THE IMPACT OF PROJECT-BASED LEARNING AND THE ENGINEERING DESIGN CYCLE ON HIGH SCHOOL PHYSICS STUDENTS

by

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ABSTRACT

Case studies indicate that embedding learning in meaningful context can attract and retain a broader range of students to STEM careers. This action research project assessed the impact of project-based-learning and engineering design on 22 high school physics students. Female students showed strongest growth. The biggest impact for all students was an increase in the belief that students are successful in science due to their effort.

INTRODUCTION AND BACKGROUND

Purpose and Background

My action research project studied the impact of a project-based learning (PBL) and collaborative engineering design on my physics students with a close look at the impact on my female students. I chose to focus on engineering design because engineering design is newly emphasized in my district and the Next Generation Science Standards (NGSS) (Next Generation Science Standards, 2014). Therefore I needed to learn how to most effectively integrate engineering design projects into my classroom, and my classroom has implications for integrating engineering design at the school, district and national levels.

The focus on gender is an important part of my reflective and reflexive practice. I was the top-performing student, male or female, in my high school physics class, and yet I never felt I had the hand's-on, intuitive grasp of the concepts that would confidently allow me to pursue a degree in physics or engineering. My experience is mirrored by female university physics students across the nation: while their grades and test scores match their male counterparts, they consistently under-perform their male counterparts on tests of conceptual understanding (Docktor & Heller, 2008). I wanted to know, at least in my classroom, if I could offer hand's-on challenges that would engage my female students and help to close the conceptual gap. On the national level, if we can find a more consistent path to attract and retain female students in Science, Technology, Engineering and Mathematics (STEM) fields, we can meet demands for technically trained workers and more women will have access to high paying technical jobs (U.S. Department of

Commerce, 2011).

Research Question

Students enrolled in high school physics courses have a variety of goals. As a female teacher of physics and action researcher, I investigated the goals that underlie my students' pursuit of physics. In addition, I investigated whether my treatments provided a collaborative, transformative educational experience that improved students' abilities and desires to conceptualize and do physics.

The primary question of my action research:

What is the impact for high school physics students if project-based learning and the engineering design cycle are utilized?

Subquestion 1: What is the impact on student attitudes?

Subquestion 2: What is the impact on future academic and career choices?

Subquestion 3: How is the impact dependent on gender?

Subquestion 4: What is impact on the teacher?

Support Team

I have 4 members on my support team. First, I asked a science teacher from my school who is also an Master of Science in Science Education (MSSE) student at Montana State University. I value his input both on content and pedagogy even though we have somewhat different teaching styles. Second, I have a student who is acting as my Teaching Assistant TA for physics this year. He has a strong background in science and psychology and is a member of our Future Educators Association. My husband provided

valuable editing for grammar and clarity. My assistant principal and a special education teacher who collaborates with me complete my team.

CONCEPTUAL FRAMEWORK

Theoretical Foundations

Situated cognitive theories of learning state that we not only need to be concerned about the knowledge that students develop but also about the context in which they develop the knowledge and how it impacts their identity as someone who does science (Brickhouse, 2001). Research in the United Kingdom suggests that it is more critical for female than male students to have learning that takes place both in a social setting that is supportive and also in a hands-on context that is meaningful to them. Female students, regardless of their academic success, are less likely to persist in physics and are less likely to feel self-efficacious (Hollins, M., Murphy, P., Ponchaud, B., & Whitelegg, 2006).

In the 1990's Sheila Tobias published a set of case studies that indicated students that were capable of pursuing science were not doing so because it was taught in a way that they did not find meaningful. She made a compelling case that science education at that time was only successful in creating scientists that felt science was inherently interesting and it was not designed to create scientists motivated by science's broader social implications (Tobias, 1990).

Nearly a century old, it is John Dewey's pragmatism that provides a way forward. Dewey is often used to support student-generated ideas or hands-on learning. It is important to understand that while Dewey's model of transformative learning includes

hands-on and student-centered learning, these elements are insufficient for transformative learning. Dewey's *Art as Experience* has been studied for its implications in the science classroom. Dewey describes a development of ideas through *anticipation;* anticipation shapes students' actions as they imagine what may or may not be and then leads to the development of new ideas and actions. The teacher cannot lay out a step-by-step transformative experience for students but can evoke one. The teacher can provide an environment where students unfold their own drama of ideas leading to action and leading to new ideas (Dewey, 1934 as cited by Wong & Pugh, 2001). In my AR, I needed to use a model of instruction that sets the stage for transformative learning.

Direction

Dewey's cyclic process of transformative education shares traits in common with the engineering design process. A guide produced by the National Science Foundation describes engineering design challenges as an ill-defined problem solved within a Project Based Learning (PBL) context. The nine-steps of the engineering design process asks students to define the problem, research the problem, develop solutions, select a solution, design a prototype, test and evaluate the solution, communicate the solution, and redesign. The redesign phase asks you to cycle back through the one or more of the prior steps. The guide discusses the importance of students following their ideas and being allowed to work through the process even when their original design will clearly, to the teacher, result in failure. They support the efficacy of the hands-on activity of the student not in creating a successful product the first time, but in transforming the thinking of the student. Even though the student is solving the problem the teacher has a critical role.

The teacher needs to ensure that the problem selected is one that intrigues students, that students have appropriate tools to choose from and that the teacher asks questions that ensure their solutions will be the result of sound mathematical and scientific reasoning (Householder & Hailey, 2012).

A study in Denmark addressed the impact of an interdisciplinary PBL curriculum on all students and particularly on female students. The researchers aggregated many international studies suggesting the benefits of PBL for all students. Among them, on the individual level are a deeper more critical understanding of science concepts, greater interdisciplinary skills, communication and collaboration skills and development of a professional identity. On an institutional level PBL lowers dropout rates and increases on-time completion of work. Most germane for my research were the study's findings on gender. They examined more than 10,000 engineering students at a Danish University over seven years and determined that a five-year curricular commitment to PBL had a more pronounced positive effect on the recruitment and retention of women (Du & Kolmos, 2009).

Methodology

To assess the impact of an engineering design challenge on students' understanding of concepts, the Force Concept Inventory (FCI) developed by David Hestenes has been used with defensible validity for many years (Hestenes & Halloun, 1995). The FCI had already been administered to more than 10,000 students in 1995 and the authors have developed values of expected growth in both traditional and interactive engagement courses. In an analysis of FCI results for over 6000 students, traditional instruction

correlated with FCI normalized gains of 0.23±0.04 while interactive engagement methods correlated with normalized gains of 0.48±0.14 (Hake, 1998). The FCI measures students' conceptual knowledge in Newtonian Physics. My first treatment covers Newton's Laws and my second treatment, the engineering design challenge, fits in the bridge between force concepts and energy concepts.

In alignment with the theories of situated cognition, it is important to measure shifts in student identity orientation toward physics through the engineering design challenge. In 1986, a group from the University of Michigan developed an 81-question instrument called the Motivated Strategies for Learning Questionnaire (MSLQ). In 1991 they published survey results for 380 Midwestern college students. In the report, they correlated students' responses on each question with the ability of that response to predict science course success. The subset of questions that had the greatest predictive correlation was the questions related to self-efficacy (Pintrich, P.R., Smith, D.A.F., Garcia, T., & McKeachie, W.J., 1991). The questions regarding self-efficacy were:

5. I believe I will receive an excellent grade in this class.

6. I'm certain I can understand the most difficult material presented in the readings for this course.

12. I'm confident I can understand the basic concepts taught in this course.

15. I'm confident I can understand the most complex material presented by the instructor in this course.

20. I'm confident I can do an excellent job on the assignments and tests in this course.

21. I expect to do well in this class.

29. I'm certain I can master the skills being taught in this class.

31. Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class (p. 14).

The study results show correlation and not causation; students may have feelings of self-efficacy due to a high level of skill, therefore they are successful because they are highly skilled not due to their feelings of effectiveness. However, the subset of questions suggests an avenue of research: if a teacher can increase students' feelings of self-efficacy through project-based learning, this may increase the probability of success in future science courses.

Other Considerations

Impact of Instructor Attributes: A female teacher of physics may be tempted to consider instructor gender and the possibility that having a female instructor may provide a role model that increases the performance of female students. Two reasons emerge that discourage such a research topic. First, the data doesn't support this outcome as studies suggest that having a female instructor reduces the performance of female students in math and science and their likelihood to take further STEM courses (Hoffman & Oreopoulos, 2007; Price, 2010). The negative correlation is strongest in biology and physics (Bettinger and Terry Long, 2005 as cited in Price, 2010). Secondly, instructor gender is an appropriate topic for policy research but not practical for teacher-initiated classroom research. Since instructor gender is not a variable that I can control, it is not useful to study this variable in relation to PBL. More instructive is the focus in Hollins, et al., 2006. Consider the following two findings,

> A major influence on students' attitudes to physics is the teacher-student relationship, particularly for girls. A positive attitude is associated with a supportive personal relationship… Students, particularly girls, value teaching approaches that give them responsibility for their learning, and the chance to make decisions and think for themselves (p. 16).

As a female teacher researcher, I *can* ask, "Through PBL and the engineering design process, am I forming the correct relationships and fostering independent decision making to increase student satisfaction with and achievement in physics for all students?"

Impact of Stereotype Threat: Research suggests that students will under-perform when they identify themselves with a group that is perceived as weak or underrepresented. The theory is that they fear that their performance will confirm the stereotype of their subgroup and anxiety leads to lower performance. (Smith & Hung, 2008) The practical implication for the teacher researcher in physics is that telling female students their performance, as females, is being studied could lower their achievement. It is important that my students have informed consent for data collection. However, for the data to be free of stereotype threat, it is inadvisable for me to disclose questions related to gender.

