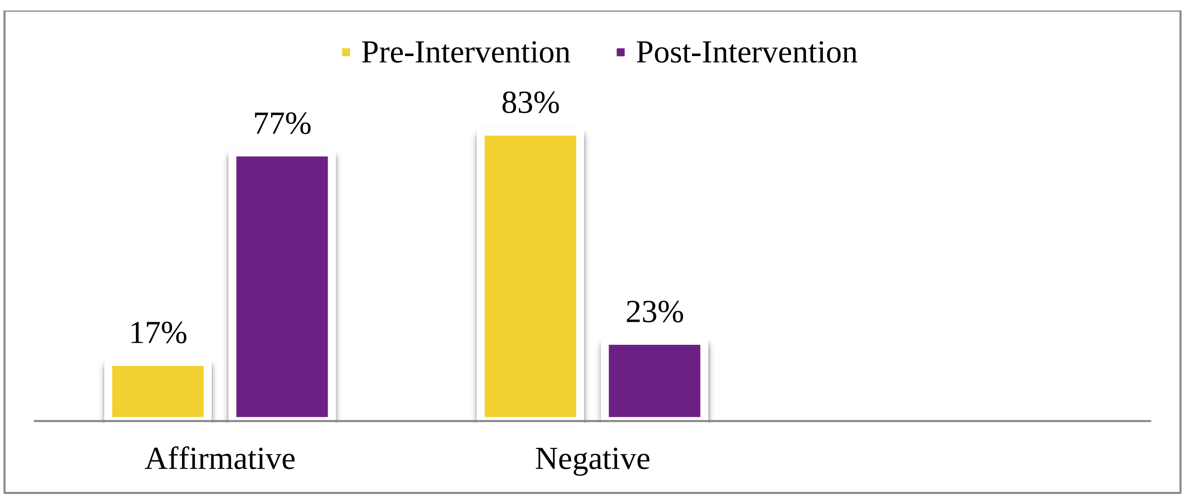

Figure 4. Student responses to Pre- and Post-Interest and Engagement Survey question "I have discussed what I have been studying in science class with someone from outside of science class in the past three days", (*N*=23).

boring everyday stuff." Another student said, "I told my mom about how my parachute opened. It slowed the fake insulin down and the egg didn't break. Mom told me that I should have used a plastic egg instead of a real one."

When asked if they liked science and engineering practices learning opportunities more than tradtional lecture and take notes learning opportunities 100% agreed or tended to agree (Figure 5). One hundred percent of respondents also indicated agree or tend to agree when asked if they learn more from science and engineering practices learning opportunities compared to traditional lecture and take notes learning opportunities (Figure 5). Several students said, "I learn better this way compared to just sitting around taking notes." According to the anecdotal record from the Small Group Behavioral

