THE EFFECT OF INQUIRY WITH SCIENCE NOTEBOOKS ON STUDENT ENGAGEMENT AND ACHIEVEMENT

by

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ABSTRACT

This study looks at the question, what are the effects of implementing a scientific inquiry approach by the way of scientific notebooks in a high school science class? There were 36 students involved in this study from two college prep physical science classes in a large, diverse high school in Sharonville, Ohio. Students used scientific notebooks and participated in scientific inquiry lessons for two physical science units, Forces and Energy. Students were given a pre and post test for each unit and their notebooks were observed for completion. An engagement observation tool was used to record engagement of students during lessons. Students’ academic achievement improved from the pre to the post test with both units. Students showed 90% engagement during the seven lessons observed. Lessons including scientific inquiry activities with the use of science notebooks have shown a positive impact in achievement and engagement.
INTRODUCTION AND BACKGROUND

Princeton High School is a large suburban school in northern Cincinnati. There are 1,665 students 9th-12th grade. Princeton has a very diverse student population with the largest group (47.8%) of students being African-American, 27.2% being white, 16.7% being Hispanic, 2.7% being Asian, 0.8% being Pacific Islander, and 4.7% being of two different races. There is 67% of our student population on free and reduced lunch. The school has been close, but has not met the 80% proficiency for the science section of the Ohio Graduation Test in the past five years. Princeton offers a host of advanced science courses with 16% of the student body participating in a new STEM program (personal communication, February 10, 2016).

During my years of teaching I have noticed a trend in students that was not apparent to me as a student myself. There is a lack of problem solving and critical thinking skills in current students. This could be due in part to the demographic of students I have taught as well as the lower academic level of the students I have taught. However, this is also something I noticed teaching affluent Advanced Placement students. There seems to be a need for the “right answer,” which creates a dependence on the teacher. Other problems I have noted in my students are the lack of acquiring science skills, inability to express themselves in writing, lack of teamwork, and lack of exploration and creativity. These issues are large source of concern for me and working in science we have the unique ability to change this through the use of scientific inquiry.

The process of scientific inquiry is often misunderstood and underused in classrooms. Throughout my teaching career I have noticed that many science teachers,
including myself, refer to the scientific method when discussing how to do science. This creates a rigid set of guidelines for the process of experimentation that is not a realistic view of how scientists experiment. Instead of doing real world science, this sets the expectation that things will go exactly according to plan otherwise it would be viewed as incorrect. In true science there are different practices that are used, but you are encouraged to step outside the box and explore. This freedom to investigate is lacking in many science classrooms.

The *Next Generation Science Standards* (NGSS) stress the importance of science and engineering practices rather than a straightforward and rigid scientific method (Llewellyn, 2013; NRC, 2012). The goal is to engage students, make connections to the real world, and improve scientific literacy all while learning the core ideas in different areas of science. These scientific practices involve the process of inquiry as well as the use of science notebooks. An inquiry approach to teaching science engages students through investigations, which require analysis and reasoning. The NGSS practices specifically include investigative work as well as analyzing data and formulating explanations. These practices will allow for student engagement in the material as well as the gaining of content knowledge. Not only are these practices part of the inquiry process, but they can be enhanced by the use of science notebooks. The use of scientific notebooks will allow for students to process this information in written form and to keep record of their investigations. Science notebooks can also be used as a tool for the teacher to check for student understanding.
In the science classroom, experiments and labs should be a time to create meaningful connections within the content being studied. Often I have observed and implemented many lab experiments, which include step-by-step procedures that often restrict engagement with the material. I discovered that through this process, my students were completing the lab but lacked a full understanding of the topic we were studying. There were even labs that I struggled to make the connections to the content as the instructor. I felt these labs were completed to fulfill a quasi-inquiry component for the class.

Lectures, textbook activities, and worksheets were part of my introduction to the world of science teaching when I was a novice. I learned rather quickly that these types of tools did not work for me due to multiple reasons. This way of instruction did not engage my students nor did it give them the depth of understanding of science concepts I was looking for.

All of these things have led me to explore inquiry as a means of teaching science content. My focus statement for this action research was, *What are the effects of implementing a scientific inquiry approach by the way of scientific notebooks in a high school science class?* In addition the following sub-questions were researched,

1. What is the effect on student engagement while doing scientific inquiry activities?
2. What is the effect on student achievement on a post-test after doing scientific inquiry activities?
3. What is the effect on student engagement while using science notebooks?
4. What is the effect on student achievement on a post-test after using science notebooks?

CONCEPTUAL FRAMEWORK

Scientific inquiry is a process that allows students to think critically when assessing data gathered from their own investigations. The Next Generation Science Standards call for this inquiry process in classrooms. There are eight essential practices that are used by scientists and are part of inquiry. Those practices include asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics information and computational thinking, constructing explanations and designing solutions, engaging in argument from evidence, and obtaining, evaluating, and communicating information (Llewellyn, 2013; NGSS Lead States, 2013).

