THE IMPACT OF A COMBINED INQUIRY-BASED APPROACH AND HARKNESS STYLE APPROACH ON STUDENTS' ATTITUDE AND CONFIDENCE

by

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ABSTRACT

The purpose of this project was to assess the impact of implementing Harkness discussion method and more inquiry-based lab exercises on three ninth grade physics classes. Student attitudes and confidence were assessed before and after replacing lectures and standard lab procedures with Harkness style class discussions and inquiry-based exercises. Student scores on regular unit tests, homework assignments and other exercises were used to assess the effect of the new teaching techniques on student performance. Students did not show improvement in attitude and confidence but their performance and overall understanding improved. Students generally enjoyed the new approach and would like to continue using discussions instead of traditional lectures.

INTRODUCTION AND BACKGROUND

Project Background

I teach three sections of ninth grade conceptual physics to students who are generally motivated and eager to learn. When faced with challenging problems or new concepts however, I have noticed that my students lack the willingness to dive into problems they aren't completely comfortable with. When my students do not understand a concept, or what steps they should take in order to correctly solve a problem, they tend to ask what the answer is instead of trying to figure it out on their own. I believe that one of the fundamental aspects of being a good scientist is a willingness to enter the unknown and be able to realize that a certain approach is not the correct one, and to learn from any mistakes that were made. Originally I thought that I needed to focus on helping my students improve their problem solving skills, which I still aim to do, but I have come to the conclusion that helping my students become confident self-starters and helping them embrace the idea that they are ultimately the ones in charge of their own learning is what will help them most in this area.

For the first few years that I taught I strictly followed a very routine approach in the classroom; I used lectures to help students learn concepts and solve practice problems and had students follow a set of written instructions on lab exercises to help reinforce the concepts. Minus the occasional question from a student, there was little discourse and even during lab exercises there was a minimal amount of peer to peer interaction. This system was effective and my students were successful, but I always felt that I wasn't using my time with students as well as I could. I also felt that my students relied too

much on me and that there might be another approach that would help them take more ownership of their learning as well as learn to work in groups more effectively. Once I began feeling more comfortable with my ability to teach the material, I found that I could focus more on my methodology in the classroom. This is when I decided that I wanted to start helping my students take more ownership of their learning. Admittedly, I have not been able to spend enough time redesigning my curriculum until this classroom research project gave me the opportunity to do so.

Last spring the other conceptual physics teacher, Curtis Phillips, and I decided we should change our curriculum to help our students take more ownership of their learning. At this point I had taken all three sections of the Physics by Inquiry classes which focused on helping teachers incorporate more inquiry-based lab exercises into their curriculum. While I worked on redesigning our approach to lab assignments, my colleague Curtis, who is also a member of my support team, visited an incredibly talented history teacher's classroom and got the idea to run our physics classes in a similar manner. The discussion-based approach that this history teacher used, and still uses, is known as the Harkness method after the oval discussion tables that were designed and used at Phillips Exeter Academy in their discussion-based classrooms. This is when I knew that I wanted to focus on the Harkness discussion method and inquiry-based lab exercises for my classroom research project.

While I will discuss the Harkness style of discussion in more detail later on, the basic explanation of the approach is that students encounter new material on their own in the form of readings or other media with some main discussion questions in mind. The

following day the class aims to answer these questions through a discussion involving every person in the class and the teacher only speaks when necessary. This requires the students to encounter and digest the material on their own and then apply these ideas in the setting of a classroom discussion. It helps to identify common misconceptions because when multiple students are incorrect, they will initially make a strong case for why their ideas are correct. The inquiry-based lab exercises will also require students to apply the appropriate concepts to different situations, discuss their approach with each other, and attempt to confirm the correct concepts that they are learning. I believe that the combination of an inquiry-based lab approach and the Harkness discussion method would allow me to help my students gain confidence in their abilities and take more ownership of their learning.

I found last spring to be one of the most enjoyable times of my teaching career, and my students definitely took more ownership of their learning and performed at a higher level. I knew then that implementing these strategies would be a great treatment to study for my classroom research project. The primary research question that I decided on is "What is the impact of implementing inquiry-based lab exercises and replacing lectures with the Harkness style class discussions on students' attitude and confidence?" My first sub question was "How does the implementation of these approaches affect students' willingness to take ownership of their learning?" My second sub question was "How does the implementation of these approaches affect student performance?" What excited me most about this project, is that if I am able to determine how I can help my

students take ownership of their learning, this will be a skill that they can apply to all of their classes, regardless of the subject.

CONCEPTUAL FRAMEWORK

Edward Harkness, an American education reformer, developed what would later be called the Harkness learning style at Philips Exeter Academy. The approach requires the teacher to relinquish control in order to allow more peer to peer interactions. The Harkness method was designed for sections of eight students with the idea in mind that teachers could use a discussion to engage boys in an environment "where the average or below boy would feel encouraged to speak up, present his difficulties, and the teacher would know…what his difficulties were… This would be a real revolution in methods." (Harkness History, n.d.) Correctly implementing the Harkness method requires a clear set of ground rules which enable this environment to be created. The importance of this environment is reinforced in other studies as well. It is essential that "comfortable discourse environments" (van Zee et. al, 2000, p. 183) be created in order to allow students to be fully immersed in the learning process and feel free to ask questions. This study also supported the fact that when invited to discuss their observations and findings, students will engage each other and have a meaningful discussion on the concepts at hand.

During discussions, not every student will know the answer right away but they still benefit from an improved conceptual understanding through peer to peer discussions and interactions (Smith et al. 2009). According to Mazur (1997), peer instruction creates an environment in which students receive more immediate feedback and engages all

students with the material. While students discuss the question at hand in groups, they are constantly thinking about the concepts involved with that question. Discussing concepts with their peers encourages students to build their higher order thinking skills, such as evaluation, as opposed to just reflecting on their own ideas (Yuruk, Beeth, & Andersen, 2009). Meltzer & Manivannan (2002) found that students are more willing to accept an explanation, from either a peer or the instructor, once they have begun formulating their own answers to questions and then discussing it with others.

While teachers seeking this level of interactive engagement amongst the students may not cover the same amount of material, students' conceptual understanding of the material is improved (Meltzer and Manivannan, 2002). In the same study, it was stressed that students may be resistant to the change in approach because they are accustomed to more traditional teaching methods. According to Garcia & Pintrich (1995) students who are more motivated will end up with better cognitive engagement. They also showed that students who report being more motivated than their counterparts have better overall grades than those students who lack motivation. Implementing a more interactive approach in the classroom improves motivation, confidence and engagement and creates positive attitudes (Cortright et al., 2005).

The traditional style of teaching physics classes does not help students work through the material on their own, leaving them with a lack of confidence in their abilities. Traditionally teachers introduce the concepts, show students how to do problems, and the students practice the problems on their own for homework. This approach is passive and is not effective for learning physics concepts nor for gaining skill

at problem solving (Hewitt, 1987; McDermott, 1991). Similar to the Harkness discussion style, inquiry style labs put the focus of the learning on the students and helps them formulate their own theories and concepts from their observations. Students must communicate what they have learned and have to question each other at every step of the way (Llewellyn, 2005). Although inquiry-based learning takes more time, students who learn using inquiry develop a great skill at problem solving as compared to students who learn using the traditional methods (Shaffer & McDermott, 1992). In a study of 70 students taking a modified Physics by Inquiry course in college, the students performed just as well as those in a traditional Physics by Inquiry course, and both groups of students severely outperformed students taught using traditional methods (Scherr, 2003).

I was not able to find any literature or studies in which both an inquiry style and a Harkness discussion style were implemented in a classroom but having read literature on each method individually, I think it is clear that they will fit nicely together. The Harkness discussions provides students the opportunity to practice interpreting information and concepts on their own and then communicating their ideas and making sure that their statements are backed up by observations or data. The inquiry-based exercises provide them with practice in testing their hypotheses and further practice communicating with their peers. The combination of the two new approaches should provide the students with many more opportunities than in a lecture format to interact with the concepts and their peers and hence help to improve their motivation and overall performance.

METHODOLOGY

My classroom research project focused on my three sections of ninth-grade conceptual physics classes. The sample includes all 48 students that I teach, all boys

ranging from the ages of 14 to 16. Given that my students are attending a prestigious boarding school many of my students come from well to do backgrounds but we also provide 48% of our students with some sort of financial aid, which allows for a diverse classroom environment. I have several international students, representing countries such as China, South Korea, Mexico, Canada, and Argentina. While I encounter a wide variety of ability levels, I can without a doubt say that all of my students are motivated to do well. With that said, considering that I teach ninth-grade boys, not all of my students understand what they need to do in order to be successful students during their first year at Woodberry.

Many of my students have taken some sort of physical science during their middle school careers although their extent to which they have experience with hands-on lab exercises varies. Occasionally throughout the year students will remark that they recall learning a certain topic during their physical science class, but their retention and ability to explain the concept correctly vary greatly. Some students come from particularly strong middle schools while others have particularly weak backgrounds. One student I have this year came from a middle school that did not give students homework assignments for all three years. Needless to say he was woefully unprepared for the work load at my school. On the very first day of class we perform a lab experiment, which gives me a very good idea of how comfortable students are with hands on exercises.

Treatment

The three-week treatment period involved implementing Harkness style class discussions and inquiry-based lab exercises while studying momentum, impulse and

springs. Nightly homework assignments required students to complete practice problems on their own and the assignments were generally given in the same format and still graded for correctness as they were before the treatment period. The only difference in homework assignments during the treatment period was that there were a few additional assignments that required students to look up concepts on their own, bring notes to class or answer questions based on the reading. The expectation was clear that they should come to class ready to participate in the discussion the following day. Before each major discussion, of which there were six during the three week treatment period, I would make sure that I had a set of questions in mind in case the conversation stalled. The most important aspect of an effective Harkness style discussion is the teacher not being the center of the discussion and creating an inviting and comfortable discussion environment. In order to make sure that I was not the focus of attention, I would ask for several different responses to each question or prompt that I provided before moving on.