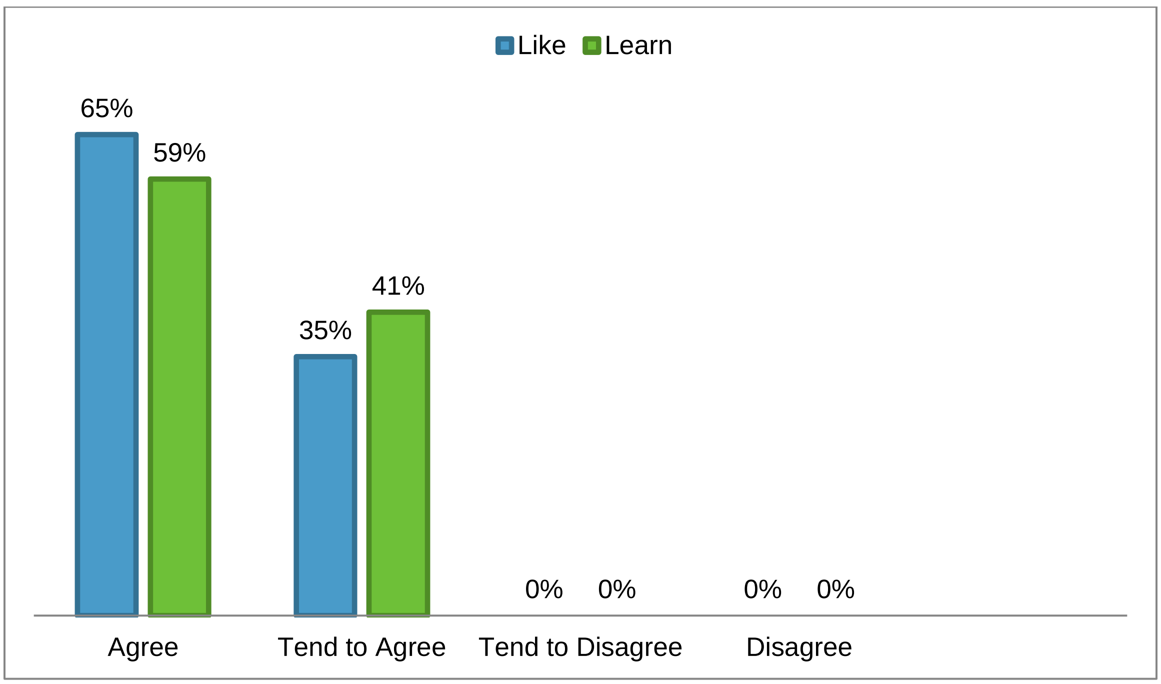

Figure 5. Response to "I like science and engineering practices learning opportunities more than traditional lecture and take notes learning opportunities and I learn more from science and engineering practices learning opportunities than I do from traditional lecture and take notes learning opportunites", (*N*=23).

Engagement Timeline (Appendix D), 100% of students were actively participating in class by talking, listening, or working while engaged in a science and engineering practices learning opportunity. The Small Group Behavioral Engagement Timeline (Appendix D), during a traditional learning opportunity, documented that 69% of students were listening and 31% were disengaged (Figure 6).

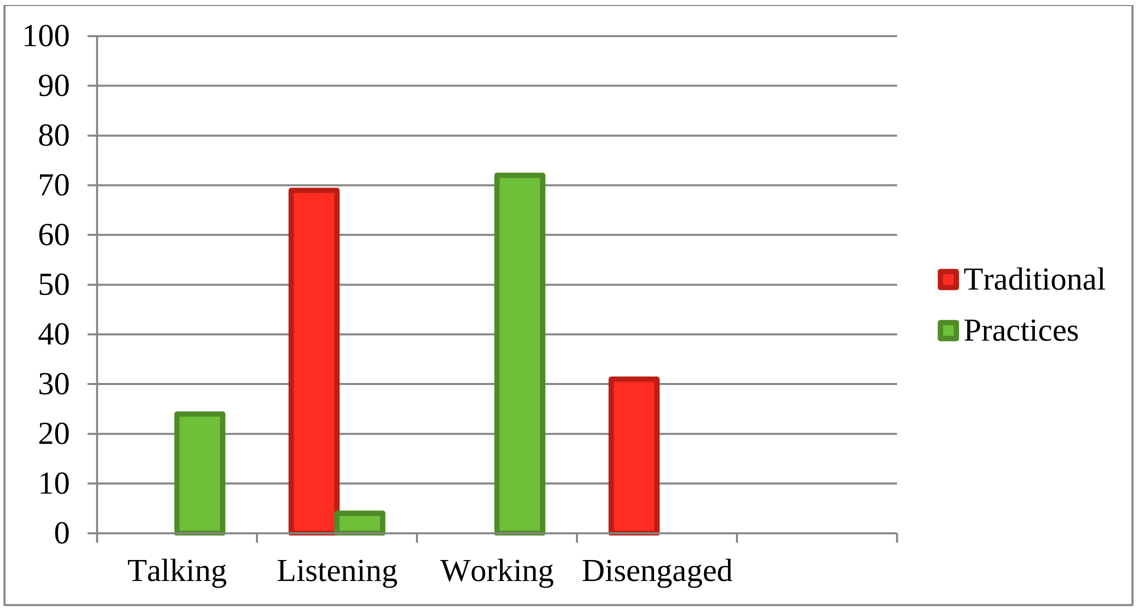

Figure 6. Data from the Small Group Behavioral Engagement Timeline, (*N*=31).