Scientific inquiry can be defined as, “the process of active exploration by which we use critical, logical, and creative thinking skills to raise and engage in questions of personal interest” (Llewellyn, 2013, p.15). Inquiry can be used as a valuable tool to help students make connections to an already existing schema as well as change or alter their previously held ideas in the light of new information. This process is also beneficial in the building of new information based on their experiences from investigations. Since inquiry involves the use of independent thought and analysis. This will create young adults who are thinkers, communicators, and problem-solvers (Llewellyn, 2013).

The prevailing method for teaching science education is the use of the scientific method. The steps of the scientific method are, “observe, develop a question, develop a
hypothesis, conduct an experiment, analyze data, state conclusions, generate new questions” (Windschitl, Thompson, & Braaten, 2008, p.942). There are many issues with the use of the traditional scientific method. One main issue is that many noted scientists do not believe in a specific scientific method (Windschitl et al., 2008). Scientists of all areas have different methods of investigation. This includes modification in asking questions, gathering data, and using evidence in argumentation (Bauer, 1992). Scientists are continually doing a variety of activities in their line of work which include, but are not limited to, creating, making, observing, investigating, and researching (Windschitl et al., 2008). Investigations are rarely identical from individual to individual including practicing scientists. There is more than one correct way to do an investigation which includes reasoning and explanations (Llewellyn, 2013). Another issue with the scientific method is that it creates a specific and rigid set-up to investigation with a generic and universal question. This stunts critical thinking by students when following a procedure they have been given (Windschitl et al., 2008).

The goal of the NGSS standards is to move away from the problematic scientific method and towards classrooms with scientific inquiry (Windschitl et al., 2008). There are five requirements necessary to consider something scientific knowledge. These are that it is testable, revisable, explanatory, conjectural and generative (Smith, Maclin, Houghton, & Henessey, 2000; Windschitl et al., 2008). If all five conditions are met, then scientific inquiry has taken place (Windschitl et al., 2008).

One key element of methods-based inquiry is using models. These models should represent the phenomenon to be understood. While testing the model, students should
explore why something is happening and not merely that it has happened. Inquiry is something often used as a novelty and reprieve from traditional teaching. When inquiry is used, it is usually not applied correctly and does not allow for explanations of why things happen. For example, a preservice teacher described the use of an investigation about plants that appeared to be inquiry. The students came up with ideas on their own, such as testing the effect of music or liquids other than water on plants. While the teacher was excited by students coming up with their own experimentation questions, there was no reason for the students to be asking these questions that would not lead to explanations of the underlying model (Windschitl et al., 2008).

There is conflicting and complicated research on inquiry and student achievement with a positive correlation. This could be due to teachers not knowing or understanding how to implement the process (Anderson 2002; Gautreau & Binns 2012; Wilson, Taylor, Kowalski, & Carlson 2010). In an investigation with a place-based inquiry approach, there was no evidence of an increase in test scores. However there was not a loss observed either. This investigation did find that the feelings of students toward inquiry became positive. There were more negative feelings towards traditional science teaching. This is important because students need to be excited about learning science (Gautreau & Binns, 2012). A study was done involving an underperforming urban school that used an inquiry-based curriculum that also included technology for three years. The results showed that students made gains in science content and process skills (Marx, Blumenfeld, Krajcik, Fishman, Soloway, Geier, & Tal, 2004). A study was done comparing an inquiry curriculum with the use of the BSCS 5E instructional model and
general teaching practices. The BSCS 5E instructional model is set up as a cycle that begins with engagement and moves through exploration, explanation, elaboration, and finally evaluation (Llewellyn, 2013). The general teaching practices included note-taking, lecturing, reviewing case studies, and learning key terms. The data showed the treatment group outperformed the control group (Wilson et al., 2010).

A connection between inquiry and student engagement has been observed. Data from students in Australia, Canada, and New Zealand was analyzed for a correlation between levels of inquiry and levels of scientific literacy, interest in science, and engagement. The results showed that students who were taught with higher levels of inquiry had below-average levels of scientific literacy but high levels of interest and engagement in science. The opposite was seen in students who were taught with lower levels of inquiry (McConney, Oliver, Woods-McConney, Schibeci, & Maor, 2014).

Student explanations are an important part of the scientific inquiry process and contain three parts: claim, evidence, and reasoning. In the review of student notebooks, there was a correlation between student explanations and higher test scores. This study also discovered that if one of the three parts of an explanation is missing, there is a higher likelihood that the claim will not connect to the data. In order for students to gain from this part of inquiry, they need to be given more opportunities and explicit instruction on how to provide the three parts of the explanation (Ruiz-Primo, Min, Tsai, & Schneider, 2009).