When the discussion focused on brand new material, we would discuss the new material and then create a fact sheet that contained all of the important information for that topic. Students have been given fact sheets for each unit throughout the year leading up to the treatment period so while I wanted to avoid just giving them the information, I thought it would be wise to still have a standard set of facts that each student could refer to. The fact sheets include relevant equations, important concepts, and information such as units. Students are required to reference the fact sheet when answering homework questions. I also implemented shorter discussions in order to review homework assignments, go over formative assessments, and prepare for lab exercises.

Before the treatment period began, I set aside some time for each section to create a set of rules that we would follow during discussions. As far as the rules go, I came up with them with the help of our resident expert on Harkness style discussions and wrote them on the board and had students review them at the beginning of each class. While I had a set of rules in mind, we used a discussion amongst the class to come up with ideas and then I mentioned the ones I had thought of. Each class ended up using the same set of rules with only slight variations in wording. The first rule was that only one person speaks at a time and that no interrupting was allowed. Initially I tried using a ball which students threw to each other and only the person holding the ball was allowed to speak. Given that my students are ninth grade boys, this lasted shortly before it became a fun activity for them to purposefully throw the ball in a way that was hard to catch, or even uncatchable. Interestingly students were initially excited about using the ball, and were sad to see the ball go, but understood that the reason I stopped using it was because of the distracting nature they created while passing the ball from student to student.

The second rule was that everyone must speak at least once in each discussion session. These two rules were meant to ensure that everyone participated during discussions. Since I was focusing on students taking ownership of their learning however, I did not spur anyone to talk even if I noticed that they had yet to participate in a discussion. I made sure to drop hints, such as saying "Let's hear from some new folks" but these hints seemed to generally fall on deaf ears. The third rule was that students had to choose different seats each day. This prevented students from always sitting next to their closest friends in the class and helped to minimize distracted side conversations or

comments. The last rule was that everyone treated the discussion as a learning process. This rule took some explaining but the idea is that students who provide a wrong answer or explanation should not be scoffed at or in any way dismissed. Rather, students who have the correct understanding of the concept should view this as an opportunity to help correct a misconception and improve someone else's understanding of the material.

Nightly homework assignments were graded in the same manner they were all year for correctness. From day one students are asked to explain their answers using a set of facts that are given out in class and are actually required to use a fact from the sheet and do not receive credit for any attempt that does not use a word for word fact from the sheet. This is to help students be able to focus on the concepts and give them a good start in writing a solid, sensible sentence about the concept at hand. They are also asked to write a second sentence connecting the fact to the answer and this gives them the chance to practice using the terms in their own words. Students' performance on homework assignments is a key factor in my project because given the nature of the process, higher homework grades correlate with those students who generally follow directions, use their notes, and do their best to connect the fact to their answer. Even though these students might not earn every point, they can earn lots of partial credit just by using a word for word fact and giving a problem a solid attempt. Continuing homework assignments in the same manner allowed me to gather data during the treatment and compare it to the homework scores from the rest of the year.

For lab exercises students were given worksheets that helped them investigate a certain concept. During the momentum unit, the lab exercises involved using carts,

tracks, motion detectors and Vernier LabQuest2 devices. Typically I have asked students to complete lab exercises on their own but during the treatment period I had them work in pairs for some lab exercises and groups of 4 for other exercises. This was dependent on how challenging I thought the lab set up was and how much equipment I had available for each exercise. The worksheets asked students to come up with a prediction of the experiment using the same techniques and expectations they are asked to use when answering homework questions. Once students checked their predictions with me, they would head to the lab area and set up the experiment and verify their predictions. Earlier in the year I usually set up the lab experiments but during the treatment period students were asked to set them up and take them down on their own. Weaker students often took significantly longer to figure out the set up so in these cases I asked a stronger student who had already completed the lab exercise to help their peers get started.

When we started the impulse unit, students again used carts and motion detectors along with force plates to perform a variety of experiments. The worksheets the students used were the same as before, asking students to formulate a prediction and then experimentally verify their prediction. The impulse lab exercises were generally easier to set up so I had students work in pairs and just left the equipment out since there was not much to be gained from setting up the experiment, which typically would only involve connecting a detector to a Vernier LabQuest2. In both cases credit was only given if their data from the experiment supported their prediction and all of their work was correct.

When we moved on to Hooke's law and the properties of springs, we discussed the concepts as a class and then students were asked to determine the spring constant for

a spring of their choosing. We had a short discussion on different set ups and techniques that could help them determine the spring constant and then they were let loose to complete the task in pairs. They were given access to a variety of materials including electronic spring scales, Vernier force probes, mechanical spring scales, masses and meter sticks. Students collected data and created force vs. displacement graphs in order to determine the spring constant of their spring. Although I did not tell them it was a formative assessment, I added in a question that asked them to write a one sentence summary about what the slope of the graph represented.

During the treatment period daily summative quizzes were replaced with formative assessments. I used a website called Socrative to give the assessments since it eased the data collection process by tracking student scores and providing a downloadable Microsoft Excel document. After each assessment we would hold a short discussion to go over the answers and students were instructed to correct anything that they got wrong based on the reasoning we came up with during the discussion of each question. The assessments were collected and graded for correctness and how well students corrected incorrect answers. While the assessments were graded, these grades did not count towards the students' grades and were only used for the purpose of collecting data for my project.

I also gave some assessments that were less quiz-like in nature. Two of the formative assessments were identical to homework assignments, but students were not required to write out an explanation of their answer choice. They were simply asked to enter the right answer using Socrative and the website gave them immediate feedback on

whether they were right or wrong. If a student got a wrong answer, they spent a few minutes after the assessment and discussion correcting their work and then turning in their assessment and corrections. Again this work was graded but solely for the purpose of collecting data. I also gave two formative assessments that focused on information the students should have learned through the lab exercises. They required students to gather information and answer questions based on a picture of a Vernier LabQuest2 showing them a graph which they could read to deduce information about the lab exercise.

The last significant change made during the treatment period was the way in which multiple choice quizzes were given. Since the second week of the year, students have taken a 10 question multiple choice quiz covering the most recent material once a week except for weeks when a test was given. Typically students were asked to correct questions over the following few days as a homework assignment and were allowed to collaborate with their peers. Since I felt that students were not taking the correction or collaboration process as seriously as I'd like, during the treatment period I had them enter their responses using Socrative and then immediately begin correcting their work. Using Socrative allowed for immediate feedback and since students were in class, it was much easier for them to find someone to collaborate with. Students are only given a half hour window during which they can go collaborate with their peers during study hall so I felt that giving them time in class would help avoid this issue.

Data Collection

During the six major more lengthy discussions, student participation was recorded on a spreadsheet I created. Students were given credit for any meaningful contribution

such as an explanation, an answer to a question, or asking a legitimate and relevant question. I considered taking away credit for participating if a particular student became a distraction but instead decided on just making note of it in my teacher journal. The participation points were used to help calculate the taking ownership score that I tracked for each student. For each discussion I found the average participation for all 48 students and used that average as the point total for that discussion. I felt this took into account the adjustment to the new approach and gave me a quantitative assessment of student participation. Although one of the ground rules was that everyone should speak once before anyone speaks for a second time, I felt that not enforcing this rule gave me a true sense of how engaged students were during discussions.

Figuring out a quantitative measure of how well students' took ownership of their learning was an important aspect of my data analysis. In order to quantify it, I created an Excel document and entered in scores for all aspects of the class during the treatment which I thought involved taking ownership of one's learning. This ended up including participation in discussions, correcting previous homework, following directions, formative assessment scores, correcting assessment questions and how many lab exercises were completed. For each contributing piece that was recorded in the taking ownership score, I assigned a point total. This allowed me to figure out the total score and then compare each students' point total to that number, hence creating an average that allowed me to quantitatively measure how well each student took ownership of his learning. Unfortunately I did not think of a way to quantify taking ownership until right before my treatment period began so I was not able to create a baseline ownership score.

I still felt, however, that the ownership could be useful when looking at student performance as well as comparing it to student responses to the survey question about taking ownership.

Formative assessments were graded by students immediately after each assessment and I checked back over the results later. When Socrative was used this was not necessary, as that website produces an Excel document that has all of the scores and responses included in it. Students were given a score based on the number of correct answers for each assessment. Since they were asked to correct their work after each assessment they were given credit for any legitimate attempt at correcting their work. So if a student earned four points out of a six point assessment, and only fixed one of the two wrong answers, he was given a final score of five out of six points. I chose this approach since I felt that it accounted for those students who followed directions and made an effort to correct their work, a process that has been stressed to them from day one as an essential aspect of mastering the material. The scores for each assessment were also incorporated into an Excel document that I used to calculate the ownership score for each student.

Throughout the treatment period, correcting old work was frequently a part of class time; students corrected their assessments each time one was given, they corrected their multiple choice quizzes and we spent one day correcting test questions. While the test they were correcting was taken before the treatment period I still thought it was important to record how many questions they corrected during the treatment period. The number of corrections that were completed were recorded and used in determining the

ownership score for each student. Since a student who got a perfect score on a test or quiz would not have corrections, I did not want to effectively penalize this student for not correcting their work. This is why I chose to count corrections as bonus points and did not enter them as a certain score out of a total and simply tracked how many questions were corrected. This effectively gave those weaker students with a lower quiz or test result with a chance to earn more "taking ownership points" by completing their corrections while avoiding any penalization for the stronger students when it came to their taking ownership score. Since stronger students generally earn higher scores, as well as earn plenty of "taking ownership points" in other areas, I felt this system was the best one that I could come up with to help track how much students were taking ownership of their learning.

Assignments that involved reading about a new topic or answering questions based on a reading were given completion scores. Homework assignments that involved practice problems were graded in the same manner as they were all year. This allowed me to use previous homework scores to find averages for students, sections and across all my students and compare to the mid-treatment homework performance. Homework scores could also be used to figure out overall performance and to compare to the ownership score. Test scores and multiple choice quiz scores were used to help determine the overall performance of students as well as compare individually to other sets of data, including scores from earlier in the year.