Student scores on the Interpreting Graphs Pre-Exam (Appendix C) compared to the Interpreting Graphs Post-Exam (Appendix C) show that 86% of students scored higher or their score stayed the same (Figure 7). Seven of the 28 students scored 100 on both the

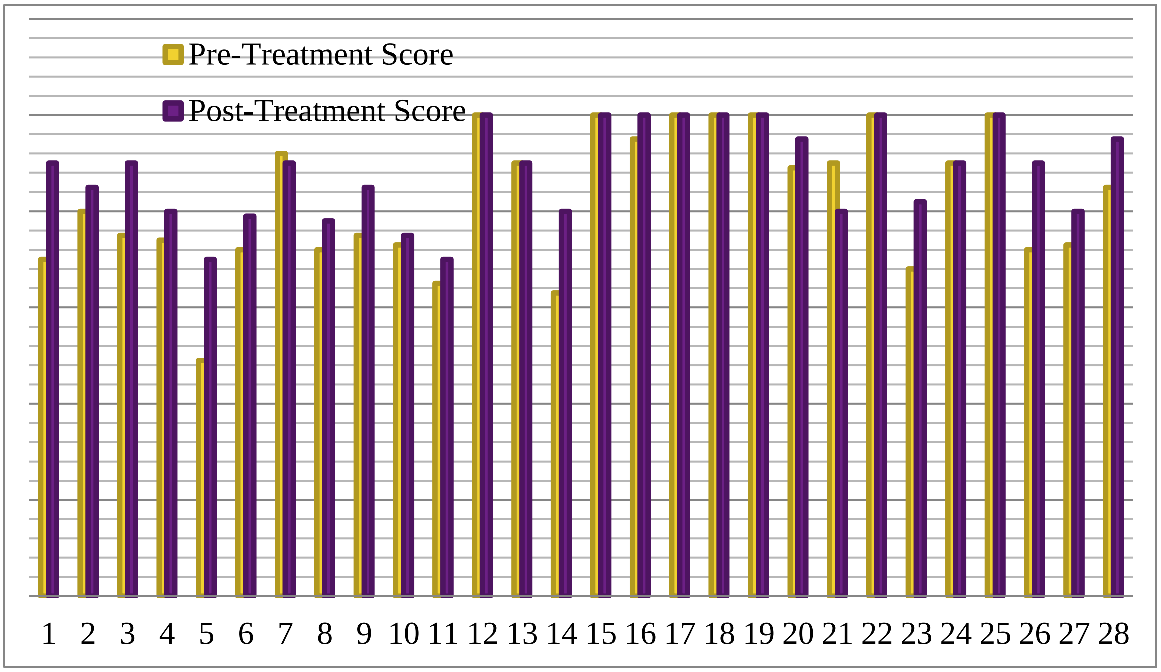

Figure 7. Comparison of pre-exam and post-exam scores, (*N*=28).

pre- and post-exams. One student said, “My grade is the most important thing in science class.” Another student said, “My grade is important to get in a good college, but learning about science is more important. At the end of the day, I won’t take my grade into the real world, but I will take what I have learned.”

The results of the Interpreting Graphs Pre- and Post-Exam (Appendix C) scores indicate that 36% of students achieved normalized gains of greater than 0.3 (Figure 8).