As a result of the literature review, I had confidence that my treatment has a strong probability of success with my population of physics students and with my subgroup of female physics students. Studies support contextualized PBL as a treatment that enhances student learning and student enjoyment of learning for all students and particularly female students. An engineering design challenge provides PBL that supports the Next Generation Science Standards focus on engineering. These practical findings are well

grounded in the theoretical work of Dewey and of situated cognition theorists. I had two possible instruments to measure my results and discovered two precautions: I should not focus on my gender as a factor but rather on the quality of relationship formation with my students and I should not reveal the gender sub-question to my students to avoid the risk of reducing their performance.

METHODOLOGY

Treatment

One of my treatments engaged my students in a two-week engineering design challenge to design and build a mini-parachute that maximized drop time and air resistance and minimized the kinetic energy on impact. An engineering design challenge provides students with a poorly defined problem so that they must do research both to define the problem and generate reasonable solutions. The engineering design process is a cycle that includes 9 steps (See figure 1).

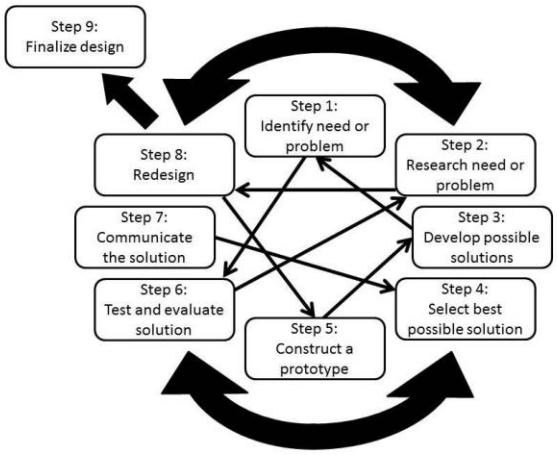


Figure 1. Engineering Design Cycle (Householder and Hailey, 2012, p. 11).

The engineering design challenge that I presented is a modification of a challenge presented in the supporting materials for my textbook (Serway, Faughn, & Holt, 2012). In step 1 of the process I present the challenge: using only the materials provided create a parachute that maximizes airtime for a specified drop. But the challenge doesn't define the problem and the constraints. Students needed to think realistically about the materials, masses, dimensions, drop zone, etc. so they can specify the constraints of their task. Step 2, research, is an important one for the teacher to foster. Originality and creativity are only valued as they are supported by research showing how others have completed similar tasks. Step 3, develop solutions and Step 4, select a solution, often run together: some students have a hard time generating many possible solutions. Often students tend to shortcut the brainstorming process, generate only one solution and rush to construction. Their failures have value but ultimately it is important to train students to research, reflect and select a solution that is most likely to succeed. Even if a design is very carefully selected, students may find that once they have a prototype that it is not successful. Students often discover that they did not fully understand the constraints and variables present in the situation. For example in the parachute design challenge some students found that they overvalued an open chute and surface area and undervalued balance and stability. As students test and evaluate their solution (Step 6), data collection becomes critical. Students need to record specifications and results and communicate them (Step 7) in a way that would be clear to an engineer engaged in a similar task but in a different location. Step 8, redesign, leads students back through the cycle if they haven't

cycled back earlier. After a few or many trips through the cycle, a design is finalized at Step 9.

The teacher has a critical role in motivating student interest in the challenge and ensuring that student solutions are well-documented results of solid scientific and mathematical problem solving rather than simply tinkering. I built in incentives for collaboration within and between groups to maximize student interdependence.

Google Apps provided an important technological structure for the project. Groups of three to four students collaborated on a common Google document that details each step of their implementation of the engineering design process. Students recorded all technical specifications and parachute prototype trial data in a Google spreadsheet.

Throughout the project I provided students with electronic comments that helped them refine their thinking and push it in mathematically and scientifically sound directions. I used intermittent formative assessments by asking students to complete Google forms. I used the results of the formative assessments (Appendix A) to provide whole class, small group and individual instructional activities to address student misconceptions or gaps in understanding. As a culminating activity, we had a competition drop where the winning parachute had the maximum average drop time. The competition data was analyzed on a common class-wide Google spreadsheet that helped students evaluate the success of their solution when compared to the solutions of other groups.

The engineering design challenge was an opportunity for students to integrate many previously covered topics such as introductory topics of precision and measurement, kinematic topics like position, velocity and acceleration, and force concepts including

free-body diagrams, net forces, and air resistance. The challenge served as an introduction to the concepts of potential energy, kinetic energy and work. Students also had the opportunity to grapple with advanced topics such as turbulence, stability and aerodynamics that are beyond the scope of the course.

Prior to the engineering design challenge in December, I used a smaller free-body diagram project in late November/early December to help introduce the engineering design cycle and project-based learning. Students became familiar with the engineering design cycle while selecting a topic for and executing a photo/video project on force vectors. I used a very similar rubric to assess both projects (Appendix B and Appendix C) so that students are familiar with the format. I will refer to the free-body diagram project as treatment 1 and the engineering design challenge as treatment 2 in my data analysis.

Treatment 1, the free-body project took place primarily outside of class. The project was launched during one class period with some time for students to brainstorm in small groups. In each class during treatment 1, some reference to the project was woven in: Some days we only discussed how the days topic, for example why inertia is not a force or net force and acceleration vectors, fit the context of their projects. Other days we did formative assessments to check their progress and introduce the engineering design process. During treatment 2, each class started with a warm-up, brief instruction to help support the documentation or data analysis for their projects, and then the rest of the class time was devoted to project work time with small groups of students researching, discussing measuring, constructing and testing. Students had free access to materials to build and measure, and I circulated to monitor group interactions and to ask questions to

push their scientific thinking. During the second project, I commented their online work daily outside of class to set targets for what should be completed during the next class and to remind them of deadlines.

Instruments

Table 1 summarizes my data collection methodologies.

Table 1
Data Collection Methodologies

	Interviews	Surveys	Student engagement tally sheets	Student Work Samples	Formative Assessment - CAT's	Force Concept Inventory (FCI)	Teacher -made tests	Teacher Journal
What is the impact for high school physics students if project-based learning and the engineering design cycle are utilized?			✓	✓	✓	✓	✓	✓
Subquestion 1: What is the impact on student attitudes	✓	✓	✓					✓
Subquestion 2: What is the impact on future academic and career choices	✓	✓	✓					
Subquestion 3: How is the impact dependent on gender?	✓	✓	✓	✓	✓	✓	✓	✓
Subquestion 4: What is impact on the teacher?								✓

The conceptual impact for all students and especially female students will be measured by four methods. I used the Force Concept Inventory (FCI) prior to the project in Early October and after the completion of the project and a unit on Circular Motion in February as one measure of student conceptual growth. My goal was to see if there is a

reduction in any gap between male and female students. Formative assessments, Pre- and Post-Treatment Chapter Tests and student work samples helped correlate the growth to the engineering design challenge. Student interviews and surveys brought this quantitative data to life: they helped me understand to what students attribute their conceptual growth.

Teacher-made tests provided a data point to support or contrast with the FCI. My experience last year was that male students outperformed female students on the FCI but not unit tests so I wanted to see if improvements on the FCI correlate with improvements on unit tests.

The impact on students' attitudes and future academic and career considerations were measured for all students through surveys (Appendix D) and in-depth for a sample of students through interviews (Appendix E). My survey and interview both were focused on subquestion 1: What is the impact on student attitudes? and subquestion 2: What is the impact on future academic and career choices? I disaggregated the data to help me answer subquestion 3: How is the impact dependent on gender?

Before I could assess impact I needed a baseline. Both the survey and the interview addressed the same subquestion; however my survey addressed the question quantitatively and my interviews were in depth with a sample of students. I felt that an interview was more appropriate for my questions regarding past science experiences at school and with family and friends.

I surveyed one class comprising all 22 of my physics students. Table 2 shows a demographic breakdown of my students.

Table 2
Demographic Information, N = 22

Gender	Juniors	Seniors	Minority	SPED	Home language not English	ELL
Male -15	10	5	4	1	4	1
Female - 7	5	2	0	0	0	0

I teach physics to a mix of American and International 10th, 11th and 12 grade students at Naples Middle High School in Southern Italy. Students come from public and private schools in the United States and throughout the world. 18% of my students have a home language other than English. Most students only attend our schools for 3 years.

Due to the small sample of female students, I predicted that I would need to see a numerically large difference in their averages on attitudes and career plans to show significant difference between genders or significant growth for my female students. Each of my sections of Likert items has four questions. This provided me with 88 data points for each student on future academic and career considerations and 88 data points on confidence toward doing science. I calculated a mean and standard deviation for both my pre- and post-treatment survey. I did a paired difference test to see if my students, and the subgroup of female students, responded more positively after the treatment.

The data was initially stored on my school Google Drive, but after students took the survey, I transferred the data to my personal and school computer and delete the copy that was on my Google drive.

I interviewed a sample of ten students, five female and five male students. While female students are approximately one-third of my physics class, the disproportionate sample of female students provided greater insight to answer my subquestion on gender. I used a random number generator to select five students of each gender to interview. In

addition I selected an English language learner, as this subgroup is always a small subgroup in my physics class with different needs and learning outcomes.