A Likert survey was given using Google Forms before and after the three week treatment period focusing on student attitude and confidence. Unfortunately, due to an

error while setting up the pre-treatment survey, the names of students were not recorded when they submitted their responses. Clearly this was not ideal as being able to compare responses on an individual basis would have been extremely helpful, especially when looking at outlier responses. The data still allowed me to look at whether or not there was an improvement in attitude and confidence for my students as a whole despite not being able to track the initial individual responses. Pivot tables were used to help filter and sort the responses in Microsoft Excel and points were assigned to responses. Responses of "Strongly Disagree" were assigned a value of 1 and the scale continued for each response up to "Strongly Agree" which was assigned a value 5. The mean and standard deviation was found for the pre-treatment and post-treatment responses and then compared. Outlier responses and samples of student responses were able to be used from the post-treatment survey.

I kept a teacher journal so that I could take note of interesting and relevant information. This information focused on student attitude, any aspect relative to student confidence that I noticed, as well as observations on how discussions were running and how well students were working together on lab exercises. The teacher journal proved to be very helpful. Since the information in the teacher journal was logged daily, I was able to correlate the results from other data sources with quantitative details on students' performance and attitude on a daily basis.

An exemption for the research methodology utilized for this project was received from Montana State University's Institutional Review Board and compliance for working with human subjects was maintained. The exemption can be found in Appendix A.

To ensure that my Likert surveys were reliable, I found an example of a Likert survey from another teacher who had sought to answer research questions regarding student attitude and confidence in a science class. Since the survey was not intended for a class of physics students, I reworded some of the questions to be more appropriate for my classes. I also added in a few questions of my own, but used the same general approach and the exact same answer choices. Once I had created my survey, I had two members of my peer review team check it to ensure that they agreed that the survey questions answered my research questions regarding student attitude and confidence. I also asked a student who struggled with reading and following directions to review the survey, which he agreed to do, to ensure that he was able to understand what all of the questions were asking and felt he could accurately respond to each of them. The teacher and the teaching assistant in the Foundations of Action Research Class also reviewed the survey. Based on the feedback from the teaching assistant, I added probe questions as a follow up to several of the survey questions. When it came time for my data analysis, student responses to these probe questions gave me extremely valuable feedback and information to help answer my research questions. For the post treatment survey I did change a couple of the probe questions to effectively get students to reflect on their experience during the treatment period and share their thoughts and opinions.

Table 1 shows the data triangulation matrix which demonstrates that I had three data collection instruments for each research question. Before the project I figured I would find the quantitative data to be the most helpful in answering my research questions. To the contrary, when it came time to analyze the data, I found the qualitative

data from the teacher journal and student responses to probe questions to be the most informative. These helped me look at overall trends and patterns, as well as identify outliers, and since the data was qualitative, I was able to gain a deeper understanding of why students responded the way they did or felt a particular way about the treatment.

Table 1
Data Triangulation Matrix

Research Questions	*Data Sources*		
	1	2	3
1. What is the impact of implementing inquiry-based lab exercises and replacing lectures with Harkness style class discussions on students' attitude and confidence?	Likert Survey	HW, Quiz & Test Performance	Teacher Journal
2. How does the implementation of these approaches affect students' willingness to take ownership of their learning?	Ownership Score	Likert Survey	HW, Quiz & Test Performance
3. How does the implementation of these approaches affect student performance?	HW, Quiz & Test Performance	Ownership Score	Teacher Journal

DATA AND ANALYSIS

Two-sample t-tests assuming equal variances with a hypothesized mean difference of zero and an alpha level of 0.05 were used to compare the pre and post treatment survey data. The two-tailed p-values were used to determine the percent chance that the results reported could occur by random chance and these values dictate whether or not the results are statistically significant. Unfortunately after analyzing the survey data I did not get the results I was hoping for and all of the questions from the Likert survey pertaining to attitude showed a lower mean score on each question. The results, however, were not statistically significant since all of the p values were over 0.05,

which is the cutoff for determining reliable data. The results for these questions are displayed in Table 2 below.

Table 2

Likert Survey Results for Questions Pertaining to Attitude.

		Q03 - I enjoy physics	Q06 - I always try my best In physics	Q12 - I find lab activities enjoyable	Q13 - I feel engaged & excited to learn physics	Q19 - I feel motivated in physics
Pre Treatment	Mean	4.064	4.191	4.000	3.979	3.915
	SD	0.322	0.463	0.696	0.282	0.340
Post Treatment	Mean	3.936	4.043	3.894	3.702	3.894
	SD	0.626	0.737	1.271	0.822	0.532
	T Stat	0.899	0.932	0.520	1.804	0.156
	Critical T Value (0.05)	1.986	1.986	1.986	1.986	1.986
	P-Value	0.371	0.354	0.604	0.074	0.876

Note. 3 = Undecided, 4 = Agree, 5 = Strongly Agree. (*N*= 47).

As you can see there was a drop in the mean value of the responses for each of these questions although the decrease was minimal and if you consider rounding the mean to the nearest whole number, it actually shows that there was not a change in the average response. In fact each question hovered around the value of 4 which corresponds with agreeing with each question. As mentioned the p-values indicated that the data was not significant and the closest question to being statistically significant was the question on being excited and engaged while learning physics. Ultimately I believe the decrease in the mean responses, however seemingly insignificant, were a result of students realizing that generally speaking they had not been doing as well on their homework assignments, data that will be brought up again later. Homework scores are my students'

most immediate form of feedback in terms of assignments and exercises that count towards their grade, so since many of them weren't performing as well as usual that could explain why the questions pertaining to attitude had a lower mean response after the treatment period.

When I saw this data I decided that I should try using a t-test on a composite of the data for each of the questions pertaining to attitude. This was done by taking the mean of the responses and then performing a t-test on those values. Again there was a decrease in the responses from the pre-treatment ($M = 4.030$, $SD = 0.216$) and the post-treatment ($M = 3.894$, $SD = 0.480$), $p = 0.266$, but again this result could not be deemed as statistically significant. While this might not be statistically significant, I believe this piece of data is further evidence that my students' attitudes in class are closely tied with their perception of how well they are doing in the class. Since homework scores were lower than usual, students were getting frustrated with the new approach since in their mind, the lack of lectures and use of discussions was the cause of the decreased homework scores. One student's response to the question asking if students felt comfortable starting challenging problems when they were unsure how to start indicates this is certainly the case "I feel nervous to mess up because it seems as if I am more focused on my grade than improving my knowledge of the subject."

Interestingly the comments students made on the questions did not change drastically between the pre-treatment and post-treatment surveys. For question three, regarding whether or not students enjoyed physics, many of the students commented on the interactive nature of the course and the lab activities. On the pre-treatment survey

one student commented “I like physics because it is a fun class and we get to do experiments and labs and it helps me learn or understand the material better” and another said “Physics always seems to fly by faster than the other classes because it is interactive.” These sentiments were also prevalent in the post treatment survey; “Class is always interactive and enjoyable” was the comment from one student and another said “Physics is one of my favorite classes with all the lab exercises and collaborative activities.”

For question 19 which asked students whether or not they felt motivated in physics the comments carried the same theme both before and after the treatment period. “I am motivated in all my classes to get good grades” said one student and another said “ I want to keep a solid grade.” This sentiment of being motivated purely for the sake of grades was also found after the treatment period unfortunately; “I want good grades and to do that I have to work hard in every class and physics is one of my classes.” Clearly these responses are evidence that my students are very focused on their grades and that their motivation is closely tied to this.

Similar results were found for the questions pertaining to confidence and these are displayed in Table 3. The responses to questions 15 and 18 showed an improvement in the average response, which was nice to see, but again this improvement was not a large increase and the data was not statistically significant. It is worth noting that student responses to question 4, which asked students if they get good grades in physics, showed a significant decrease from the pre-treatment (M = 3.936, SD = 0.583) and the post-treatment (M = 3.426, SD = 0.408), p = 0.009. Notice that the p-value here was very low,

indicating that this piece of data was statistically significant. As you will see later, student homework performance did drop significantly and based on their responses to question 4, I think it is fair to say that my students were well aware that they were not doing quite as well as usual. During the treatment we were covering momentum right after covering forces, so while the content itself was not all that challenging, students often confuse concepts from forces and momentum so this may have been a driving factor. I also believe the lower homework scores may have been a driving force behind the drop in the average response value from the pre-treatment and post-treatment responses regarding attitude and confidence.

Table 3

Likert Survey Results for Questions Pertaining to Confidence.

		Q14 - I enjoy challenging problems in physics	Q 15 - I feel comfortable starting easy problems	Q16 - I feel comfortable starting hard problems	Q18 - I feel confident in my ability to succeed in physics
Pre Treatment	Mean	3.596	4.426	2.872	4.191
	SD	0.855	0.337	0.896	0.332
Post Treatment	Mean	3.340	4.553	2.702	4.255
	SD	1.273	0.383	1.301	0.499
	T Stat	1.200	-1.032	0.787	-0.480
	Critical T Value (0.05)	1.986	1.986	1.986	1.986
	P-Value	0.233	0.305	0.433	0.632

Note. 2 = Disagree, 3 = Undecided, 4 = Agree, 5 = Strongly Agree. (*N*= 47).

Given that my project was based on trying to get students to take more ownership of their learning through improving their attitude and confidence in their ability, I needed

to also consider the questions pertaining to taking ownership. Responses to question 5 regarding students trying their best, showed there was a decrease in the pre-treatment (M = 4.213, SD = 0.475) and the post-treatment (M = 4.106, SD = 0.706), p = 0.504, but again this data was not statistically significant. The responses to question 20 which asked students whether or not they took ownership of their learning in physics also showed a decrease from the pre-treatment (M = 4.191, SD = 0.376) and the post-treatment (M = 4.085, SD = 0.514), p = 0.411, but again were not statistically significant. Given that I had one piece of data from the surveys that was deemed statistically significant, I knew I needed to take a closer look at some of my other data. The observational data I recorded in my teacher journal certainly helps explain some of these results but I will go into that detail during the interpretation section.

When students were asked what being successful in conceptual physics meant to them, their responses were eerily similar to the responses given for the question asking if they were motivated. Nearly every response mentioned something about getting a good grade; “Having an A,” or “Straight As” or “Get good grades” are examples that accurately represent the sentiment of my students. I was pleased to see one student write “Understanding the material to the fullest of my ability. I want to be able to explain it to someone who has never taken physics before.” Unfortunately the message that was being sent about taking ownership of their learning and to do all they can to maximize their success is overshadowed by their desire to get good grades.