Notebooks serve many purposes in scientific inquiry, including the ability to observe student progress (Roberson & Lankford, 2010; Ruiz-Primo et al., 2009). Since
inquiry focuses on students actively participating and doing science, notebooks are a good vehicle to allow this to occur. Notebooks allow students to gather data, make claims about what was observed and use reasoning to connect everything together (Roberson & Lankford, 2010). In order to keep intellectual integrity in their work, students must keep an accurate record (Llewellyn, 2013).

The use of notebooks also enables students to practice communication, one of the most important science process skills. Notebooks can be a tool to help students learn how to clearly explain their understanding of scientific concepts. Notebooks can be used to deepen understanding of knowledge if the process involves reflection which is student driven (Butler & Nesbit, 2008).

Students gain the ability to critically think and analyze information through the use of notebooks. Students are no longer passive observers of experiments or lessons, but now they are creating their own investigations. This will foster an ability to take responsibility for their learning (Roberson & Lankford, 2010).

It is important to start out simple and to engage students when using science notebooks. Students need to see the importance of this work and take ownership in the process (Leffler & Crauder, 2011; Roberson & Lankford, 2010). Consistency in the setup of science notebooks is important and it is crucial to continue using the same approach for the duration of the course (Leffler & Crauder, 2011). Guidelines for laboratory notebooks ensure that experiments can be repeated and convey accurate results, since they could be used as a legal document (Robertson & Lankford, 2010). Science notebook entries should include, date and time, question, prediction, procedure
with data, conclusions, and a line of learning. The line of learning is an extension of the concept being taught. It is understood that not all of these parts will be used in every notebook experience (Butler & Nesbit, 2008).

Notebooks can be an important formative assessment tool for both the teacher and the students. There are two schools of thought when it comes to grading notebooks. One is that notebooks should not be used as a grading tool but rather as a means for students to process information. The grading should be done more formally with turned in assignments or summative assessments (Leffler & Crauder, 2011). On the other side, the notion is that notebooks can be used as a grade but are not only for that purpose (Roberson & Lankford, 2010). Notebooking is an ongoing process, and peer and teacher feedback is vital. In addition, students should be able to use notebooks as a working document to change conclusions and ideas based on feedback and new information (Leffler & Crauder, 2011; Roberson & Lankford, 2010).

Peer review of notebooks can be an added benefit to both the author and the editor. Editing encourages reflection of the student’s work, as well as an opportunity to correct errors (Butler & Nesbit, 2008; Roberson & Lankford, 2010). Providing guidelines for peer review allows for structure in the editing process. Some things peer reviewers should look for are correct calculations, clear procedures, understandable data tables, and correct formatting (Roberson and Lankford, 2010). There are many different ways of gathering feedback including, but not limited to, self, science teacher, peer, and English teacher. Feedback can be given to the author either in writing or in person.
Feedback is important as a way to gain greater understanding and improve writing (Butler & Nesbit, 2008).

**METHODOLOGY**

Thirty-six high school physical science students participated in this study. The research ran for a three-month period. This population of students included 6 Caucasian, 3 Hispanic, 1 Pacific Islander, and 26 African-American students. There were 9 students with Individualized Education Plans (IEPs). There were 33 freshmen and 3 sophomores involved in this study. The school called both classes involved in the study college preparatory courses. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A).

The treatment began in January with inquiry based activities and science notebooks. All students kept their science notebooks in the classroom for daily use and some brought them home for use as a study tool. The use of science notebooks was a relatively new concept to all of the students in the research group. They had used them during the first semester chemistry portion of the course and only a few had used them before this school year. Inquiry activities were not used as much during the first semester of this course. At the beginning of the treatment, the procedure for science notebooks was reestablished. This included a lesson on what goes into a science notebook and the importance of the science notebook. The science notebooks were used throughout the treatment for research, discovery, predictions, lab activities, demonstrations, and inquiry activities. The use of inquiry activities in the units of forces and energy was part of the
treatment. The lessons included discrepant events, scientific argumentation, questioning, predicting, discovery, and inquiry labs. Students had participated in inquiry activities in middle school.

The Pre-treatment Questionnaire was given to all the students to gain an understanding of what methods they have been taught science in the past (Appendix B). This allowed me to see if they were familiar with notebooks and inquiry methods. Students were given the Forces Pre-test at the start of the unit (Appendix C). At the beginning of the unit on energy they were given the Energy Pre-test (Appendix D). The tests were used as a basis for achievement between the pre and the post-test. The pre and post-test were the same tests, one for each unit. The data was analyzed for normalized gains and a Wilcoxon Rank Sum Test was performed. The Wilcoxon test determined if the null hypothesis was accepted or rejected. A box and whisker plot was created to show the change in scores from the pre to the post-test.

Throughout the action research-based classroom research project, an outside observer came into class once a week to record student engagement. The outside observer was a fellow teacher. The recordings were taken every five minutes for a 20 to 30 minute time frame. This was recorded with the Student Engagement Observation Tool (Appendix E). This data was analyzed for correlation between engagement and achievement. This information was used in conjunction with student feedback from surveys and interviews about their engagement compared to traditional learning settings.