My post-treatment survey included all of the questions from my pre-treatment survey as well as a variety of questions about the conceptual and practical impact of the treatments. In addition, I sought feedback about other non-treatment aspects of the physics course. It also included open-ended questions asking students to comment on each treatment and to suggest changes to the course.

Validity and reliability were addressed as all of the paired questions on my pre-and post survey were tested by my peers in my MSSE course and edited after suggestions from my project advisor. My pre-treatment interview questions were piloted with my physics students in 2013-14 while my post-treatment interview questions were tailored to probe for information based on students' post-treatment scores and survey response.

I applied for and received an exemption for my research from the Institutional Review Board for the Protection of Human Subjects at Montana State University (Appendix F). My data was collected from October of 2014 until March of 2015.

Timelines

Most of my data was collected in November and December during the two treatments. Table 3 below shows how data collection was spread through the first semester.

Table 3
Data Collection Timeline

Interviews	November and January. Pre-project and post-Project.
Surveys	October and January.
Student engagement tally sheets	During the project in December for two class periods.
Student Work Samples	During the treatments in November and December.
Formative Assessment -CAT's	Once in November. Weekly to biweekly in December.
Force Concept Inventory (FCI)	October and March. Pre-Test and post-Test.
Teacher-made tests	October, November and January.
Teacher Journal	3-5 times per week in November and December.

Table 4 shows a timeline for the support from my team.

Table 4
Support team timeline

Item for Critique	Deadline	Format
Research questions and treatment	October 1	by e-mail/face-to-face
Survey/interview questions checked for clarity and bias	October 15	e-mail
Review of formative assessments and data collection procedures	November 7	face-to-face
Review of formative assessments and data collection procedures	December 1	face-to-face
Mid-treatment meeting	December 8	face-to-face
Data Review	March 1	e-mail/face-to-face
Capstone First Reading	March 15	e-mail/face-to-face

DATA AND ANALYSIS

For subquestions 2 and 3 I looked at the impact of treatments on students attitudes and their future career and academic considerations. For survey data, I calculated a mean for each item by converting my Strongly Agree/Strongly Disagree scale to 5 to 1.

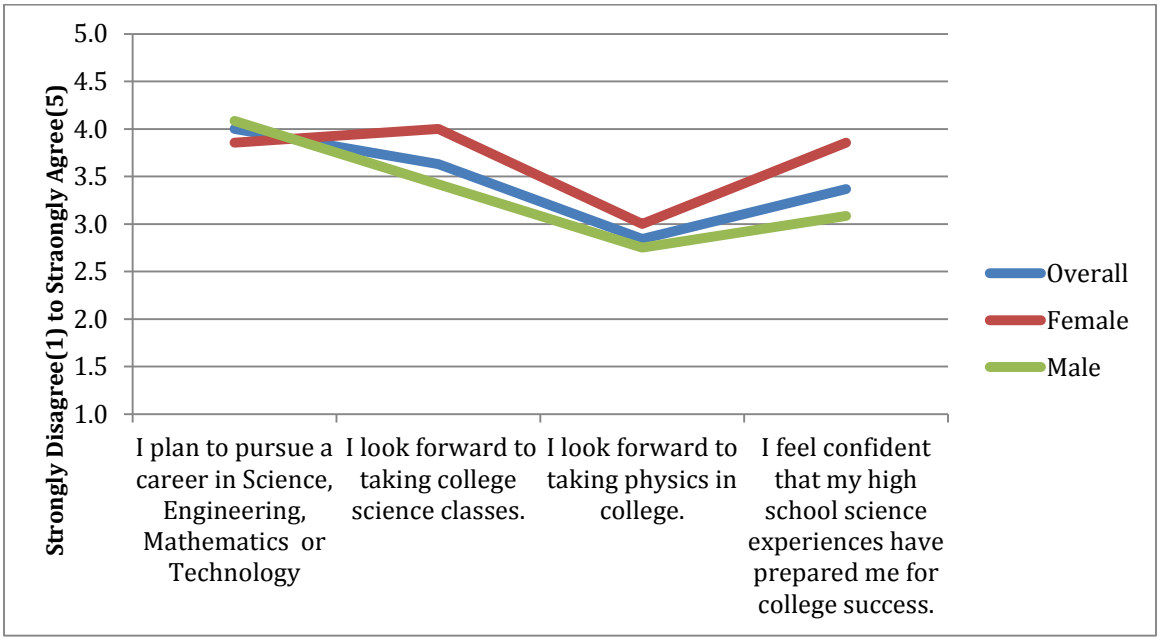


Figure 2. Stem eagerness, (*N* = 21).

In October, my students generally felt good about their science preparation and the majority of them planned to pursue a STEM career. However, eagerness to take physics in college was the weakest data point. Post-Treatment I examined the distribution of responses to the statement; " I look forward to taking physics in college."

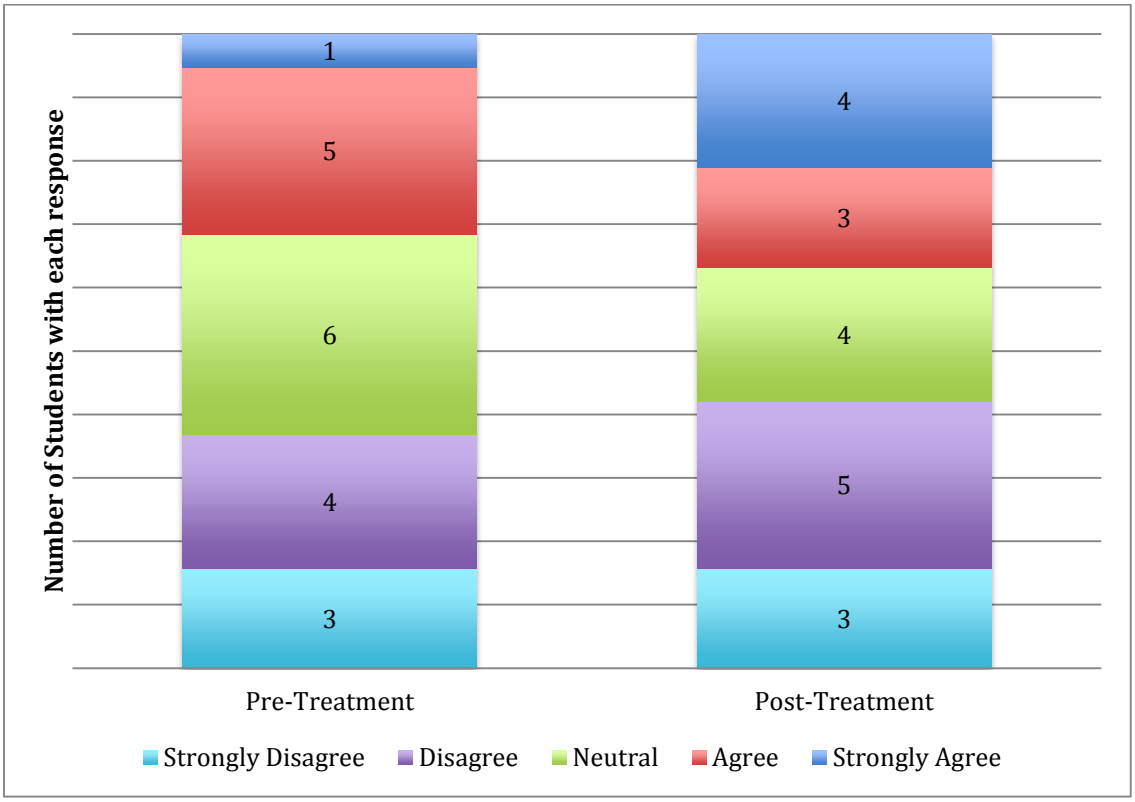


Figure 3. "I look forward to taking physics in college", *(N* = 19).

I found that the distribution of responses changed with more students strongly agreeing and an additional student disagreeing while the average increased only slightly from a mean of 2.9 to 3.1 and this increase was not statistically significant, $t(34) = 0.402$, $p < .35$.

When I examined the pre-treatment survey data, I found one notable difference in attitudes with regard to gender (figure 4).