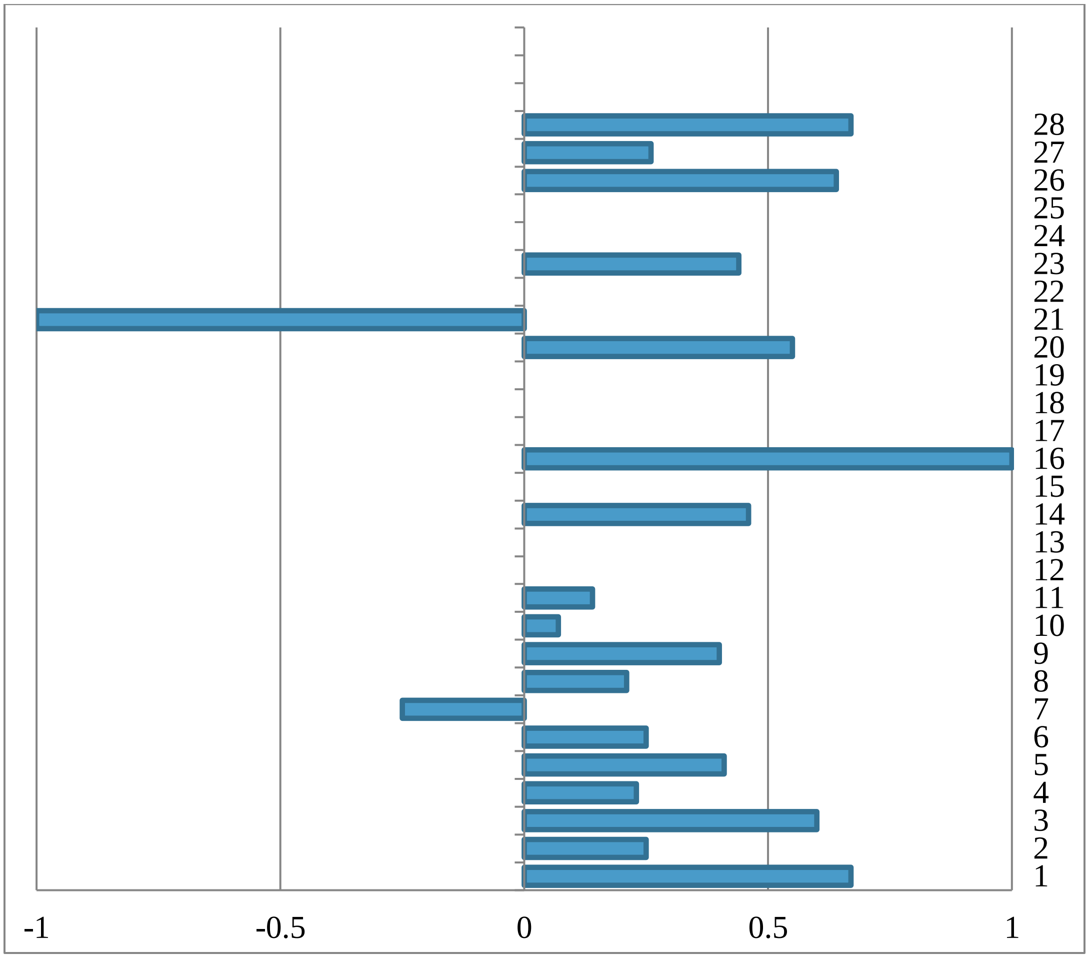

Figure 8. Normalized gains from pre-exam to post-exam, (*N*=28).

According to Hake (1999), values of less than 0.3 indicate small normalized gains, values between 0.3 and 0.7 indicate medium normalized gains, and values greater than 0.7 indicate large normalized gains. The mean score increased from 82.5 to 88, and the median increased from 82.5 to 90 (Figure 9). When asked why he did better on his Post-Exam than his Pre-Exam a student said, “I understand it better than I did before.”