Students’ science notebooks were graded with the Science Notebook Rubric to determine the students control and ownership over their work (Appendix F). This
information was used to observe understanding of the content as well as correlation between achievement and use of science notebooks.

I kept a journal throughout the course of the study to record observations and concerns that arose. This information provided information for the value added section as well as insight into student work and engagement.

At the culmination of the treatment, students took the Post Inquiry Question Survey (Appendix G). The information gathered informed me of the attitudes of the students towards science notebooks and inquiry activities. This data was analyzed for percentages of agreement and disagreement. Twelve students were selected based on their survey answers to be part of the Final Interview to gain more insight into the success of science notebooks and inquiry activities (Appendix H). This data was analyzed for trends and common themes. It was also used to support claims from other data.

The data sources described above are summarized in the Triangulation Matrix, in Table 1. The information provides the triangulated data for my research questions regarding science notebooks and inquiry increasing engagement and achievement.

<table>
<thead>
<tr>
<th>Table 1. <strong>Triangulation Matrix</strong></th>
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<tr>
<td><strong>Focus question</strong></td>
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<tr>
<td>Does inquiry improve engagement?</td>
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<td>Does inquiry improve achievement?</td>
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<td>Do science notebooks improve engagement?</td>
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<td>Do Science notebooks improve achievement?</td>
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DATA AND ANALYSIS

The pre-treatment questionnaire indicated that 100% of students had encountered some kind of inquiry type lessons in a previous science class (N=36). Some of the inquiry activities they reported to have experienced were demonstrations, problem solving, making predictions, and creating your own procedure. Three students reported using scientific notebooks previously, but I was unaware if they were thinking of the previous semester of my class or a previous science class entirely.

The comparison of the pre-test and post-test for forces showed a normalized gain of $g = 0.38$, which was medium growth. The average percent increase for students was 24%. There were four students who had a loss of percentage on the post-test and one student who earned the same grade on the post-test. The percent passing rate for the post-test was 66.7%. The average score on this post test was 63%. The p-value for a Wilcoxon-sign rank test was 0.000001. This p-value was well below the 0.05 alpha level which means that the null hypothesis, scientific inquiry and science notebooks do not improve student achievement, was rejected.

A box-and-whisker plot was created to observe the change in scores from the pre-test to the post-test to assess the achievement. It is important to note the median on the post-test was a passing score and on the pre-test the 3rd quartile was not above a passing score. The 1st quartile on the post-test was a higher score than the 3rd quartile on the pre-test. The increase in achievement from the pre-test to the post-test can be noted by the increase in the highest scores (Figure 1).
The comparison of the pre-test and the post-test for energy showed a normalized gain of $g = 0.51$, which was medium growth. This was 0.13 higher than the forces test which was the first unit studied. The average percentage increase for students was 33%, which was also higher than the forces test. All students improved from their post-test to their pre-test as well. The percent-passing rate for this post-test was not much higher than the forces pre-test at 69.7%. Three students from the previous data were excluded due to attendance during the pre or post-test or refusal to take the post-test. The average score on this post-test was 68%. The p-value for a Wilcoxon-sign rank test was 0.0000005. This p-value was well below the 0.05 alpha level which means that the null hypothesis, scientific inquiry and science notebooks do not improve student achievement, was rejected.

The results of the pre/post energy test indicated that the median score on the post-test was well above passing while the highest score on the pre-test was right at a passing
score. There was a large increase in the maximum score on the post-test being 32 points higher (Figure 2).

*Pre-test Energy*

![Box-and-whisker plot for pre-test energy data](attachment:image1)

*Post-test Energy*

![Box-and-whisker plot for post-test energy data](attachment:image2)

*Figure 2.* Box-and-whisker plot pre-test and post-test energy data, \(N=33\).

In analyzing the post inquiry questions over half of the students felt better prepared using science notebooks and scientific inquiry practices. Responding to the phrase “I felt better prepared for the test by using science notebooks,” 30% of students agreed, 33% of students strongly agreed, and 30% of students disagreed. In response to the phrase, “I felt better prepared for the test by doing inquiry activities,” 60% of students agreed, 24% of students strongly agreed, and 9% of students disagreed. Graph one below was from the question, “I felt better prepared for the test by using science notebooks” and graph two below was from the question “I felt better prepared for the test by doing inquiry activities” (Figure 3).
Figure 3. Likert survey data about preparedness using scientific notebooks and inquiry activities, \((N=33)\). On the Y axis 1 = I felt better prepared for the test by using science notebooks and 2 = I felt better prepared for the test by doing inquiry activities.