Since the survey data from before and after the treatment was less than favorable, I decided to compare data collected during the treatment period. I compared the number

of times students participated in each discussion at the beginning of the treatment to the end of the treatment period. During the early phases of the treatment, students participated less (M = 1.56, SD = 0.889) than they did near the end of the treatment (M = 2.20, SD = 2.381), p = 0.015. Finally I managed to find statistically significant data that could help tell a more reliable story. While the standard deviation indicates that there was a wide range of how much students participated, the improvement in the average amount of participation each class indicated that students spoke up more later on in the treatment period. There were only six students whose participation in class did not improve, or who participated less later on in the treatment period. Of these six students, two were students who typically do very well in my class and based on their answers to the survey questions, simply disliked the class discussions. The other four students were weak students who typically do not feel comfortable sharing their thoughts for fear of being wrong in front of their peers. This was certainly an observation I had made in my teacher journal and when I looked at participation on a student by student basis there was a clear pattern that most students participated more by the end of the treatment period. So while no improvement in attitude or confidence was reported, I believe my students were making gains in their confidence in the classroom, it just didn't show up in the survey because their homework grades are so important that they lost confidence due to lower homework scores.

I also decided to compare the average student scores on the formative assessments from the beginning of the treatment period to the later stage of the treatment. In the beginning of the treatment, students scored lower on the assessments (M = 79.7, SD =

2.71) than they did later on during the treatment period (M = 87.3, SD = 1.21), p = 0.009. Of course this could be explained by a better understanding of the material, but it is worth noting that at the beginning of the treatment we were covering momentum and impulse and at the end of the treatment we were covering springs. While these topics might not seem related, studying springs after momentum works nicely since springs are applicable to situations involving a change in momentum. Studying springs after momentum also helps students keep the concepts of forces and momentum separate while also developing an understanding of how they can be related. Regardless I believe these results indicate that students were performing at a significantly higher level on assessments by the end of the treatment period. Despite the fact that students generally reported feeling less confident after the treatment period, it's clear that by the end of the treatment period they were able to gain a more complete understanding of the material at hand.

As previously mentioned, students were well aware that they had not been doing as well as usual on homework assignments during the treatment period. When I compared the mid treatment homework average for all of my students (M = 71.3, SD =12.8) to the homework average for the entire year leading up to the treatment period (M = 76.1, SD =11.9), p = 0.062, it was clear that performance on homework assignments had indeed decreased. At this point I thought it would be helpful to look at the average homework score for all students during each unit. I could not include our first unit on optics because we switch some students to honors after that unit, so I did not have homework scores for any of the new students I received after that switch. This data is displayed in Figure 1.

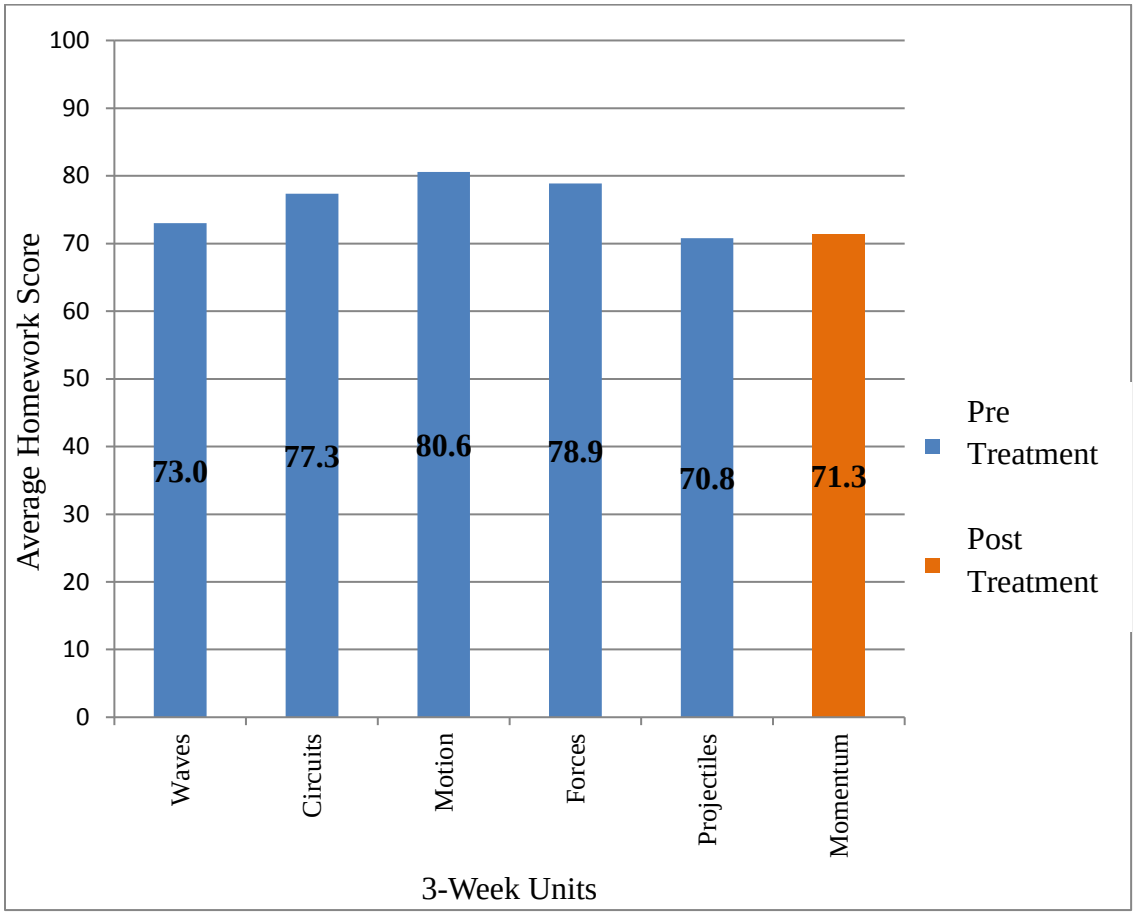

Figure 1. Average homework score for all students during each 3 week unit, (N = 48).

I thought it would prove helpful to compare student performance on homework assignments during the treatment period with the ownership score that I created during the three week treatment period. I used the standardize function in Microsoft Excel to standardize both the homework scores and the ownership scores. This technique makes the mean of the scores a zero and makes it possible to determine how one standard unit of an improved ownership score would affect the standard unit of homework score for my students during the treatment period. Once the data was standardized I used a scatter plot with a trend line to determine the relationship between the ownership score and the homework score. This data can be found in Figure 2.

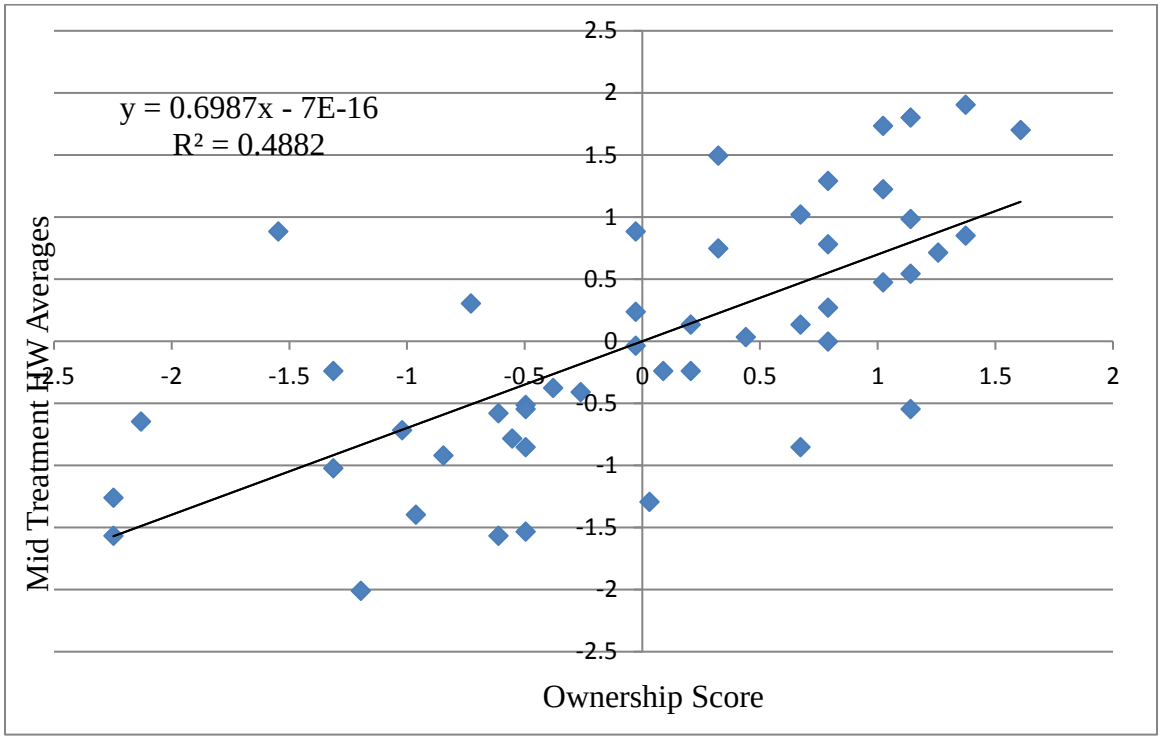

Figure 2. Standardized ownership score compared to standardized homework averages during the treatment period, (*N* = 48).

Clearly there is a positive, linear relationship between students' ownership score and their average homework score during the treatment period. The slope of the line was determined and the 0.698 value indicates that for every increase of one standard unit of a student's ownership score there is a 0.698 standard unit increase in their homework average. It is important to note that this does not mean that the homework average increased by this amount, it is the amount that the standardized units increased. This was reassuring as I have always believed that the more ownership a student is willing to take the better they will perform on nightly assignments. I found one point on the graph to be a particularly interesting outlier. The point at (-1.5, 0.88) is from a student who has an A- in my class but during the treatment period only participated a couple of times and didn't correct several of his formative assessments. This student responded to the survey

question asking if students took ownership of their learning that he "Agreed" and commented "Yes I do but I think the material needs to be lectured to us before we take the learning into our own hands." This stuck out to me because he frequently zoned out during discussions so it is no surprise to me that he felt the need for material to be delivered to him in some other way.