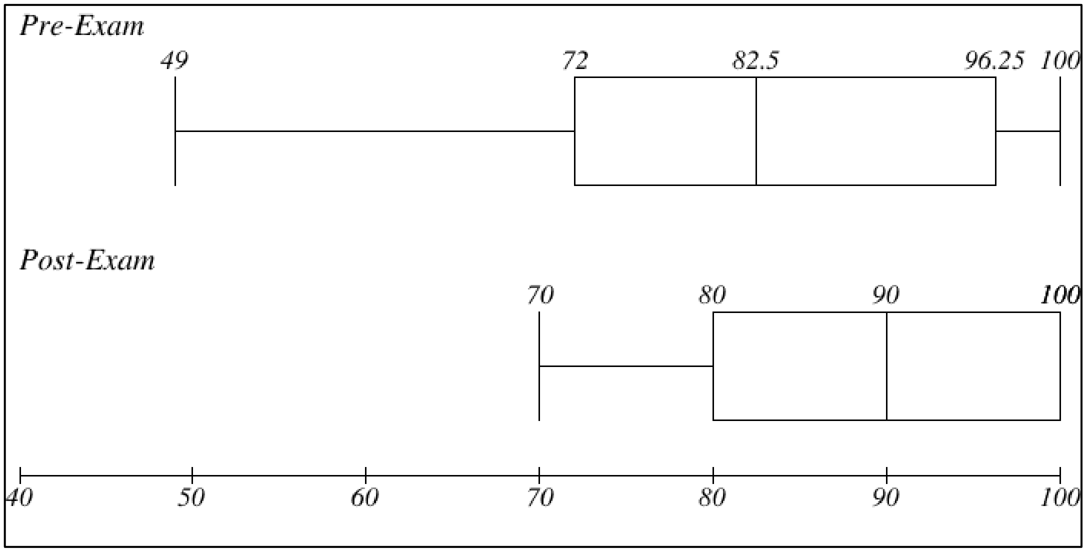

Figure 9. Interpreting graphs pre- and post-exam score distributions, (*N*=28).

INTERPRETATION AND CONCLUSION

The goal of this study was to determine the effect of the application of science and engineering practices on ninth grade introduction to physics and earth science student achievement. Quantitative data comparing Pre- to Post-Exam scores showed an increase in both the mean and the median values, the mean increased from 82.5 to 88 and the median increased from 82.5 to 90. Qualitative data from surveys and interviews revealed student's increase in interest and motivation when participating in learning opportunities as scientists and engineers. Students felt that they learned more from science and engineering practices learning opportunities than traditional lecture and take notes learning opportunities. In fact, all students preferred engaging in the practices over traditional lecture style classes.

The data suggests that students engaged in learning opportunities that employ the science and engineering practices have an increased interest in the content and are more motivated to actively participate in class, which ultimately coorelates to higher achievement. One student said, “I like hands on learning because I don’t get distracted so easily.” Data from the Post-Interest and Engagement Student Surveys, as well as the Post-Treatment Student Interviews indicate that students are more interested when they are active participants in class (Appendix B and Appendix E, respectively). Beesley, Barker, Germeroth, and Apthorp (2010) claim that engaging students in interesting, challenging, and developmentally appropriate topics will elicit a high level of motivation. Interest in the topic of study is the impetus for student motivation.

All students benefited from the practices, even the seven students that scored perfect 100’s on both the Pre- and Post-Exams. Students were more engaged in the learning process when participating in science as a scientist and an engineer. Many students indicated that they may zone out during a lecture, but that was not an option while working within the parameters of the practices. One student said, “taking notes gets boring and I accidentally zone out and miss a lot of information.” Another student agreed, but added “with lectures I can’t always stay focused long enough to remember everything.” The science and engineering practices provided students the opportunities necessary to deepen their understanding and elaborate on the scientific processes at play in the real world.

Based on the results of this study, students desire authentic real-world science experiences. A student said, “I like the building opportunities because it give me a chance to think like a scientist and helps me with problem solving.” Students are motivated by science and engineering practices learning opportunities. Schlechty (2001) suggests that students must believe the work they are asked to complete is worthy of doing; they must see its importance and relevance. Students are able to see the relevance in identifying and solving real-world problems as scientist and engineers. They want to be scientists and engineers right now, they do not want to wait to plan and carry out investigations or construct explanations and design solutions. Students want to experience science, they want to help add to the body of scientific knowledge that already exists. Today, people do not need to remember facts, formulas, or trivial minutia that can be quickly accessed on the Internet.

According to the results of this study and others like it, students learn by doing. In fact, John Dewey (1916) believed that learning naturally occurs when students are given something to do that requires thinking and replicates what interests and engages in ordinary life. One student claimed, “I learn best when I get to work on it myself, not someone else doing it for me.” Most students prefer a hands and minds on approach to learning science.