When interviewed, students were able to expound upon the aforementioned data and the discrepancies between the use of science notebooks and inquiry activities. There were 12 students interviewed total from the two classes. Ninety-one percent of students felt that science notebooks were beneficial because they were able to “look back” or study notes.” Students indicated that the least beneficial part was “organization” (16% of the students) and “too much writing” (33% of the students). Twenty-five percent of the students felt that science notebooks did not help their ability to master concepts because they “don’t learn from writing.” Forty-one percent of students agreed that they were able to master concepts using science notebooks because they could “read” or “review” notes. All of the students interviewed said that inquiry activities increased their ability to master the concept. Seventy-five percent of students indicated that was because of the “hands-on” or “doing” nature of the lessons.
The science notebook rubric was mainly used during the unit on Forces to determine if there was any correlation between correct use of notebooks and achievement. The use of science notebooks was heavily incorporated into the Forces unit and not as much during the Energy unit. There were 19 students who were consistent with their use of notebooks. This included having 90-100% of the notebook elements present. Eighty-four percent of this group passed the test. One of these student’s scores lowered from the pre-test, but this student still had a passing score. The students’ average post-test score for this group was a 71%, which included two outlier scores of 36% and 44%. There were six students who were inconsistent with their use of notebooks. This group of students used their notebooks for at least half of the assignments observed and had the vital parts of the assignments present. All of the students in this group passed the test with an average post-test score of 71%. There were 11 students who were poor with their use of notebooks. This means that the students did less than half of the assignments observed and were missing vital parts of the assignments. Only 18% of those students passed the post-test. In this group, 27% of students scored lower on the post-test than their pre-test score. The average test score for students in this group was 45%.

The amount of engagement during lessons was observed and it was determined that engagement was consistently above 80%. This data was from the observation of seven lessons. The average engagement from seven observations was 90%. Seventy-one percent of the lessons observed included writing in notebooks. The average engagement of these lessons was 88.8%.
Over half of the students reported agreement that they felt engaged in learning using science notebooks and by doing science inquiry activities. Responding to the statement, “I felt engaged in the learning by using science notebooks,” 45% of students agreed, 21% of students strongly agreed, and 27% of students disagreed. In response to statement, “I felt engaged in the learning by doing inquiry activities,” 58% of students agreed, 24% of students strongly agreed, and 15% of students disagreed (Figure 4).

During the interviews students answered questions about their engagement in regards to using the science notebooks and the scientific inquiry activities. When asked if the use science notebooks helped their engagement, 75% said yes. Seven of those student stated that having to “write” made them be engaged and focused on the lesson. Three of those students said that because the lessons were “visual” and “seeing” the information was why science notebooks helped them to be engaged. Twenty-five percent
of students interviewed felt that the notebooks did not help them to be engaged. One student said it was because it was “not active” and the other two students said it was just “writing words.” All of the students interviewed said that scientific inquiry activities helped them to be engaged in the lessons. Eight students said they were engaged because of the activities being “hands on” or “doing.” Some of the other reasons students said were because the of “fun,” “participate,” “visual,” and “real life.”

INTERPRETATION AND CONCLUSION

Overall there seemed to be positive correlations with the use of scientific inquiry activities and the use of science notebooks in regards to student engagement and student achievement. The normalized gains from the pre to the post tests showed growth for both units with the energy unit being higher. This shows achievement did increase using inquiry and science notebooks. The passing rates on the tests were not overwhelming, but for the students in my classes, having above a 60% passing rate is very positive.

The student engagement in lessons was also a positive outcome. There were few cell phone issues during the time of inquiry and science notebooks. The high engagement was especially notable for one of the classes. I chose two classes that were different for this study. One of the classes was made up of students who took other honors courses for English and social studies and the other class was made up of students that did not have another honors class in their schedule. This changed the original dynamic of the two classes drastically. The class with many honors students is generally on task, engaged, and participating while the other class struggles in all of these
categories. However, during this study their “on task” behavior, engagement, and participation was at a similar level and that was very high.

It is interesting and understandable that the notebooks had more negative responses during the survey. While over half of the students did respond positively to the notebooks, there were still some that felt they were not able to learn best using them due to their kinesthetic learning style. It is interesting to note that the students who did use their notebooks had higher test scores than those who did not or use them inconsistently. This backs up the fact that the writing and the processing of information in a written form are beneficial for achievement. The high level of engagement was more so due to the scientific inquiry activities that were hands on, exciting, and fun. There was still an ability to be engaged with the notebooks since students were in charge of writing down information.

I do feel that the quality of the research was good. The data was collected in as controlled of an environment as I could make in the classroom. There were outside observers for the engagement and the pre and post test data was done appropriately. There were normal absences for students and some normal disruptions on some school days. I felt that I could have hooked the students more with the science notebooks as I had in the past, but due to a new school or just different students that did not happen. I do wish there had been an easier way to have a control group to make more comparisons to. This was not feasible in the setting and with my want for all students to have the inquiry and notebook experience. The demand of the notebooks did take a toll on me
during the end of the research and were not utilized as much as they had been in the beginning.