Question 20 on the survey asked students whether or not they took ownership of their learning and the results are displayed in Table 4. Before the treatment period students were asked to define what taking ownership of their learning looked like to them. The response I was looking for was not prevalent but one student hit the nail on the head "Taking ownership of my learning is taking notes, paying attention in class, and going the extra mile to get work done and to further your understanding of the subject." Students generally included one of these aspects in their response but no one seemed to see the whole picture as well as this student. On the post treatment survey the number of students who thought they took ownership of their learning generally decreased but the number of students who responded with "Agree" or "Strongly Agree" only dropped from 42 to 39.

Table 4
Students Responses to Questions Regarding Ownership in Physics of the Likert Survey.

Response	Pre-Treatment	Post-Treatment
Strongly Disagree	0	0
Disagree	0	1
Undecided	5	7
Agree	28	26
Strongly Agree	14	13

Note. (*N*= 47).

The follow up question for question 20 was changed slightly to ask if they had taken ownership during the treatment period and the comments made by those students who disagreed or were undecided matched their response to the question. One student who was undecided said "I think I just need to do what is required, no questions asked." The student who disagreed made a very interesting comment that showed more evidence that students relate taking ownership directly to their grade.

> No, I have not been struggling for the majority of the year and now I am finding myself in the B range on the last test and that is frustrating to me because my homework grades have improved exponentially but my test grades are showing the opposite.

Another comment from a student who put undecided for his post-treatment response to question 20 was "Teachers are supposed to teach you so yes I taught myself some stuff but you still need a teacher to learn." Interestingly this student is constantly asking me to explain what he did wrong and to tell him the answer and gets very frustrated when I tell him to try to figure it out on his own or ask his peers for assistance. Again I found evidence that grades seem to be the driving factor behind many students' approach to the class and that poor grades mean that the teacher is not doing a good enough job of teaching the material.

The overall performance on the unit test at the end of the treatment period was surprisingly similar to the overall performance of students on tests up to that point of the year. The average score for all of the tests before the treatment period was slightly higher (M = 74.7, SD = 176.3) than the average score on the test at the end of the treatment period (M = 74.1, SD = 272.3), p = 0.843. While the p-value indicates that this data was not statistically significant and the standard deviation shows that scores on the test varied

widely, I think it says a lot that the average performance on the test during the treatment period was not drastically different than the overall test average for the year. I feel confident in making this statement since the average score of the tests during the momentum unit are only 4 points away from the circuit test and forces test, which are the highest and lowest test averages of any of the three week units throughout the year. So while the average homework scores may have dropped, it seems that students were still able to gain a solid understanding of the material and perform just as well on the unit test as they had on previous tests.

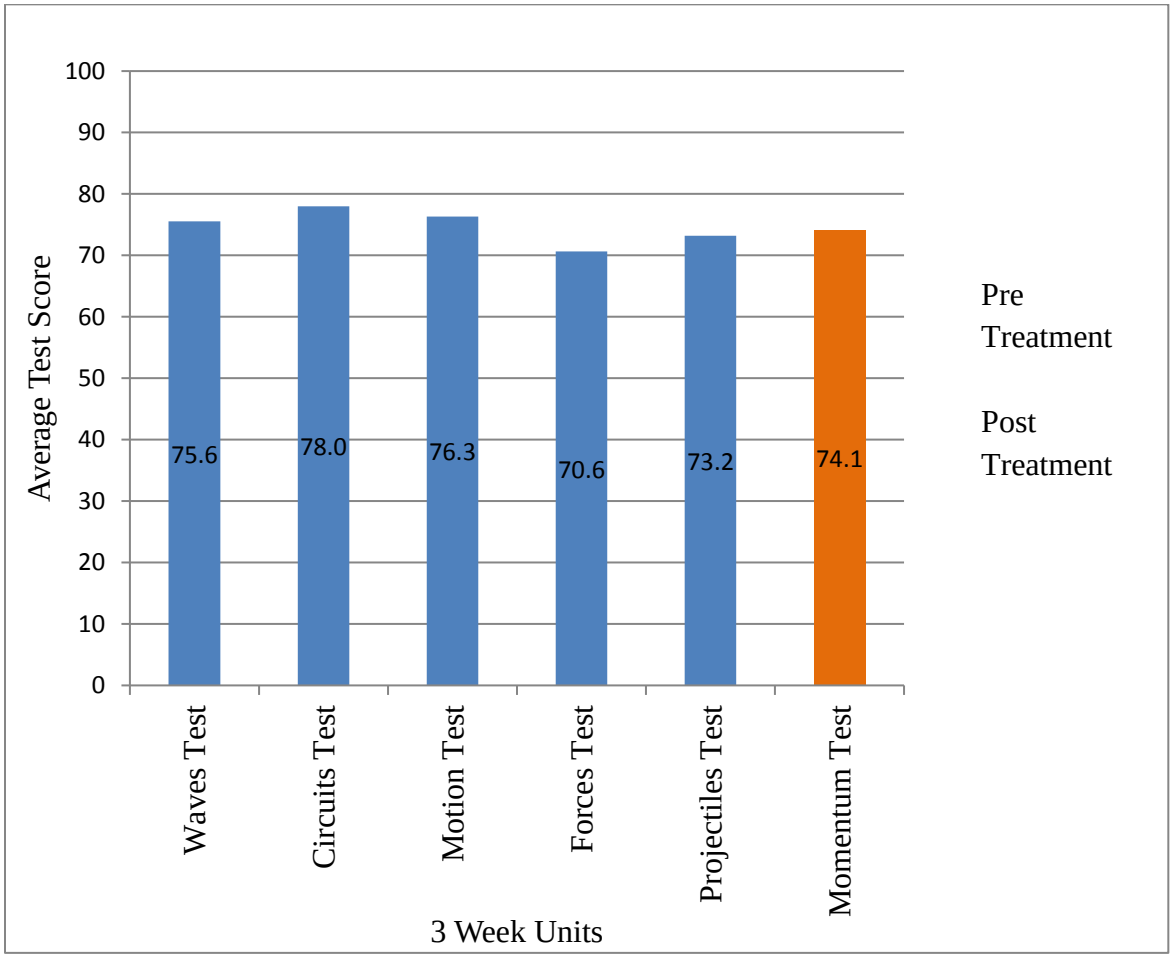

Figure 3. Average test score for all students during each 3 week unit, (N = 48).

Another significant aspect of my class involves multiple choice quizzes. All of the multiple choice quizzes consist of 10 multiple choice questions, mostly focusing on the most recent material with anywhere from two to three questions that review concepts from earlier in the year and are scored out of 20 points. Students are asked to correct the quizzes and explain why the answer is correct. If students don't provide correct explanations when they correct the questions or if they don't correct all of the questions they got wrong they do not receive credit for the correction. Each corrected question earns them half credit back so these quiz scores are a good indication of whether or not students corrected their quizzes. The multiple choice quiz average for all of the quizzes leading up to the treatment was lower (M = 16.7, SD = 3.48) than the average for the two multiple choice quizzes during the treatment period (M = 17.9, SD = 3.56), p = 0.002. When I noticed this I decided it would be helpful to look at the pattern of the average multiple choice quiz score, as shown in Figure 4.

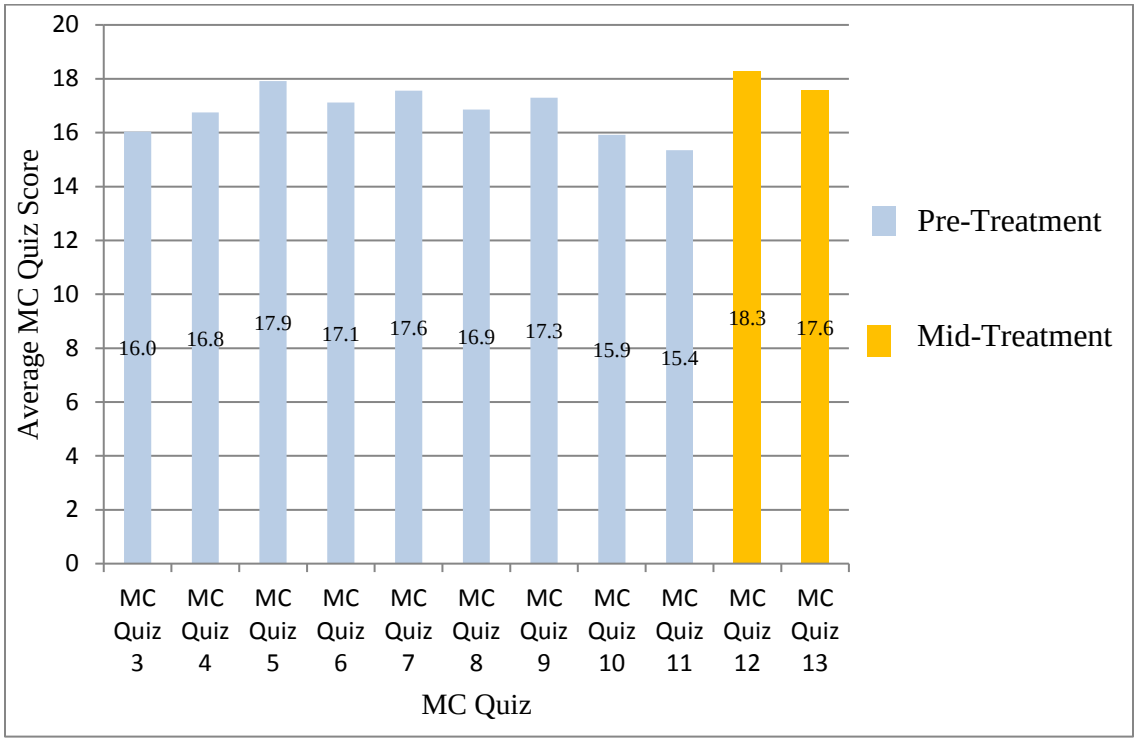

Figure 4. Average multiple choice quiz scores pre and mid treatment, (N = 48).

I believe there are two important and relevant reasons for the improved multiple choice quiz scores. First, through the new class discussions and inquiry-based lab exercises, students were able to achieve a more complete understanding of the material as well as a better ability to solve problems on their own. Secondly, since students are able to earn half credit back on missed questions by correctly explaining the right answer to a question they missed, the higher scores also indicate that students corrected more questions than usual. Both of these factors indicate that the approach used during the treatment period helped students achieve a higher overall performance on multiple choice quizzes through improved understanding and better ownership on their part.