VALUE

Students need the knowledge and tools to make sound logical decisions about the world around them. A thorough understanding of science and scientific processes is essential for students to be prepared for the problems they encounter and the decisions they make. One issue that our students will grapple with over the course of their lifetimes is climate change. President Trump pulled the United States out of the Paris Climate Agreement making it more difficult for humanity to slow world-wide rising temperatures. But, our students will use science, specifically science and engineering practices, to find possible solutions to the problem. They will use science to balance the push of economics with sound logical choices that protect our environment.

Science and engineering practices encourage students to see how science is relevant to their lives. When students work as scientists and engineers they quickly see that they are engaging in authentic and important work, they become motivated and are captivated by their work. When the connection between student and science content is created, as a result of active learning, science education becomes interesting and relevant. Students prefer actively participating in scientific endeavors as scientists and engineers over sitting, statically, waiting for the traditional lecture and notes style lesson to be over. It is clear that students need and prefer learning opportunites that allow them to tackle genuine, complex, and real-world problems.

Science classrooms generate a multitude of data; collect it, analyze it, and reflect on it. Exam grades may provide numbers to generate a student's score or grade in a particular class, but those numbers don't necessarily fully describe student achievement. End of unit testing or summative assessments are important when comparing a student's degree of acquisition of knowledge to a standard, but that is not the whole story. Formative assessments or during unit assessments help paint a more complete picture of student achievement, while allowing educators to closely monitor student progress over the course of the learning experience. As science educators, we look for validity across a variety of summative and formative instruments. We link surveys with interviews and compare those results to exam scores. We look at what it takes to affect normalized gains and improve standardized tests results, all while providing learning opportunities that increase student interest and motivation in a manner that I now know will improve student achievement. The science and engineering practices provide educators with learning opportunities that contribute to better communication with students. What students have to say is important. As I interviewed my students and took notes on their insights, I could see that they took the exercise seriously and I was amazed at the depth and complexity of their responses. I see value in summative and formative assessment, but I also see a tremendous benefit from utilizing other indicators of progress; interest and motivation surveys, interviews, and student engagment timeline charts.

The scientific community is constantly developing, refining, and expanding the body of scientific knowledge. We, as science educators, must continually develop, refine, and expand our repetoire of teaching practices. It is imperative that we are not complacent or static in our teaching. Our student population is dynamic, fluid, and ever-changing. We need to evolve with them to remain germane. It is my endeavor, as I move forward, to stay abreast of trends in science education and employ a variety of learning opportunities, not relying on any one particular style or method of teaching. I will continue to collect student data and regularly reflect on and respond to its implications. It is my intent to continue my work with and research into the NGSS science and engineering practices, which will ensure an unequivocal correlation between the intent of the practices and the learning opportunities that are provided to my students. I want the practices to become part of the normal classroom routine.

This study has changed the way I view educational research, theory, and best practices. I now see myself as a reseacher in my own classroom, and I do not have to pour over existing studies and research to chart a course of action. Although, it is reassuring to be validated when I do consult existing research. I am a more confident educator and a more self-reliant researcher as a result of this study. I am better able to identify issues, collect data, interpret that data, and reflect on my own practice. This, of course, leads to a multitude of questions that I will need to address as I move forward; how does interest and engagement affect student truancy, how do I custom tailor science classes to meet the needs of every student with limited resources at a small rural school, and is utilizing the science and engineering practices to effect student achievement enough?

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APPENDICES

APPENDIX A

PRE INTEREST AND ENGAGEMENT SURVEY

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

Pre-Interest and Engagement Survey

1. I like science.

agree tend to agree tend to disagree disagree

2. I am good at science.

agree tend to agree tend to disagree disagree

3. I am interested in what we have been studying in science class for the past three days.

agree tend to agree tend to disagree disagree

4. I have been engaged during science class for the past three days.

agree tend to agree tend to disagree disagree

5. I have discussed what we have been studying in science class, in the past three days, with someone outside of science class.