I have some questions after doing this action research. How can I use notebooks as a better tool where students truly process their ideas and conclusions? Is there a way to get students to truly explore without the need for approval from the teacher? This was difficult with some students being almost entirely dependent on me for help during the inquiry activities. How can I create inquiry lessons that are easily accessible for students and teachers? Currently the preparation time, the stress during the lesson, and the grading of notebooks after the lesson is sometimes more than what it seems it is worth. I would like to be able to find a happy medium for teachers to be able to implement these activities and notebooks into their courses while still being able to keep up with rigorous state standards.

VALUE

Through this research I was able to have students step out of their comfort zones and learn things on their own through experimentation. Although students jumped out of their comfort zone, many were also in a comfortable place doing hands on activities. The nature of the inquiry along with the science notebooks allowed all types of learners to learn in their respective ways. There were activities and lessons to engage visual, logical, verbal, physical, interpersonal and intrapersonal learners. Students were able to develop critical thinking skills and processing skills. I truly only had one student who was completely against this process. When I asked them they relayed that they would rather be doing worksheets.
I found it interesting that there was a difference in the normalized gains in the two units. The normalized gains were higher for the unit on energy and the percent passing rate was slightly higher. The thoughts I had were that the unit was a lot shorter in time that the unit on forces. Also, we used the notebooks a little bit less, but students still had to do writing and processing other ways. Another possible explanation could be that the concepts of energy more easily understandable than the concepts for forces.

I did many formative assessments the day after lessons and the responses were very encouraging. Most of the concepts students understood the next day and if there was a misconception that lingered I was able to address it after scanning the formative assessment at the beginning of class. One of the formative assessments was a misconception probe. This was followed by a conceptual change model where students explored their misconception. Due to the nature of inquiry and that this had been our first inquiry activity in the action research, it did not go as planned. Some students kept their misconception because of misinterpreting the data. Twenty-four percent of students had a conception change. The normalized gain for this conceptual change was 0.53 which is a medium gain.

This action research process opened up my eyes to many things. I am reinvigorated for inquiry and science notebooks, even as difficult as it were to implement. I saw more students engaged and excited about learning. Students were making connections they found and were creating their own procedures. Students were working together to find solutions to problems. I realized that the dependency of my students was very deep rooted and truly a learned helplessness from their backgrounds. This includes
their homes and the education system. They are very used to correct answers and that there is only one way and one correct answer. This was difficult to start to break this and would be very beneficial to begin this process at the beginning of the year. I did find simple wins when a normally non-communicative student spoke during a lesson and he often does not work or participate! Another win was when we did a scientific argument and all the students were excited about what they wrote and wanted to argue their points. There were some reasoning that I had not yet thought of that were great to see. In this process I realized I need to create a way for science notebooks to not be overwhelming for the students nor to myself in the grading process. The notebooks being at their fingertips for class and to take home in invaluable and a tool I intend to continue to utilize. I very much enjoyed analyzing the data and I wish I had more time in the day to analyze data more often. Sometimes what you feel is going on is not actually supported by the data and judgment can be clouded.
REFERENCES CITED


APPENDIX A

IRB EXEMPTION
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MEMORANDUM

TO: Bridget Sparks and John Graves
FROM: Mark Quinn, Chair
DATE: November 20, 2015
RE: "The Effect of Scientific Inquiry and Science Notebooks on Student Achievement and Engagement"
[BS112015-EX]

The above research, described in your submission of November 20, 2015, 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:

- (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.

- (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, if wholesome foods without additives are consumed, or if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

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

PRE TREATMENT QUESTIONNAIRE
Pre-Treatment Questionnaire:

1. Have you ever used science notebooks in the classroom before?
   a. If yes, how were they used?
   b. If yes, what did you like about them?

2. What types of activities have you done in other science classes prior to this course? Select all that apply.
   Note taking
   Lecturing
   Procedural labs
   Worksheets
   Videos
   Demonstrations
   Questioning
   Problem solving
   Discovery lessons
   Creating your own procedure
   Making predictions
   Other:_______________________________
APPENDIX C

PRE AND POST FORCES UNIT TEST
1. A tug-of-war that results in one team pulling the other across the line is
   a. action forces  c. unbalanced forces
   b. reaction forces  d. balanced forces
2. Whenever an object is standing still, which value is always zero?
   a. speed  c. momentum
   b. velocity  d. all of the above
3. Weight is best described as
   a. an object’s resistance to acceleration.
   b. the downward force exerted on an object due to gravity.
   c. what causes an object to fall.
   d. a force solely dependent on an object’s mass.
4. A force is continuously applied to an object, causing it to accelerate. After a period of time, however, the object stops accelerating. What conclusions can be drawn?
   a. The object is experiencing some kind of friction.
   b. Gravity on the object has increased.
   c. The mass of the object has increased.
   d. The momentum of the object has reached a maximum.
5. Any change in an object’s velocity is caused by
   a. the object’s mass.
   b. the object’s direction.
   c. a balanced force.
   d. an unbalanced force.
6. An example of helpful friction is
   a. writing on paper with a pen.
   b. getting holes in your socks.
   c. car tires wearing out.
   d. scraping your knee on the floor.
7. The first law of motion applies to
   a. only objects that are moving.
   b. only objects that are not moving.
   c. all objects, whether moving or not.
   d. no object, whether moving or not.
8. Which is an example of balanced forces acting on an object?
   a. a kangaroo jumping
   b. a person standing on the ground
   c. a car turning a corner
   d. a person pushing a sofa
9. If you push a bowling ball and a golf ball with the same force, you would see
   a. a greater acceleration on the bowling ball.
   b. a greater acceleration on the golf ball.
   c. the same acceleration on both balls.
   d. no acceleration on either ball.