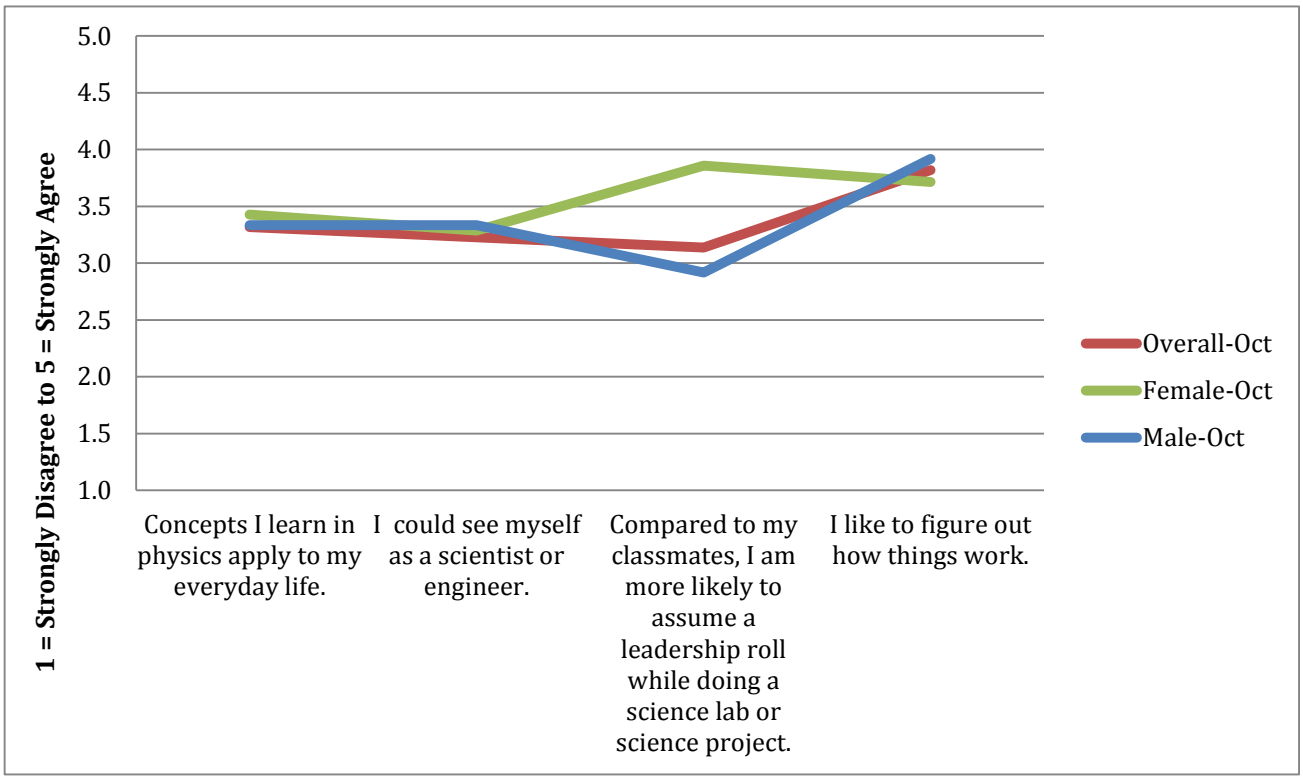


Figure 4. Scientific confidence, (N = 21).

In October, my male and female students rated themselves nearly identically in all areas of scientific confidence except the likelihood that they would take a leadership role in a lab or project. Here I was surprised to discover that my female students rated themselves higher. I performed a t-test for difference of means and found this difference to be significant, $t(20) = 1.85$, $p < .040$. I needed to think about what this meant for my engineering design treatment. I had hypothesized that an engineering design challenge would provide more engagement for my female students, but from my students' perception data my female students are more likely to jump in and take leadership in

traditional labs. This matched my observations of the female students in this year's physics class.

In general, when comparing the distribution of students' eagerness to pursue science and scientific confidence, figure 5, I saw a change similar to that seen in eagerness to take college physics; a slight shift upward with no significant change in mean.

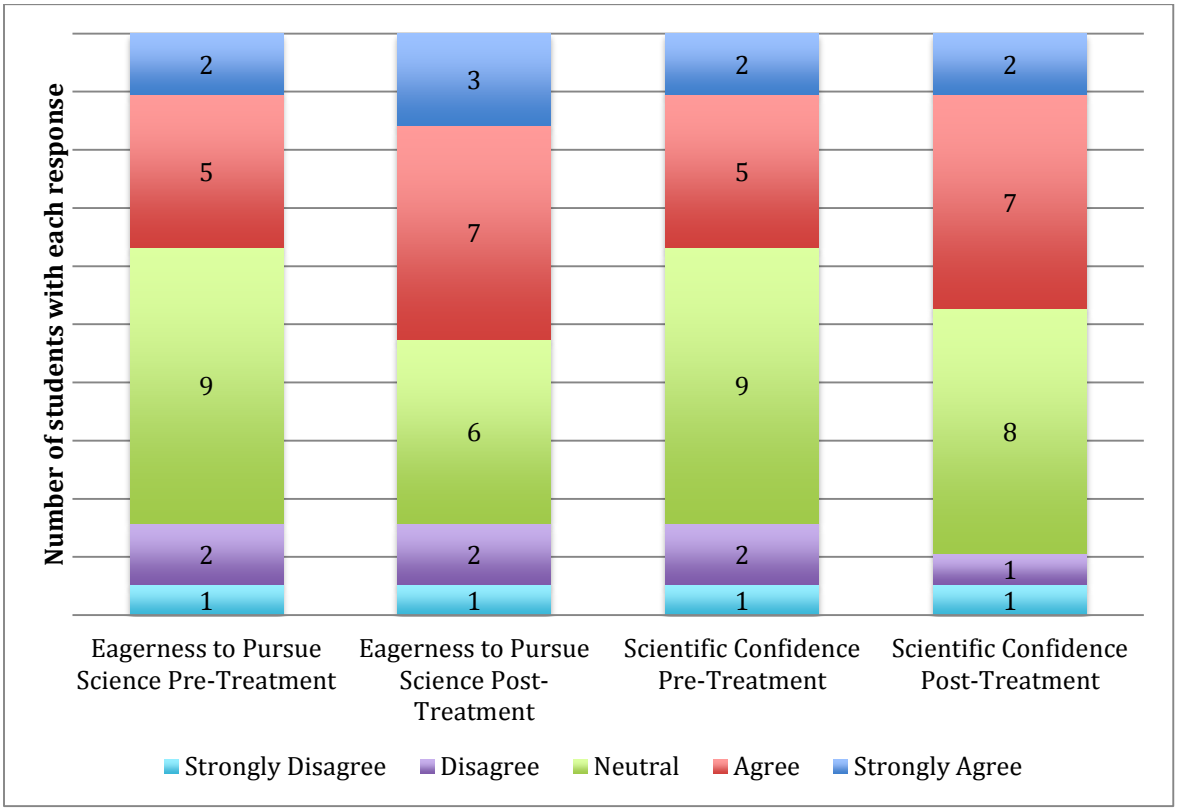


Figure 5. Science attitudes pre- and post-treatment, (*N* =19).

I did not see a major change in the distribution of students future career plans pre- and post-treatment as shown in figure 6. Two male students who have been less successful in class removed STEM career choices from their post-treatment responses in favor of a military career choice. However, I did have two male students who showed significant change in career plans post treatment. Both had unknown career plans pre-treatment.

Post-treatment one student listed plans to be an engineer and the other listed plans to work in the space industry.

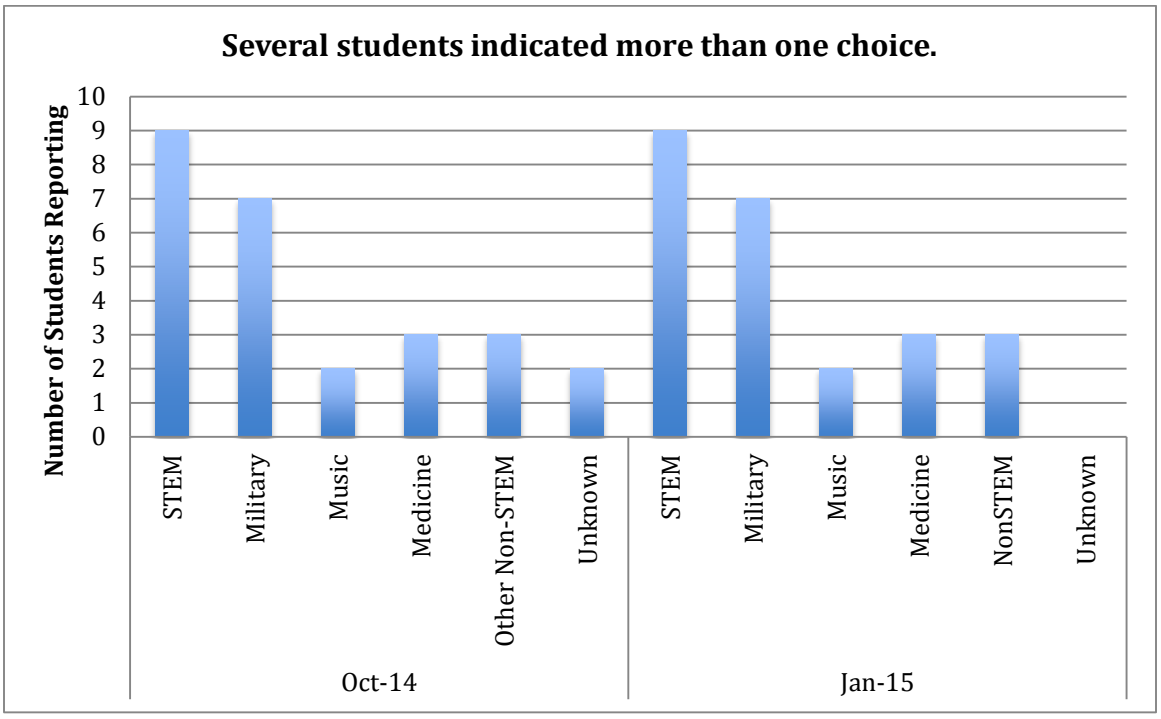


Figure 6. Future career plans, (N = 18).

The junior student who listed plans to pursue a space career was in my interview sample. He attributed the change to his experience in physics this year. His eagerness to take future physics courses increased from neutral to strongly agree over the course of treatment. He responded positively to the first treatment stating that even though he struggled with the project at the time, the free-body diagrams were the most important concept he had learned in the course thus far. He also achieved a perfect score on a conceptual formative assessment just following treatment.

His response to the second treatment was mixed. He stated that the he gained confidence during this treatment because his group had the winning design but that he had felt confused by the data analysis portion at the time. Interestingly, he stated that

during a third post-treatment project-based learning assessment he finally mastered data analysis with a spreadsheet.