agree tend to agree tend to disagree disagree

APPENDIX B

POST INTEREST AND ENGAGEMENT SURVEY

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

Post-Interest and Engagement Survey

1. I am interested in what we have been studying in science class for the past three days.

agree tend to agree tend to disagree disagree

2. I have been engaged during science class for the past three days.

agree tend to agree tend to disagree disagree

3. I learn more from science and engineering practices learning opportunities, like those provided in the past three days, than I do from traditional lecture and take notes learning opportunities, like those provided last week.

agree tend to agree tend to disagree disagree

4. I like science and engineering practices learning opportunities, like those provided in the past three days, more than I like the traditional lecture and take notes learning opportunities, like those provided last week.

agree tend to agree tend to disagree disagree

5. I have discussed what we have been studying in science class, in the past three days, with someone outside of science class.

agree tend to agree tend to disagree disagree

6. I learn more from science and engineering practices learning opportunities, like those provided in the past three days, than I do from traditional lecture and take notes learning opportunities, like those provided last week.

agree tend to agree tend to disagree disagree

7. I have discussed what we have been studying in science class, in the past three days, with someone outside of class.

agree tend to agree tend to disagree disagree

APPENDIX C

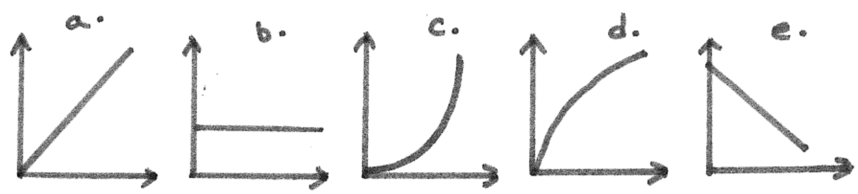
INTERPRETING GRAPHS EXAM

Pre Name: ______________________

Interpreting Graphs Exam

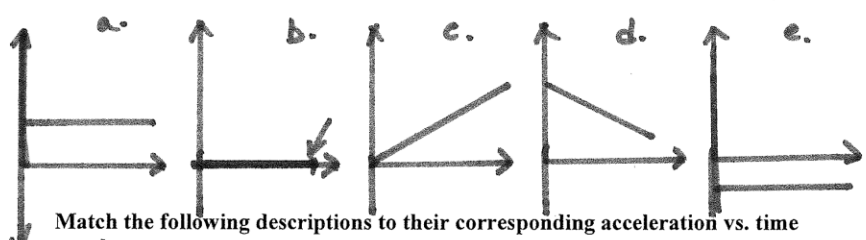
Match the following descriptions to their corresponding position vs. time graphs.

1. The object is not moving.
2. The object is speeding up.
3. The object is slowing down.
4. The object is moving away from the motion detector with a constant velocity.
5. The object is moving towards the motion detector with a constant velocity.



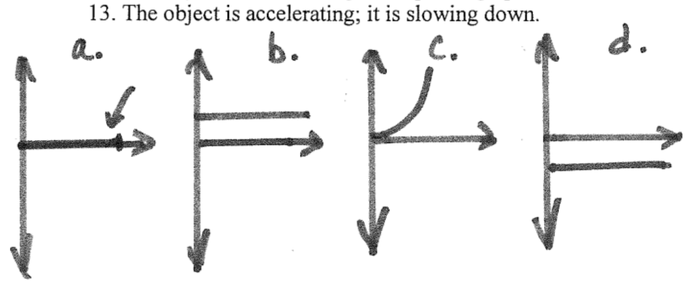
Match the following descriptions to their corresponding velocity vs. time graphs.

6. The object is not moving.
7. The object is speeding up
8. The object is slowing down
9. The object is moving away from the motion detector with constant velocity.
10. The object is moving towards the motion detector with constant velocity.



Match the following descriptions to their corresponding acceleration vs. time graphs.

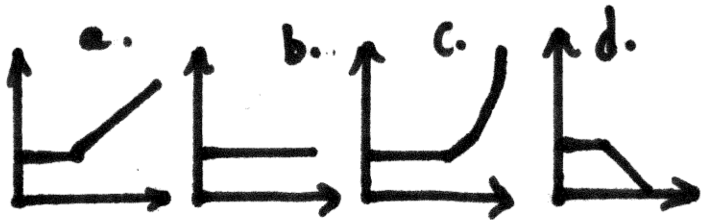
11. The object is not accelerating.
12. The object is accelerating; it is speeding up.
13. The object is accelerating; it is slowing down.