10. Friction is defined as the
    a. force that opposes motion between two surfaces that are touching.
    b. rate at which velocity changes.
    c. resistance of an object to a change in its velocity.
    d. speed of an object in a particular direction.

11. What will happen if you drop a feather and a pebble from the roof of a house at the
    same time?
    a. The feather will fall fast because it has less mass.
    b. The feather will fall faster because air resistance affects it more
    c. The pebble will fall faster because air resistance affects it less.
    d. They will fall at the same rate because gravity is the only force acting on the
        objects.

12. A measure of inertia is an object’s
    a. weight.
    b. mass.
    c. speed.
    d. acceleration.

13. Which of the following is not a factor in calculating momentum?
    a. mass
    b. direction
    c. acceleration
    d. speed

14. Automobile seat belts are necessary for safety because of a passenger’s
    a. weight.
    b. gravity.
    c. speed.
    d. inertia.

15. The tendency of an object at rest to remain at rest is
    a. inertia.
    b. momentum.
    c. free fall.
    d. acceleration.

16. When objects are moved further apart from each other, the force of gravity between
    them
    a. increases.
    b. stays the same.
    c. decreases.
    d. decreases at first then increases.

17. Which object does not have momentum?
    a. a fish swimming in a pond
    b. a feather falling to the ground
    c. a rock by the side of the road
    d. a boulder rolling down a hill
18. Suppose you are pushing a car with a certain net force. If you then push with twice the net force, the car’s acceleration
   a. becomes four times as much.
   b. becomes two times as much.
   c. stays the same.
   d. becomes half as much.
19. Which law of motion explains why a rowboat moves forward when a paddle pushes against the water?
   a. Newton’s first law.
   b. Newton’s second law.
   c. Newton’s third law.
   d. none of the above.

Answer the following questions on your answer key.

20. Why does a large car have a lower gas mileage? (Why does it use more gas?)

21. If a bowling ball and a golf ball are both dropped from the same height. Which will hit the ground first? Explain your answer.

22. In terms of Newton’s 3rd law of motion, which states that for every action there is an equal, and opposite reaction, why should you not kick a brick wall? Explain in terms of Newton’s 3rd law.
APPENDIX D

PRE AND POST ENERGY UNIT TEST
Post-Test Energy  Assume gravity is 10 m/s²

Work and Energy  \[ \text{work} = \text{force} \times \text{distance} \quad \text{power} = \frac{\text{work}}{\text{time}} \]

Do not write on the test.  \[ \text{PE} = \text{mass} \times \text{gravity} \times \text{height} \quad \text{KE} = \frac{1}{2} \text{mass} \times \text{velocity}^2 \]

1. Which of the following processes requires the most work?
   a. A 10 kg weight rests on a table.
   b. A person holds a 1 kg weight still with outstretched arms.
   c. A person lifts a 1 kg weight 1 m off the floor.
   d. A 10 kg ball is rolled across the floor at a constant speed for a distance of 10 m.

2. A man pushes a crate along a factory floor by exerting a force of 55 N. If the crate moves a distance of 4.0 m, how much work does the man perform?
   a. 165 N  c. zero
   b. 220 N  d. 145 J

3. A weightlifter presses a 400 N weight 0.5 m over his head in 2 seconds. What is the power of the weightlifter?
   a. 100 W  c. 400 watts
   b. 25 watts  d. 100 watts

4. A simple machine is a device that
   a. requires less work to do a given task.
   b. decreases the amount of work done by a given force.
   c. increases energy.
   d. can multiply and change the direction of an input force.

5. What is the mechanical advantage of a double pulley?
   a. 1  c. 2
   b. 1.5  d. 3

6. An inclined plane
   a. changes the direction of the force only.
   b. changes the magnitude of the force only.
   c. changes both the magnitude and the direction of the force.
   d. decreases the amount of work done.

7. Which of the following is a compound machine?
   a. a wheel and axle  c. an escalator
   b. a pulley  d. a ramp
8. What is the gravitational potential energy of a 54 kg box that is 8.0 m above the ground?
   a. 5,500 J   c. 3,400 J
   b. 4,300 J   d. 550 J

9. Which of the following is an example of mechanical energy?
   a. a light bulb   c. riding a bike
   b. Standing on a hill   d. a granola bar

10. The primary source of the sun’s energy is
    a. chemical energy.   c. mechanical energy.
    b. nuclear energy.   d. potential energy.