Considering that I found statistically significant data from homework assignments and multiple choice quizzes, and that despite the high p-value, I felt confident in the

average test scores, comparing overall student performance seemed an appropriate lead to follow. The t-Test results for the homework, multiple choice quizzes and tests are displayed in Table 5.

Table 5
t-Test Results for the Pre and Mid Treatment Average Homework, Average Multiple Choice Quiz, and Average Test Scores

	Pre Treatment		Mid Treatment		
	Mean	SD	Mean	SD	P-Value
HW	76.116	11.9	71.322	12.8	0.062
Test	74.736	13.1	74.132	16.3	0.844
MC	16.757	1.84	17.927	1.86	0.003

Note. (N = 48).

Based on the fact that two out of three of the major contributing factors for students overall grades improved, I think it is fair to say that students' overall performance improved during the treatment period. This is also supported by the fact that student participation and average scores on formative assessments also improved throughout the treatment period. It is worth noting that three students who had grades in the D or F range had three of the worst taking ownership scores, and these three students did not see an improvement in their overall grade during the treatment period and have been performing at this level since the beginning of the year.

Given that the ownership score correlated well with the homework averages I decided to compare the ownership score to students' overall grade, again using a scatter plot. Before plotting the data I standardized both the overall grades and the ownership scores. The plot of this data can be found in Figure 5.

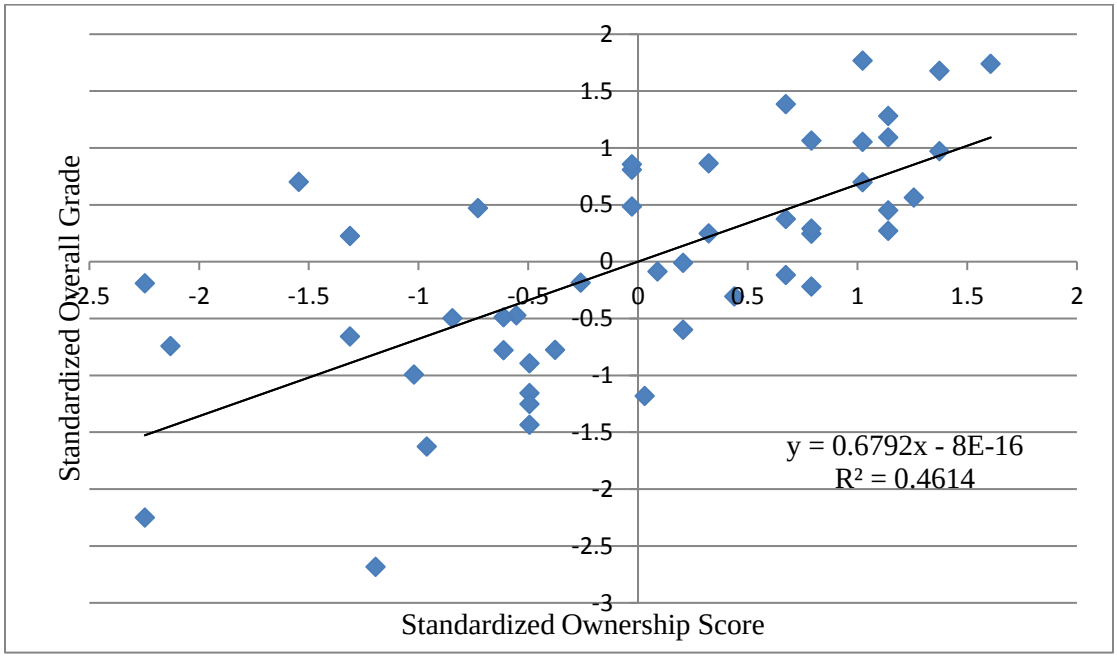

Figure 5. Standardized ownership scores compared to standardized overall grades, (*N* = 48)

Again we see a strong correlation between ownership score and student performance and the slope value of 0.679 indicates a direct and positive relationship between overall grade and ownership score. It is worth noting that three students who had grades in the D or F range had three of the worst taking ownership scores, and these three students did not see an improvement in their overall grade during the treatment period. When I saw the results of this graph, it helped me feel much more confident in reporting that the more students take ownership of their learning the better overall grade they are likely to achieve.

For the post treatment Likert survey I added an additional question that asked students if they enjoyed replacing the lectures with class discussions. The possible answers differed from the previous questions. The possible answer choices were: I enjoyed it and would like to continue using more class discussions, I enjoyed it but would

rather we go back to Mr. Tisch lecturing, I don't feel strongly one way or another, I disliked it but saw the value in the new approach, I disliked it and hope we do not rely on class discussions any more. For the data analysis a scale of one to five was applied with five corresponding to the response that students enjoyed it and want to continue and 1 corresponding with disliking the use of discussions and not wanting to rely on them anymore. The responses to this question are displayed in Figure 6.

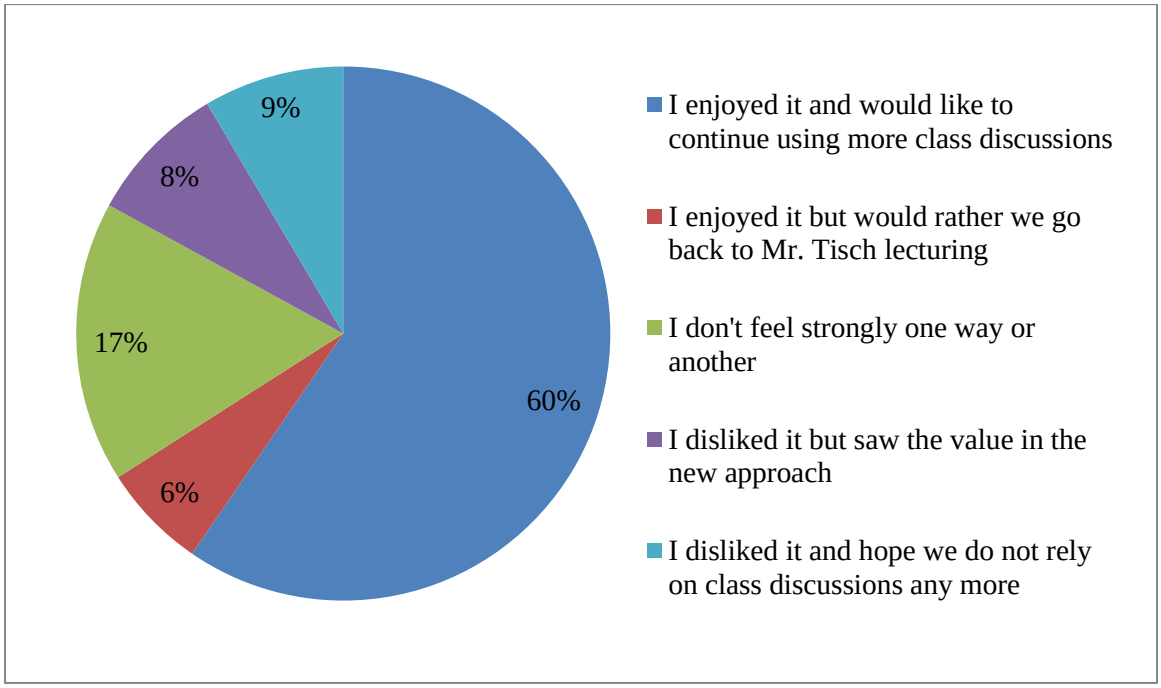

Figure 6 . Student responses to Question 21 of the post treatment survey asking if they enjoyed replacing lectures with discussions, (N=47).

As you can see 60% of students said that they enjoyed the discussions and would like to continue using them in place of lectures. The students who chose this response provided comments that alluded to how helpful it was to hear their peers explain concepts. One of these students responded "In class discussions help me hear other peoples' way of thinking" while another wrote "I enjoy discussions because when students explain things to each other they increase their understanding and I find that I

am able to see things from different points of view." The students who said they disliked the discussions all touched on the sentiment that they felt they learned more through lectures. One student wrote "I felt much more comfortable about truly knowing the material with lectures and don't feel I have nearly as good of a grasp on the material without lectures" while another wrote "I like the lectures a lot better because the teacher can help alot more in how I learn." One of these students had a particularly interesting and detailed response:

> I liked the new idea of not having lectures on material, but having class discussions. The thing is that making our own facts sheets gets very sloppy and without an official sheet, my notes got scrambled and I did not have the fact sheet for most of the unit because I lost it. The ball was a bad idea and it was a distraction. Discussions are good, but I feel like they would be more productive and interesting if we did discussions in smaller groups. With the whole class discussing the same thing, it almost becomes a lecture, just spread out through the student body.

I found it interesting that this student mentioned that he lost the fact sheet that he copied down in his notes and seemed to blame the fact that it was not a printed fact sheet that was handed out to him. Whether or not I printed the sheet or he wrote it in his notes is clearly not the cause of him losing the fact sheet. As I mentioned earlier, due to a mistake in setting up my survey on Google Forms, I was not able to compare individual responses to the survey questions. Being able to do so would have been a powerful tool for looking at patterns amongst individual responses as well as outlier students. This was only further evidence that students did not feel entirely comfortable with the removal of my hand in their learning and explains why the survey results indicated a decrease in overall student attitude and confidence.

INTERPRETATION AND CONCLUSION

While the survey results indicated a decrease in student attitude and confidence, those values were not statistically significant. The responses on the survey questions made it clear just how important grades are for my students, however, and I believe this tells an essential aspect of the story. In most cases their parents are paying a lot of money, or in other cases less money with the help of financial aid, for their son to attend Woodberry. As such, I expect that the pressure from home to do well and get the best grades possible is a driving factor in causing grades to be so important for my students. This combined with my students' strong desire and motivation to do well doesn't help in fighting the battle against learning for the sake of grades.