Pre   Name: ____________________

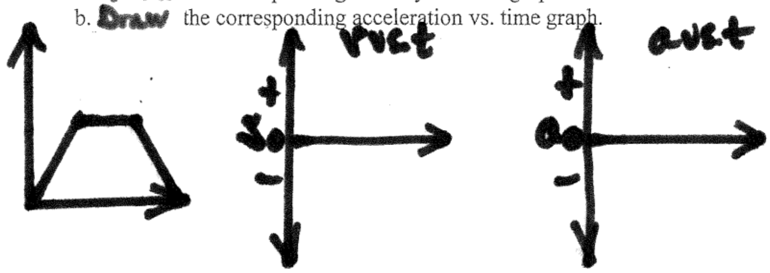
Select the best choice.

14. Which graph shows an object not moving, but then accelerate (speed up) away from the motion detector?
15. Which graph shows an object not moving?
16. Which graph shows an object not moving, but then move away from the motion detector with a constant velocity?

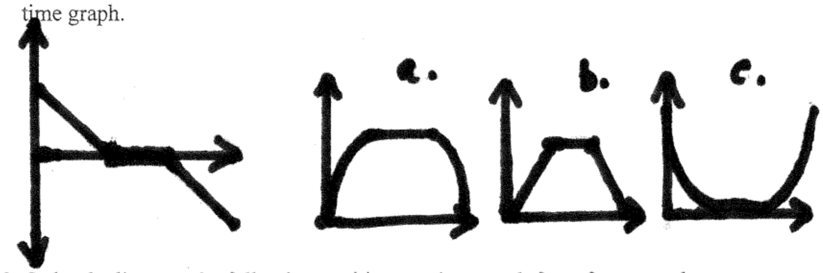


17. Given the following position vs. time graph:

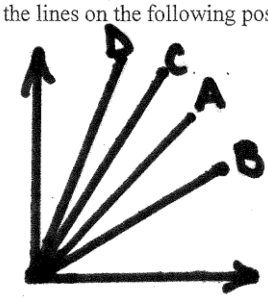
    a. Draw the corresponding velocity vs. time graph.
    b. Draw the corresponding acceleration vs. time graph.



18. Given the following velocity vs. time graph choose the corresponding position vs. time graph.



19. Order the lines on the following position vs. time graph from fastest to slowest.



a. DCAB
b. DCBA
c. CDBA
d BACD

APPENDIX D

STUDENT ENGAGEMENT TIMELINE CHART

Small Group Behavioral Engagement Timeline

	Date	Time	Period	Student Engagement *
Group 1				
Group 2				
Group 3				
Group 4				
Group 5				
Group 6				
Group 7				
Group 8				
Group 9				
Group 10				
Group 11				

*What each student is doing in the group: talking, listening, working, or disengaged.

APPENDIX E

STUDENT INTERVIEW

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

Post Treatment Student Interview Questions

1. Do you like science? Why or why not?

2. How do you learn best?

3. Is it easier for you to learn on your own or in a classroom with others? Why do you think that is?

4. Do you prefer traditional lecture and take notes learning opportunities or learning opportunities that make use of the science and engineering practices? Why?

5. What is more important to you in science class, learning about science or your grade in science? Why?

6. Do you discuss what you study in science class with someone from outside of science class? Why or why not? How often?

7. Do you have anything that you would like to add?

APPENDIX F

IRB EXEMPTION

INSTITUTIONAL REVIEW BOARD

For the Protection of Human Subjects
FWA 00000165

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MEMORANDUM

TO: Steven Knowles and Marcie Reuer

FROM: Mark Quinn *Mark Quinn CJ*

DATE: November 22, 2016

SUBJECT: "*The Effects of the Application of the Science and Engineering Practices on Student Achievement*" [SK112216-EX]

The above research, described in your submission of November 21, 2016, 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.