11. Which of the following statements is not true?
    a. The energy of a closed system is constant.
    b. The energy of an open system can increase.
    c. If the kinetic energy of an object decreases, the nonmechanical energy will decrease.
    d. Energy cannot be created or destroyed.

12. Which of the following statements about work and energy is not true?
    a. When work is done, energy is transferred or transformed.
    b. Energy may be defined as the ability to do work.
    c. Work and energy are always equal.
    d. Work and energy have the same units.

13. Gravitational potential energy depends on
    a. the mass of the object.   c. the acceleration due to gravity.
    b. the height of the object.   d. All of the above

14. A medicine ball has a mass of 5 kg and is thrown with a speed of 2 m/s. What is its kinetic energy?
    a. 100 J   b. 2,000 J
    c. 10 J   d. 500 J

15. A pendulum swings back and forth and has a kinetic energy of 400 J at a particular point in its path. Which of the following statements is not true?
    a. Both the kinetic and potential energy are decreasing.
    b. The minimum kinetic energy is zero.
    c. When the kinetic energy is zero, the potential energy will be 400 J greater.
    d. The potential energy increases when the kinetic energy decreases.
Read each statement, and write in the blank the word or words that best completes the statement.

16. A quantity that measures the rate at which work is done is called ________________.

17. The stored energy resulting from the relative positions of objects in a system is called ________________.

18. The sum of the kinetic and potential energy of large-scale objects in a system is called ________________.

19. The source of the energy when dynamite explodes is ________________ energy.

20. A(n) ________________ is an inclined plane wrapped around a cylinder.

21. Energy is transferred as ________________ when mechanical energy decreases and temperature increases.

Read the question, and write your response on your answer sheet.

22. Three children exhaust themselves trying to push a large rock that does not budge. Have they done any work? Explain your answer.

23. Where does energy go when it seems to have disappeared?
APPENDIX E

STUDENT ENGAGEMENT OBSERVATION TOOL
## STUDENT ENGAGEMENT OBSERVATION TOOL

<table>
<thead>
<tr>
<th>Time</th>
<th>12:25</th>
<th>12:30</th>
<th>12:35</th>
<th>12:40</th>
<th>12:45</th>
<th>12:50</th>
<th>12:55</th>
<th>1:00</th>
<th>1:05</th>
<th>Total</th>
<th>Teacher Action</th>
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### On Task:
- N1 – on task: listening/watching
- N2 – on task: writing
- N3 – on task: speaking
- N4 – on task: reading
- N5 – on task: hands on activity

### Off task:
- F1 – off task: passive
- F2 – off task: doing work for another class
- F3 – off task: listening to others
- F4 – off task: disturbing others
- F5 – off task: playing

### Observations:
- Average on-task sweeps/student =
- Average # students on task/sweep =
- Type of on-task: Top segments:
APPENDIX F

SCIENCE NOTEBOOKS RUBRIC
Science Notebooks Rubric

Included in notebook post   Yes/No
1.  Title
2.  Date
3.  Observations
4.  Questions/Answers
5.  Predictions
6.  Diagrams
7.  Data
8.  Conclusion/summary
APPENDIX G

POST INQUIRY QUESTION SURVEY
Post Inquiry Question Survey

Please check your agreement with the following statements.

<table>
<thead>
<tr>
<th>Questions</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I enjoyed using science notebooks.</td>
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<td>2. I enjoyed doing inquiry activities.</td>
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<td>3. I felt a sense of ownership over my learning by using the science notebook.</td>
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<td>4. I felt engaged in the learning using the science notebooks.</td>
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<td>5. I felt engaged in the learning doing science inquiry activities.</td>
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<td>6. I felt better prepared for the test by using science notebooks.</td>
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<tr>
<td>7. I felt better prepared for the test by doing science inquiry activities.</td>
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<td>8. I would like to continue to use science notebooks in the future.</td>
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<tr>
<td>9. I would like to continue the use of inquiry activities in the future.</td>
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APPENDIX H

POST INTERVIEW
Post interview:

1. Did you feel that the purpose and use of scientific notebooks was adequately explained?
   Why or why not?
2. What part of using the science notebook was the most beneficial to you in your learning experience?
3. What part of using the science notebook was the least beneficial to you in your learning experience?
4. What part of doing scientific inquiry activities was the most beneficial to you in your learning experience?
5. What part of doing scientific inquiry activities was the least beneficial to you in your learning experience?
6. Do you feel that using science notebooks helped your ability to master the concepts being taught?
7. Do you feel that doing scientific inquiry activities helped your ability to master the concepts being taught?
8. Did you feel that the use of scientific notebooks helped you to be engaged in the lessons? Explain how.
9. Did you feel that doing scientific inquiry activities helped you to be engaged in the lessons? Explain how.
10. Is there anything you would like to add?