When we dropped lectures and standard direction-following lab exercises, students no longer had my guidance and input at every step of the way. They had to rely on their peers and themselves more often than before the treatment period. Interestingly some of my brightest students were the ones who disliked the discussions. They seem to be the students who just want to know the correct concept, apply it to the problem at hand, finish the problem, get a good grade, and move on. In my teacher journal, I made note of any time a student got frustrated with a lab exercise or with me for not just showing them how to complete the problem. In the journal I wrote down quotes such as "Can't you just show me how to set up the spring?" and "Well I don't get what we're trying to measure" and "How do you measure the distance the spring stretches?" While the weaker students frequently tried to ask me questions or get me to help them, they rarely got frustrated when I told them to ask their peers or figure it out for themselves.

The stronger students would always whine and moan and say that I should save them the time and explain it.

I found it interesting that a major complaint was that I stopped printing and handing out the fact sheets for students to have. For whatever reasons the printed version of the fact sheets that came directly from me seemed to give students more confidence in the material as opposed to the fact sheet we created as a class at the end of a discussion. As I said to them many times, during the process of creating the fact sheet I let them come up with the wording but I always made sure that nothing they came up with was wrong and that they had all the information they would need. This did not seem to alleviate the concern that creating fact sheets as a class was not as effective as just being given the facts right from the get go. One student wrote "When you "lectured" you gave us solid fact sheets that we followed along with and we were able to get a firm understanding at once instead of piece by piece." Again I think this comes back to the security blanket that students yearn for since that is the traditional approach they are used to. When this security blanket was removed, students did not feel as sure of themselves and hence were not as willing to jump on board with the idea that they could take their learning into their own hands. I believe this also had a direct and negative effect on their attitude and confidence in the class.

Interestingly, as the treatment period continued, I noticed students became more comfortable with the idea that their peers could provide just as good of an explanation as I could, despite the fact that I've been telling them this since day one. A few of them even touched on this concept in their responses to the survey questions. One student

wrote “I enjoy discussions because when students explain things to each other they increase their understanding and I find that I am able to see things from different points of view.” While that student has been one of my best students all year, one of my weakest students shared a similar sentiment; “I think discussions help me understand material through other people's viewpoints possibly giving me reasons to help me better understand something.” This second student has had a grade in the D range all year and during the treatment period was able to raise his grade into the C range for the first time.

The fact that student performance improved on the formative assessments from the beginning of the treatment (M = 79.7, SD = 2.71) to the end of the treatment (M = 87.3, SD = 1.21), p = 0.009, shows that as students got more comfortable with the new approach, they gained a better overall understanding of the material. So while the data from before and after the treatment did not show an improvement in attitude and confidence, I believe that throughout the treatment period students gained confidence and a better attitude about taking ownership of their learning. I think this was especially true for my weaker students. One student who has been struggling saw the discussions as an opportunity to establish himself as a leader in the class, and was gently forcing all students to participate. As I mentioned previously, I purposefully did not meddle in the discussions when it came to getting students to participate. When I asked a question and the hands went up, this student would figure out who hadn’t spoken yet and call on them. I took note of this in my journal and on the first day he did this I wrote “Will he continue to do this?” and “How will the class react if this continues?” Sure enough the class embraced his leadership and after a few days, the students who were not participating

early on were offering their opinions and explanations more readily and without prompting from their student leader.

I believe this example is important to discuss because I found that class dynamics have a massive effect on how well the discussions run. My teacher journal was instrumental in helping me document this. When I implemented the same style of discussions last spring, I had smaller classes and the transition was much easier, the discussions ran more smoothly and the engagement was much higher across the board. My classes this year are bigger and I believe the discussions work best in smaller class sizes. In fact Harkness stated that sections of 8 students were most ideal for these types of discussions. One of my sections this year has a particularly difficult blend of a group of my brightest students along with my weakest students. This class really struggled to buy into the discussion based approach and on the first major discussion we had there was one point when no one responded to a question for 30 seconds. The brightest students just seemed to not be interested in participating while the weaker students were too scared to give the wrong answer or sound silly in front of their peers. Despite the different class dynamics, each class showed an improved willingness to participate and take the discussions seriously throughout the treatment.

The fact that 60% of students said they would like to continue using discussions instead of lectures seems to contradict the fact that, according to the survey responses, students' attitude and confidence dropped during the treatment period. I think the fact that they still were not entirely comfortable with the removal of my more regular input and saw a decrease in their homework grades were the biggest factors in this discrepancy.

I wonder if the treatment period continued for another 3 weeks and I gave the survey again, if the results would then finally show the improvement in attitude and confidence that I hoped for. It is worth noting that since I officially ended the treatment period and gave them the post treatment survey, we have continued using the same approach and students are the most comfortable and confident I've seen them all year. We just started studying simple harmonic motion, which involves the most difficult equations the students have seen all year combined with some concepts like frequency and period that were covered earlier in the year. Students have been so successful with the labs, that they finished the exercises a full class period before I expected everyone to have completed their work.

On the whole, my students definitely began taking more ownership of their learning during the treatment period. The multiple choice quiz scores improved dramatically compared to earlier in the year and these grades involve correcting work so the higher average indicates that more students were completing their corrections and that their corrections were right. The higher assessment scores also support an improvement in taking ownership since all of the assessments involved correcting work and turning it back in on their own. Looking back I wish I had thought of creating the taking ownership score before the treatment period began so I could have a quantitative baseline to compare their treatment period ownership scores to. Nevertheless, my observations in the class during both discussions and lab activities provide enough evidence to support this.

Even after the treatment period ended, students have been so motivated and self-directed that I have been able to get grading done during lab exercises and am rarely interrupted with a question. I believe students also have a much better understanding of what exactly taking ownership of their learning means. In the pre treatment survey responses, many more students mentioned getting good grades in the explanation of what taking ownership meant to them than in the post treatment survey responses. The post treatment responses also included more comments that mentioned specific aspects or examples of what taking ownership means. One student commented "Reading and creating our own notes is on me. If I take better notes I will do better."

Given that students performance on tests remained the same compared to earlier in the year, that the multiple choice quiz scores increased dramatically, and that more lab exercises were completed than usual, it is clear that students' overall performance improved. Outside of the quantitative nature of this improvement, most notable was the qualitative nature of the improvement in overall performance. Student explanations became more robust and detailed, and important aspects vital to a correct explanation were included more often. When students helped each other in class, their back and forth discourse was more two-sided than before whereas beforehand the strong student was simply telling the weaker student the answer. Students began arguing more and when they did not agree they would often bring in a third student to help them determine the correct approach or answer. On the test given at the end of the treatment period, I noticed a significant improvement in the quality of the work on the short answer section in which students had to show their work.

One explanation for the lower average homework scores would be that the homework assignments were the same style and format that have been given all year, and were not adjusted to reflect the change in approach in the classroom. While some of the nightly assignments were different, such as more reading assignments, in hindsight I wish I had considered changing more of the homework assignments. As I mentioned earlier, students did not feel as confident using their own hand written fact sheets from class to help them on the homework assignments as they did when using the typed versions I handed out earlier in the year, so this could explain the decreased homework scores as well.

Overall, I believe my students found the treatment beneficial and enjoyed hearing the varying viewpoints of their classmates. The more open ended inquiry style labs definitely forced them to think through their approach and realize how the concepts applied to the specific situation they were investigating. While students clearly felt uncomfortable at first without lectures and directions for lab exercises, they gained confidence throughout the treatment period and gained a better conceptual understanding of the material. Unfortunately, it seems my students remained very focused on their grades and this seemed to have a profound effect on their confidence and attitude. Students gained a better understanding of what taking ownership of their learning should look like and many students improved in this area. Based on my post treatment observations this trend has continued and with their final exam looming on the horizon I think the timing could not be better.

Based on the results of my research project, I believe that while students are slow to warm up to discussions and inquiry-based lab exercises since it requires less involvement from the teacher, they ultimately benefit more from tackling the material on their own. Had I been able to extend my treatment period and surveyed students on their attitude and confidence after an additional three weeks of treatment, I believe the overall responses to the attitude and confidence survey questions would have shown a statistically significant improvement. So in response to my first action research question, I found that student attitude and confidence did not improve, although I believe it is clear over a longer treatment the survey results would have been more favorable. In response to my second action research question, I found that students took more ownership of their learning as indicated by the improved participation, formative assessment scores and multiple choice quiz scores. I would add that my observations since the end of the treatment period also support that students are more willing to take ownership of their learning now than they were before the treatment period. In response to my third action research question, I found that while performance on nightly homework assignments got worse during the treatment, students gained a more complete understanding of the material and their overall performance in my class generally improved. Despite the drop in attitude and confidence, in the post survey responses 60% of students said they enjoyed the new approach and wanted to continue using it for the remainder of the year.

VALUE

While the results were not as clear as I had hoped for, I believe this project makes it clear that student-centered learning helps students take more ownership of their

learning and gain a better overall understanding of the concepts. As anyone who has tried inquiry based learning or replaced lectures with discussions is aware of, students can be slow to warm up to the new approach, so some griping should be expected but ultimately they see the benefit in the approach that puts the learning in their own hands. Typically the use of discussions and open ended lab exercises slows the pace down but ultimately the skills that the students gain outweigh any downside to the slower pace. While their overall performance improved slightly, I believe the most valuable aspect of the new approach was the skills that students gained. Most importantly, these skills are not exclusive to learning in a science classroom, and I believe students will be able to implement these techniques and skills in all of their classes going forward.

When we began the major class discussions I was surprised by how hard it was to get everyone to speak up and be engaged. I have continued using discussions after the treatment period and no longer use the ball to indicate who should be speaking but rather rely on the old fashioned raising of the hands. While a few students still tend to shout out answers or speak out of turn they have generally improved in this area. I know that I tend to be a more relaxed teacher when it comes to how my class operates, but I plan on being more adamant about not speaking out of turn at the beginning of next year to help set the precedent for a better discussion environment. Having a set of questions which I could use to spur on the students when the discussion slowed was essential and anyone who relies on discussions should always be sure to have questions in their back pocket. I also found that asking misleading questions, questions that had more than one answer, and describing situations which were not possible all generated some of the best discussions

we had. I do believe that the discussions work best with smaller class sizes as I found that with 16 students in a class, it was too easy for students to get away with not participating.