On the pre- and post-treatment I asked my students to state their agreement with the statements, “Students are successful in science due to their talent.” and “Students are successful in science due to their effort.” The average response to the talent statement was neutral with no significant change in student response over the course of the treatments, $t(32) = 0.160$, $p < .44$. Prior to treatment the female students had a more uniform agreement, ($M = 4.1$, $SD = 0.38$), to the statement, “Students are successful in science due to their effort,” than did the male students, ($M = 3.8$, $SD = 1.15$). Also there was a significant change over the course of the treatments in students response to the effort statement with students shifting from agreement to strong agreement, $t(32) = 2.11$, $p < .022$. During the course of treatment my physics students had a significant shift toward belief that effort is what makes you successful in science. Research suggests that shifting students mindsets from a belief in fixed talent to a belief in ability to grow can have a significant impact on achievement (Dweck, 2006).

To measure conceptual growth pre-treatment to post-treatment, I analyzed student growth on the FCI, figures 7 and 8, and students grades on chapter tests pre- and post-treatment, figure 9.

Figure 7. FCI Average score, (*N* = 20).

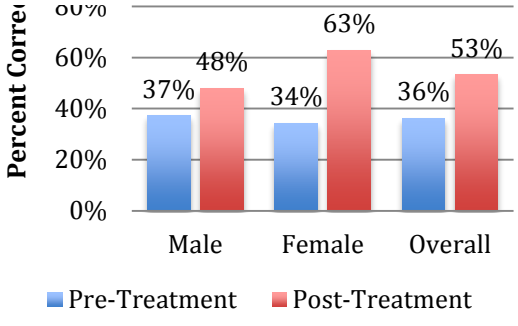
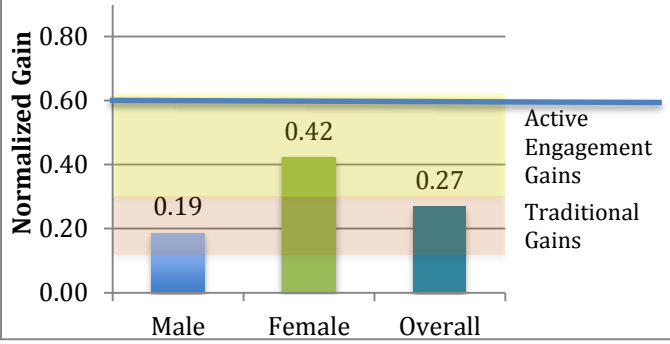


Figure 8. FCI Normalized gain, (N = 20).



The difference between genders on the FCI was striking; prior to treatment the male students out-performed the female students. After treatment the female students outperformed the male students. Also the female students had a normalized gain score of 0.42. Female gains are consistent with the gains found in studies of active engagement, 0.48 ± 0.14. In contrast the male students had normalized gain scores of 0.19. This is consistent with the gains expected in traditional lecture based courses, 0.23 ± 0.04.

The results in figure 9 of the pre- and post-scores on chapter tests showed this same relationship.

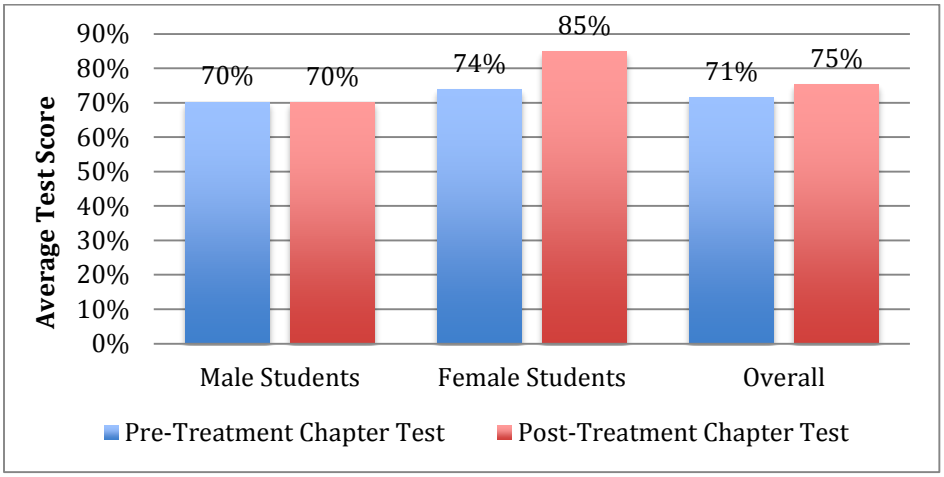


Figure 9. Average scores on chapter tests, (*N* = 21).

The female students gained 11% while the male students showed no gain. I asked myself: if my female students improved their scores during the course of treatment, does this improvement correlate to their eagerness to pursue physics? It seems that for my female students, the combination of belief that effort results in success and a contextualized hands-on learning environment led to a paired growth in conceptual understanding and eagerness to pursue physics.

In figures 10, 11, 12, and 13, I explored the correlation between conceptual gain and eagerness to pursue physics. First, I considered the correlation between academic success and eagerness to take physics pre-treatment.

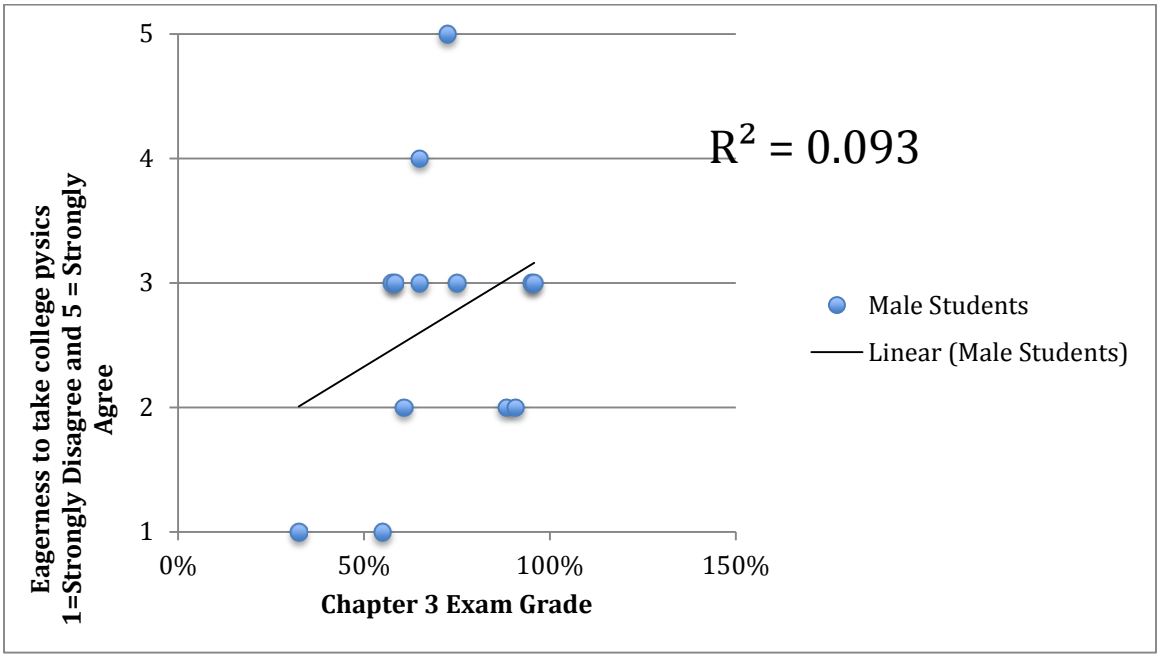


Figure 10. Pre-Treatment correlation exam grades and eagerness to take college physics, (n = 13).

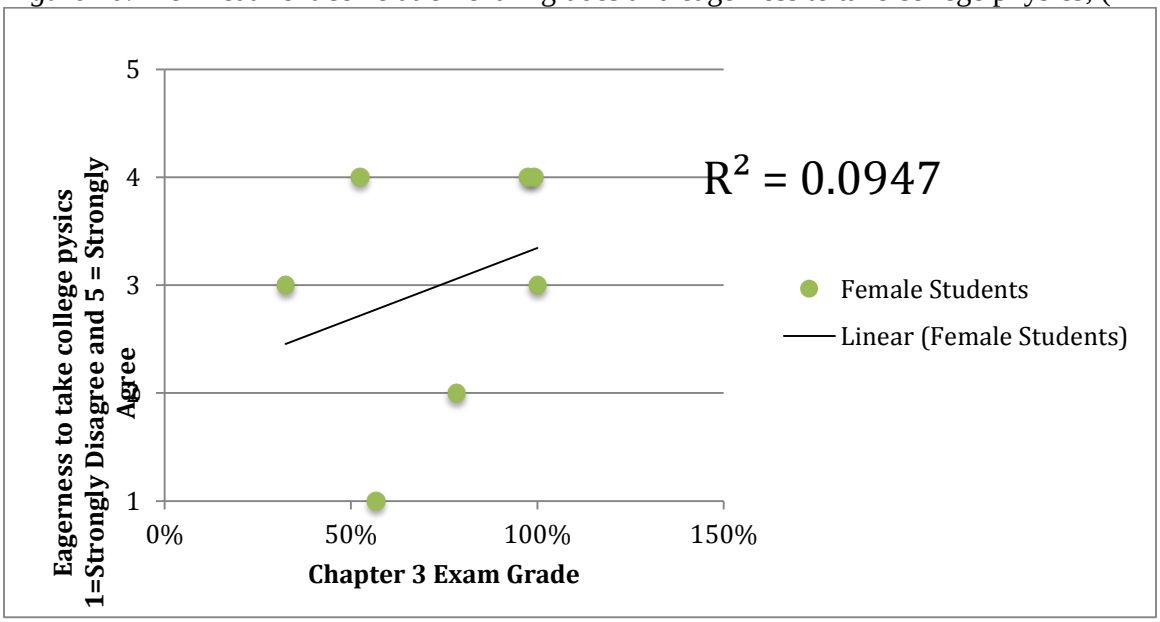


Figure 11. Pre-Treatment correlation exam grades and eagerness to take college physics, (n =7).