Since I was trying to track how well students took ownership of their learning during discussions by recording the frequency of their participation I did not make a point of calling out anyone who was not participating. Now that my project is over I have made a point to look at my sheet and call on anyone who hasn't spoken yet or if I notice a particular student zoning out I make sure to call on them even if other students have their hand raised. Based on a student's recommendation, I have also tried breaking up the class into groups of four and having them discuss amongst each other before discussing it all together. This technique has been helpful and I have found that it forces everyone to be more engaged. I would actually consider having students arranged in clusters of four at a table and run the whole class that way but I share my classroom and can't try that arrangement until next school year.

While my typical teaching style in the past few years has never been lecture heavy, I plan on removing myself from the equation as much as possible going forward. I will continue doing this for the remainder of the year, and plan on starting the year this way next fall. I also plan to eliminate using the fact sheets because I really want the students to feel like they have learned the information on their own, not just been given it from the teacher. I don't expect that I will be able to get students to completely separate their idea of being successful from their overall grade in the course, but I do believe I can

help them to understand that learning is not just about the grade as well as show them that the skills they learn in my class are applicable to all of their classes.

The inquiry style lab exercises took longer for students to figure out but eventually they gained a better overall understanding of the purpose of each lab exercise. Having to set up and take down the lab on their own was the biggest aspect that slowed them down but eventually they were able to do so more quickly. I noticed that students were more willing to help each other with setting up the labs as well as walking each other through the steps. An added benefit of this technique was that I did not have to spend time setting up or cleaning up the lab since I simply took out the equipment they needed and let them use what they needed. A highlight for me was when students were given a spring and asked to determine the spring constant. There are numerous ways to do this and students employed just about every set up and technique you could. They were blown away when I told them to step back and look around the room at the different set ups. This is something I hope to do more often next year as the experience was extremely beneficial and eye opening for the students.

I wish I had come up with the idea of a taking ownership score earlier in the year for a few reasons. First, when students knew I was specifically tracking this aspect of their learning they seemed to be more willing to take ownership, even though they knew it didn't count towards their grade. Secondly, having an ownership score for students throughout the year would have given me a baseline to compare with their ownership score during the treatment period. Last but not least I reported the ownership score in every students marking period comment, and I've gotten lots of feedback from parents

and advisors that they found it helpful and it gave them more specific information with which to start a conversation with their son or advisee. Next year I plan on having participation as part of students' overall grade and want to keep track of their ownership score for the whole year.

This project has helped me come up with many ideas for how I will change my teaching strategy for the future. I am always excited and willing to try new approaches but I now have the tools for collecting reliable data. This will allow me to determine how effective new techniques and approaches are, as well as find more ways to improve upon these techniques. I also feel more confident with receiving and giving feedback and plan on making the exchange of feedback from myself to students, from students to me, and from student to student a more regular part of my class. I expect that implementing more discussions and inquiry style labs will help me create new ideas and techniques which I will be able to use to keep the classroom environment exciting and engaging.

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APPENDICES

APPENDIX A

IRB EXEMPTION

MONTANA STATE UNIVERSITY

INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
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MEMORANDUM

TO: Alexander Tisch and Walter Woolbaugh

FROM: Mark Quinn, Chair Mark Quinn CTJ

DATE: December 2, 2015

RE: *"Impact of the Harkness Method and Inquiry-Based Lab Exercises on Student Attitudes and Confidence" [AT120215-EX]*

The above research, described in your submission of December 2, 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:

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

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

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

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

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

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

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

APPENDIX B

ADMINISTRATOR APPROVAL

Administrator Approval

I, Matt Boesen, Dean of Faculty of Woodberry Forest School, verify that I approve of the classroom research conducted by Alex Tisch.

_____, DEAN OF FACULTY

(Signed Name, Title of Position)

MATTHEW BOESEN

(Printed Name)

12/1/15

(Date)

APPENDIX C

CONSENT FORM

Consent Form

I, Matt Boesen, Dean of Faculty of Woodberry Forest School, verify that the classroom research conducted by Alex Tisch is in accordance with established or commonly accepted educational settings onvolving normal educational practices. To maintain the established culture of our school and not cause disruption to our school climate, I have granted an exemption to Alex Tisch regarding informed consent.

(Signed Name)

MATTHEW BOESEN

(Printed Name)

12/1/15

(Date)

APPENDIX D

PRE TREATMENT LIKERT SURVEY ON STUDENT CONFIDENCE AND ATTITUDE

Participation in this research is voluntary and participation or non-participation will not affect a students' grade or class standing in any way.

1. I enjoy school.
   Strongly Disagree Disagree Undecided Agree Strongly Agree
   Please explain why your answer to question 1.

2. I get good grades in school.
   Strongly Disagree Disagree Undecided Agree Strongly Agree

3. I enjoy conceptual physics.
   Strongly Disagree Disagree Undecided Agree Strongly Agree
   Please explain your answer to question 3.

4. I get good grades in conceptual physics.
   Strongly Disagree Disagree Undecided Agree Strongly Agree

5. I always try my best in all of my classes.
   Strongly Disagree Disagree Undecided Agree Strongly Agree
   Can you give an example of what trying your best means?

6. I always try my best in conceptual physics.
   Strongly Disagree Disagree Undecided Agree Strongly Agree

7. I would enjoy being a scientist.
   Strongly Disagree Disagree Undecided Agree Strongly Agree
   Please explain your answer to question 7.

8. I find reviewing homework helpful.
   Strongly Disagree Disagree Undecided Agree Strongly Agree

9. I find lectures on material in conceptual physics helpful.
   Strongly Disagree Disagree Undecided Agree Strongly Agree

10. I find it easy to pay attention when teacher lectures on material.
    Strongly Disagree Disagree Undecided Agree Strongly Agree

11. I find the lab activities in conceptual physics help me understand material.
    Strongly Disagree Disagree Undecided Agree Strongly Agree

12. I find the lab activities in conceptual physics interesting and enjoyable.
    Strongly Disagree Disagree Undecided Agree Strongly Agree
    What lab activities have you enjoyed most? Why?

13. I feel engaged and excited to learn in conceptual physics.
    Strongly Disagree Disagree Undecided Agree Strongly Agree

14. I enjoy challenging problems in conceptual physics.
    Strongly Disagree Disagree Undecided Agree Strongly Agree

15. I feel comfortable attempting problems when I know how to start.
    Strongly Disagree Disagree Undecided Agree Strongly Agree

16. I feel comfortable attempting problems when I am unsure how to begin the problem.
    Strongly Disagree Disagree Undecided Agree Strongly Agree
    Please explain your answer to question 16.

17. I find working in groups helpful.
    Strongly Disagree Disagree Undecided Agree Strongly Agree

18. I feel confident in my ability to be successful in conceptual physics.
    Strongly Disagree Disagree Undecided Agree Strongly Agree
    Explain what being successful in conceptual physcis means to you.

19. I am motivated when it comes to conceptual physics.
    Strongly Disagree Disagree Undecided Agree Strongly Agree
    Please explain your answer to question 19.

20. I take ownership of my learning in conceptual physics.
    Strongly Disagree Disagree Undecided Agree Strongly Agree
    Do you think you took ownership of your learning during the last few weeks? Please explain.

APPENDIX E

POST TREATMENT LIKERT SURVEY ON STUDENT CONFIDENCE AND ATTITUDE

Participation in this research is voluntary and participation or non-participation will not affect a students' grade or class standing in any way.

1. I enjoy school.
   Strongly Disagree Disagree Undecided Agree Strongly Agree
   Please explain why your answer to question 1.

2. I get good grades in school.
   Strongly Disagree Disagree Undecided Agree Strongly Agree

3. I enjoy conceptual physics.
   Strongly Disagree Disagree Undecided Agree Strongly Agree
   Please explain your answer to question 3.

4. I get good grades in conceptual physics.
   Strongly Disagree Disagree Undecided Agree Strongly Agree

5. I always try my best in all of my classes.
   Strongly Disagree Disagree Undecided Agree Strongly Agree
   Can you give an example of what trying your best means?

6. I always try my best in conceptual physics.
   Strongly Disagree Disagree Undecided Agree Strongly Agree

7. I would enjoy being a scientist.
   Strongly Disagree Disagree Undecided Agree Strongly Agree
   Please explain your answer to question 7.

8. I find reviewing homework helpful.
   Strongly Disagree Disagree Undecided Agree Strongly Agree

9. I find lectures on material in conceptual physics helpful.
   Strongly Disagree Disagree Undecided Agree Strongly Agree

10. I find it easy to pay attention when teacher lectures on material.
    Strongly Disagree Disagree Undecided Agree Strongly Agree

11. I find the lab activities in conceptual physics help me understand material.

Strongly Disagree Disagree Undecided Agree Strongly Agree

12. I find the lab activities in conceptual physics interesting and enjoyable.
    Strongly Disagree Disagree Undecided Agree Strongly Agree
    What lab activities have you enjoyed most? Why?

13. I feel engaged and excited to learn in conceptual physics.
    Strongly Disagree Disagree Undecided Agree Strongly Agree

14. I enjoy challenging problems in conceptual physics.
    Strongly Disagree Disagree Undecided Agree Strongly Agree

15. I feel comfortable attempting problems when I know how to start.
    Strongly Disagree Disagree Undecided Agree Strongly Agree

16. I feel comfortable attempting problems when I am unsure how to begin the problem.
    Strongly Disagree Disagree Undecided Agree Strongly Agree
    Please explain your answer to question 16.

17. I find working in groups helpful.
    Strongly Disagree Disagree Undecided Agree Strongly Agree

18. I feel confident in my ability to be successful in conceptual physics.
    Strongly Disagree Disagree Undecided Agree Strongly Agree
    Explain what being successful in conceptual physcis means to you.

19. I am motivated when it comes to conceptual physics.
    Strongly Disagree Disagree Undecided Agree Strongly Agree
    Please explain your answer to question 19.

20. I take ownership of my learning in conceptual physics.
    Strongly Disagree Disagree Undecided Agree Strongly Agree
    Do you think you took ownership of your learning during the last few weeks? Please explain.

21. Did you enjoy replacing lecture with class discussions

I enjoyed it and would like to continue using more class discussions
I enjoyed it but would rather we go back to Mr. Tisch lecturing
I don't feel strongly one way or another
I disliked it but saw the value in the new approach
I disliked it and hope we do not rely on class discussions any more

Please explain your answer to question 21.