Prior to treatment, both male and female students showed no correlation between their exam grades and their eagerness to take college physics.

Post-treatment, however, male students continued to have a low correlation, while female students eagerness to take physics in college was highly correlated to their classroom success.

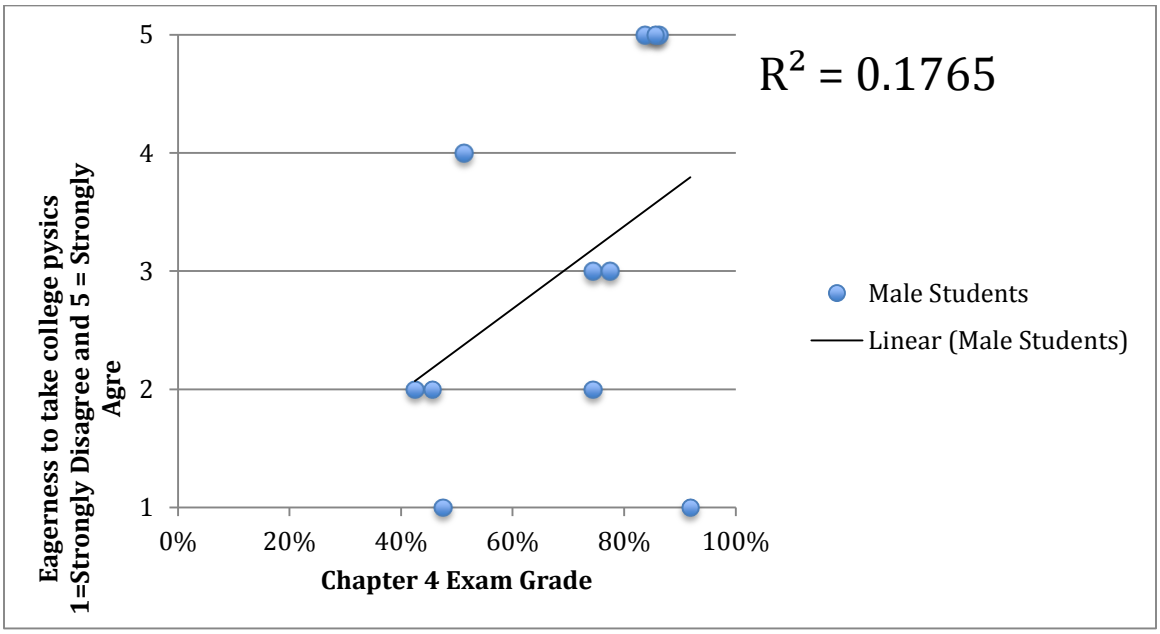


Figure 12. Post-Treatment correlation exam grades and eagerness to take college physics, (n = 13).

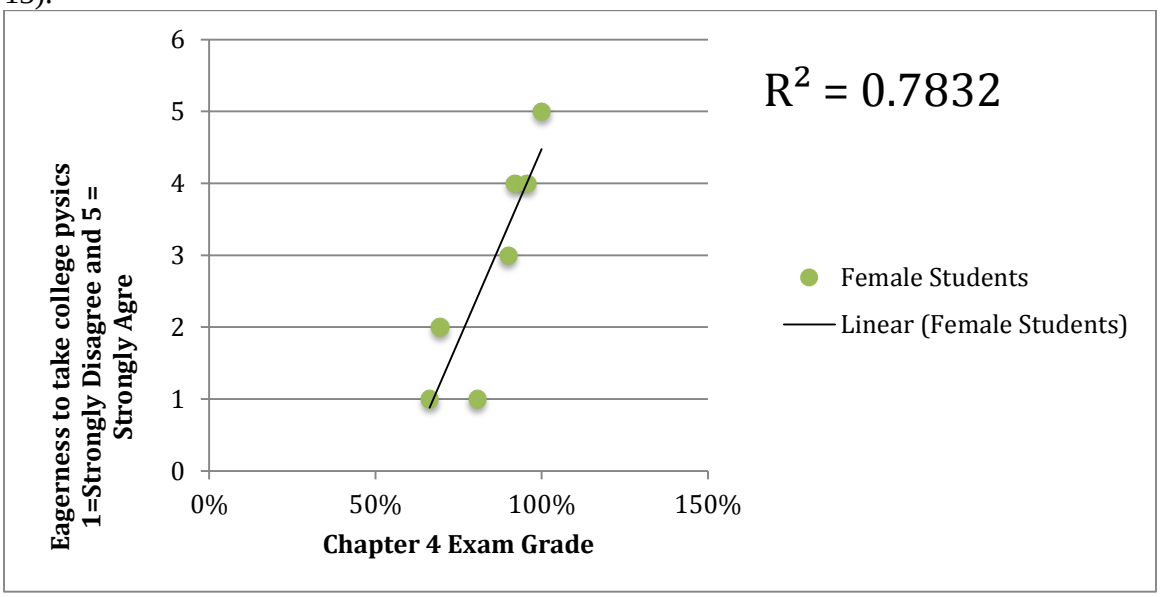


Figure 13. Post-Treatment correlation exam grades and eagerness to take college physics, (n =7).

In figure 14, my analysis of the correlation between eagerness to take physics and normalized gain on the FCI echoed the results of my classroom assessment.

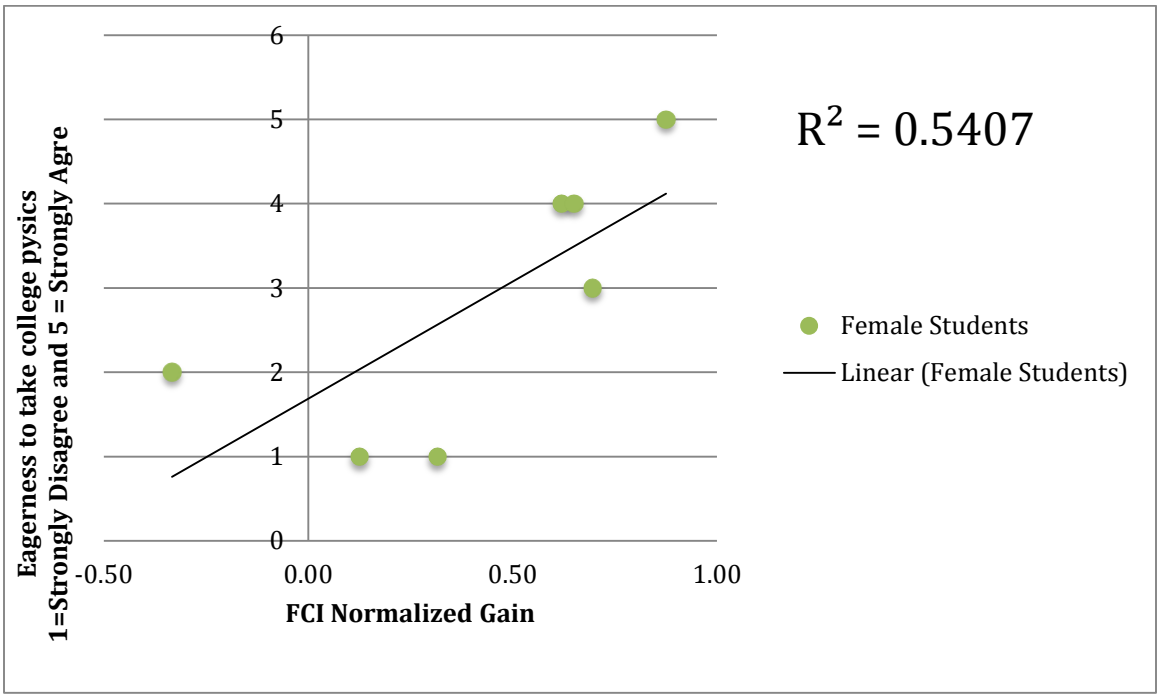


Figure 14. Post-Treatment correlation FCI gain and eagerness to take college physics, (n =7).

In general my data indicates that for my female students as they gain conceptual knowledge, this knowledge translates into eagerness to pursue physics in college while no correlation is found for my male students. What remains to be shown is whether or not my treatment is a co-factor in the correlation. To explore this correlation more deeply, I looked at my interview and survey data for my female students.

First it is worth remembering that my female students, as seen in figure 4, state that they are significantly more likely to take the lead in science projects or experiments; reporting on average that they agree versus my male students who give a neutral response on average. It is possible that the leadership and active role for this particular group of

female students improves their performance in general as they are more actively engaged at all times not just during the project-based learning treatments.

Of note and strengthening the correlation, the female student who showed the least growth in eagerness to take college physics, and was my only student to show a decrease in her FCI score, was also my student least engaged in both treatments. In each project she had complaints from a partner that she was not contributing significantly and in the second treatment participation log completed by myself and my assistant principal, I recorded that she spent less in class and out of class time engaged in hands-on building, research and collaboration.

Two female junior students in my interview sample had an increase in their eagerness to pursue college physics and high FCI normalized gains of 0.87 and 0.65. They gave very different reasons for their gain in confidence and conceptual knowledge. One student credited her improvement to virtual labs and activities pulled from physics classroom.com (Henderson, 2015). She was fairly indifferent to the projects citing frustrations with having to work with others and that she didn't like that the numbers were less easy to work with than the number on exams. The other credited her improvement to hands-on activities in general, "I just found that this class is really fun and the concepts do apply to real-life," and also to the relationship that she had built with her instructor. She stated, "Your teaching: you explain things in a way I can understand. …I am confident that I can succeed in projects because I have had you before and I know what to expect."

The theme of instructor relationship recurred throughout my interviews without regard for gender. A junior boy whose confidence and conceptual understanding have both grown stated, “part of the reason is definitely having a teacher who if you have a question, they don’t treat you like you are slacking off and not paying attention for not knowing –just a generally positive environment.” Of the students in my interview sample who showed high growth, all but one mentioned having an instructor who is willing to help as an important factor in their confidence.

Both of my treatments involved project-based learning and were opened ended but they also differed in some significant ways. The first treatment, the free-body project, took significantly less class time and allowed students to make a very personal choice of activity and of group or individual completion. The second treatment, the STEM parachute project happened almost completely in class, although all but two students spent at least 2 hours in my classroom working on their parachutes outside of class time. Figure 15 compares students’ feelings about the two projects.

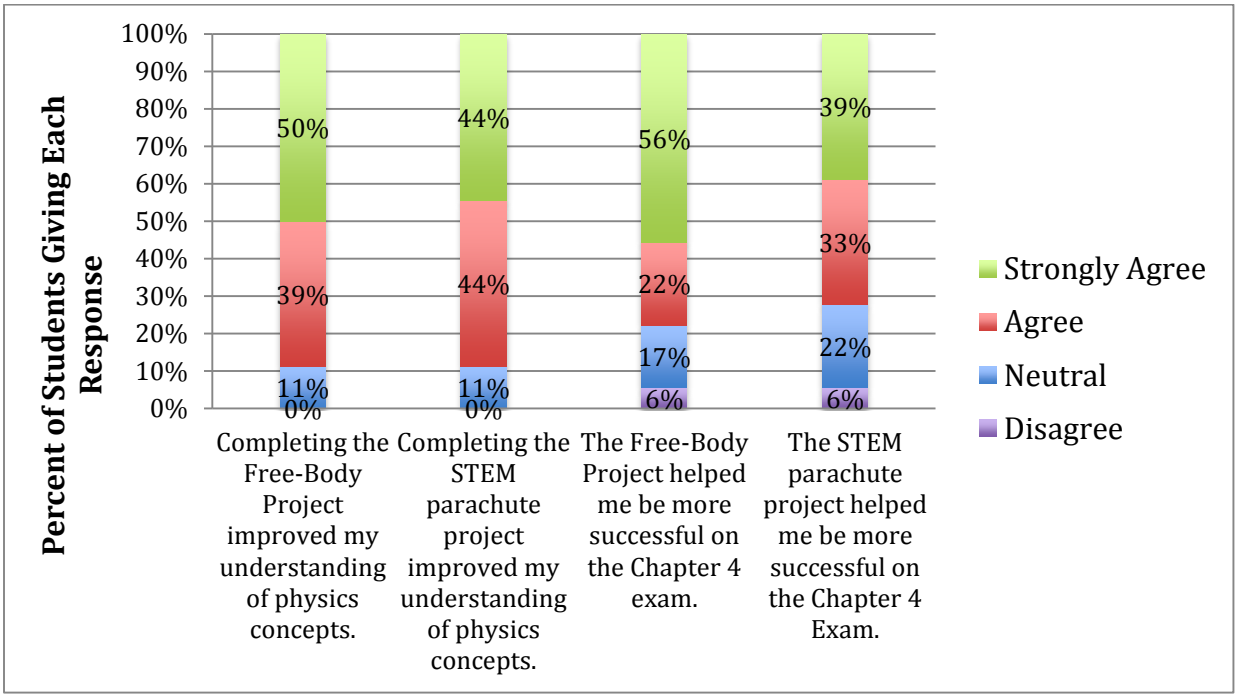


Figure 15. Comparison of impacts, Treatment 1 and Treatment 2, (N = 18).

Students felt strongly that both projects helped improve their conceptual understanding and test grades. However, students felt more strongly about the impact of the first treatment than the second. I asked students to reflect, "How did you feel about completing the free-body project to assess your understanding of forces? Would you prefer a test? Explain." All but two of the students stated that they strongly preferred the project to a test. This was true for students of all achievement levels: A Senior girl who earned an F on the Chapter 3 Exam stated, "I liked the project so much more. This was hands-on and made me work for my answer not just telling me I got it wrong and getting a bad grade I could make sure everything was perfect."

A junior boy who earned a high A on the Chapter 3 test stated, "Not only did I greatly enjoy the project, but I feel as if it has assessed and furthered my knowledge more so than a single assignment in science has ever before. I would certainty not prefer a test, because

there is no opportunity to learn and grow during test. Also, in a test there is no way to put in extra time to make it spectacular or to add creativity. The lab was great!"

A few students noted that even though they felt the project was preferable they would like a test on the material as well because they felt that the project did not ask them to apply their mathematical skills; this is a concern I shared and ultimately lead to my decision to give a chapter 4 exam.

In my interviews, all but a female junior stated that the free-body project improved their conceptual understanding and confidence. Student response on the STEM parachute project was more mixed. For most of them this was a first exposure to the engineering design process and they were surprised by how much time it took to come up with and build a design, how often they needed to rebuild and how careful they had to be if they wanted to improve their time. One senior girl commented, "I think that maybe I am confident that I could do better if I tried again but my design didn't make me very confident." A top achieving junior student stated, "My confidence dropped and rose because we went through several failed prototypes before we got one that actually succeeded but once we got one to succeed it helped a lot conceptually."

Each day I rated in my journal how successful the class was in building student confidence. My rating of the classes during each treatment also showed less gain in confidence during the second treatment. During the first treatment, I rated the classes as 4.5 (out of 5) in terms of success in building confidence. During the second treatment, I rated the classes at a 4.2 in terms of success in building confidence. Most notably, I rated my success in building confidence at a 3 the night before the launch: "I am exhausted. I

had all but two female students from different groups come to seminar to work on their projects today. They were doing mostly building, testing and small modifications. The atmosphere was supportive but also somewhat tense as only small improvements are still to be made and a few groups made adjustments that made their time worse. One group of all female students tested 45 times in total--focusing in on their consistent drop technique. Three groups continued testing 45 minutes after school ended with an additional group testing and modifying for 1.5 hours."

My journal reflected my agreement with students that the second treatment would have less effect on the Chapter 4 test: "Even though balanced forces was a part of the project - I think that what students learned was much more about the air pressure, stability surface area, mass and ratios, design, data collection and documentation than about forces. I was hoping for some discussion of string tension forces and chute inflation in terms of Newton's Third but I did not find this."

My journal had 17 entries: three entries prior to the first treatment, seven entries during the first treatment and six entries during the second treatment. I looked in my journal at the type of student-teacher interactions before and during each treatment in figure 16. The conceptual and grade interactions are not the normal interactions that occur about concepts during physics class; they are interactions that are initiated by students outside of class time.

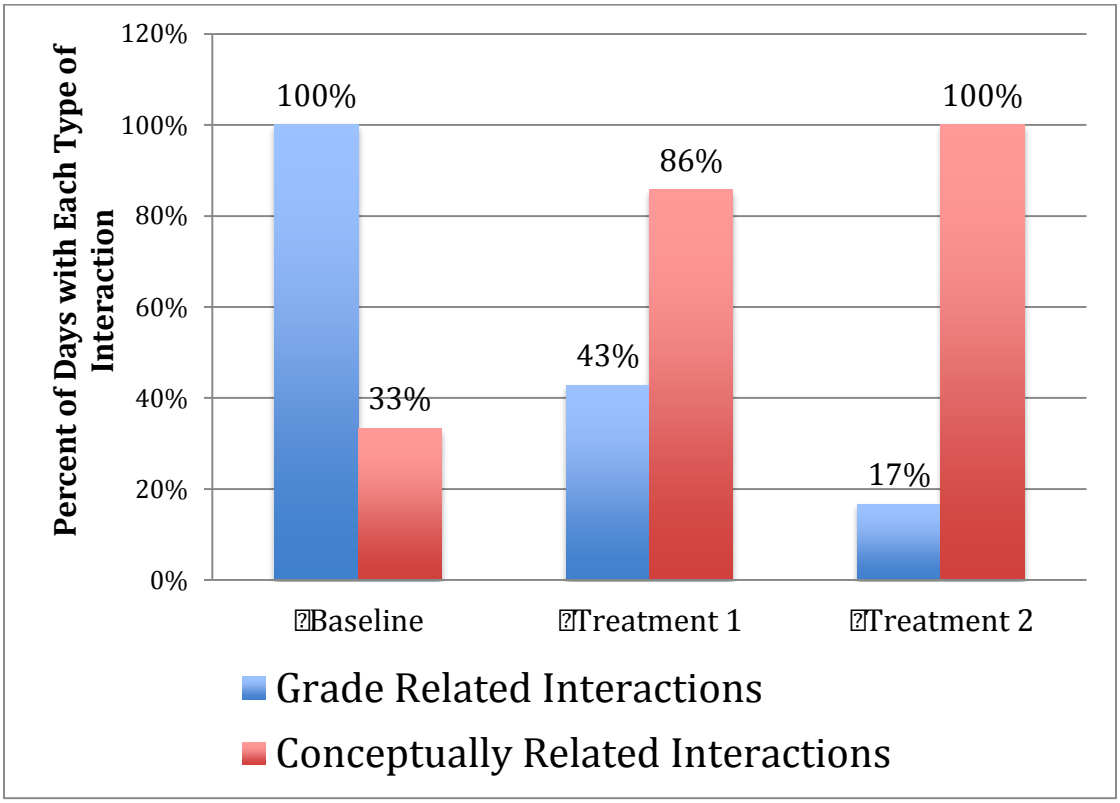


Figure 16. Student initiated interactions with teacher, pre- and during treatment.

On each day prior to the project, I had interactions about grades. I had one conceptual interaction one day prior to the project. However this was with a girl who cried because she thought that she had understood everything for the test but had not understood how to do the last problem on the test. She got all the other answers on the test correct but was focused on what she didn't understand.

On six of the seven days during the first treatment, students approached me in the hall or after school to discuss their projects. I also noted increased student to student interaction about physics during the project; on December 3, I wrote, "I had two students arguing intensely about the applied force for their project and whether it was sustained after the push off. I hope this level of involvement leads students to sustain their knowledge of forces."

During the second treatment, the student-initiated interactions were multiple and daily. Students were very invested in making the best parachute and winning and I had to be careful to not give any group too much advice. One group was so focused on rebuilding for a winning parachute that they failed to focus beyond the design to document their research and analyze their data. It is interesting that this group of three male students had a very low average FCI normalized gain of 0.06 and an average score of 46% on my post-treatment chapter test.

INTERPRETATION AND CONCLUSION

My data suggests that project-based learning and the engineering design project had a measurable impact on my students, me as a teacher and our classroom environment. Subquestion 1 asked, " What is the impact on student attitudes?" The most notable change in student attitudes was the increase in students' belief that they are successful due to their effort. As seen in figure 15, more than 75% of students agreed or strongly agreed that each treatment had improved their conceptual understanding and successfully prepared them for the traditional assessment. It is worth noting, however that students felt more confident about the conceptual preparation from treatment 1 than from treatment 2. I think that this is because the open-ended nature of treatment 2 functioned as more of an eye-opening exposure to the engineering design process that students were more likely to describe as challenging and fun than confidence building. One senior boy who plans to study aeronautical engineering stated, "I really enjoyed this experience and believe that all physics students should partake in an experiment like this." My teacher journal data similarly described the impact of treatment 2 as more difficult to measure as

students engaged many topics that were beyond the scope of the course and not always the concepts that I envisioned.

Subquestion 2 asked, "What is the impact on future academic and career choices?" While my students in general had slightly more positive attitude toward science in their future academic and career choices post-treatment, the changes were not statistically significant. In part this is because 75% of my sample had planned to pursue a STEM career prior to the treatment. This compares to 20% of American High School students who choose to pursue a STEM career (STEM Education Statistics, 2014).

Subquestion 3 asked, "How is the impact dependent on gender?" The conceptual growth of my female students was the most striking finding of my action research. My female students, as seen in figure 9, started out with an average below that of my male students and ended with an average FCI score significantly above that of my male students. Also for my female students, but not my male students, conceptual achievement correlated with eagerness to pursue physics in their future. I am cautious, however, about attributing this impact to gender. As seen in my data, this particular small sample of 7 female students is also more likely to believe success is due to effort and more likely to take leadership in labs and projects. The findings are consistent however with the research that states that female students are more likely to pursue science in their future that they find contextually engaging (Tobias, 1990; Hollins, et al., 2006).

By far the biggest answer to subquestion 4, "What is impact on the teacher?" was on the context in which I relate to my students. My interview sample consistently noted that a positive relationship with me, their teacher had a strong impact on their success. At the

same time, most but not all students described the hands-on activities as most responsible for increasing their confidence in their ability to do physics.

As I noted in my teacher journal, figure 16, the quality and quantity of student interactions changed during the treatment period. Prior to treatment, my interactions outside of class were primarily with struggling students in a cycle of reteaching and retesting. Our interactions had contexts created by the textbook or me. During the treatment cycle, I had interactions outside of class with students across achievement levels and around a context of their choosing. Not only did the percent of interactions that were conceptually rather than grade related triple, the actual number of interactions greatly increased. These interactions gave my students a more favorable impression of me and they also allowed me to better know my students and differentiate for their interests.

While students attributed their learning to their positive relationship with their instructor, I do not think that this relationship would be as readily forged without respectful, student-initiated contexts created by the project-based learning and engineering design cycle.

VALUES

The success of project-based learning in improving students attitudes and improving the conceptual understanding of my female students in particular will lead me to include a further embrace of project-based-learning to improve understanding and engagement throughout the year. I also hope to share the model with my department and district as we move forward in the implementation of the Engineering Design Cycle in the NGSS. I

would like to include an additional engineering design challenge so I can assess if students approach a new open-ended challenge with more confidence and sophistication.

The growth of my female students as measured by the FCI warrants further research. The findings that my female students not only experienced more growth, but actually surpassed their male peers is striking as it contrasts with research. A study of over 5500 students at the University of Minnesota shows that even given context rich instruction, male students outperform female students by 13.4% in post-tests (Docktor and Heller, 2008). I will continue to disaggregate student growth by gender next year to see if the findings are consistent.

Because the most significant change in attitudes was an increase in the belief that students are successful in science due to their effort, I plan to survey my students at the beginning of the year about the growth versus fixed talent mindset. I would like to research ways to increase the growth mindset for all my students even earlier in the year.

For me as an educator, my engagement with situated cognition has had the most impact on me. I have come to value how students contextualize and feel about what they learn as much as what they learn. This is a significant shift in my role as a teacher. I will continue to explore how I can embed more student generated contexts into my math and physics classes to help my students think of themselves as mathematicians and scientists. Project-based learning and engineering design challenges function not as fun add-ons to entertain students but as the foundation of helping students build a solid situated, conceptual knowledge of physics.

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APPENDICES

APPENDIX A

FREE-BODY FORMATIVE ASSESSMENT AND SURVEY

Free-Body Pre-Assessment

* Required

Name: *

What is your name? (Last, First)

Chapter 4 Project Progress *

Which best describes your progress on the Chapter 4 Free-Body Project?

Time Commitment *

Estimate how much additional time you will need to complete your free-body project.

	1	2	3	4	5	6	7	8	9	10	
1 hour	○	○	○	○	○	○	○	○	○	○	10 or more hours

Time Commitment *

Estimate how much time you have spent on your free-body project.

1	2	3	4	5	6	7	8	9	10

Learning Style *

I learn best by(choose only one)

- Listening to an explanation
- Watching or seeing a diagram
- Doing something hands-on
- Doing mathematical calculations or formulas

Comments *

How did you feel about completing the free-body project to assess your understanding of forces? Would you prefer a test? Explain.

Types of Force *

A boy is standing on a slide moving right and down on a slide that makes a 35 degree angle with the horizontal. He is accelerating -speeding up. List each type of force that applies.

- Spring
- Tension
- Normal
- Friction
- Magnetic
- Gravity
- Applied

Net Force*

A boy is standing on a slide moving right and down on a slide that makes a 35 degree angle with the horizontal. He is accelerating-speeding up. What is the net force?

- More than zero
- Zero
- There is not enough information to tell.

Constant Velocity

A boy is standing on a slide moving right and down on a slide that makes a 35 degree angle with the horizontal. He is accelerating-speeding up. List three changes to the situation that could give him a constant velocity.

APPENDIX B

ASSIGNMENT AND RUBRIC, TREATMENT 1

Homework: Free–Bodies Diagrams Project

DoDEA Standard Pb: The student will demonstrate an understanding of the principles of force and motion and relationships between them. Pb.7: Use a free-body diagram to determine the net force and component forces acting upon an object.

Take a video and photograph of yourself or a friend or family member on a playground or participating in a sporting activity as approved by your instructor. In the photograph, you must be in contact with the ground or an object that is not in free fall. You must be acted on by more than 2 forces.

Turn your photograph into a free body diagram. Have photograph and draft answers for the following questions by Monday, November 25th for B-day and Tuesday, November 26th for A-day. Project Due by Wednesday, November 27 for B-day and Monday, December 2nd for A-day.

1) What are the contact forces that are acting on you or your friend, the free body in your diagram?
2) What are the field forces acting on your free body?
3) Are these forces balanced or unbalanced? Justify this answer by vector addition.
4) If the forces are balanced, explain how the you or your friend are
   a. Moving at a constant velocity
   b. At rest
5) If the forces are unbalanced, explain how your diagram and vector addition indicate the direction of the acceleration.
6) Is your inertia increasing, decreasing or staying the same. Explain how you know.
7) Demonstrate by video or diagram what forces you would need to change, add or remove to:
   a. Put your object in motion if it is at rest.
   b. Decelerate your object to rest if it is in motion.

Acceptable Activities – many more possibilities please ask your instructor.

- Swinger being pushed.
- Swinger in motion not being pushed.
- Someone climbing a ladder
- Playing on monkey bars
- Someone spinning on a merry-go-round.
- Teeter-totter not at equilibrium. Swimmer doing a turn or stroke
- Soccer player planting for a kick
- Football player making a tackle
- Basketball player making a foul or being fouled.
- Wrestler being pinned or pinning someone
- Cheerleader getting ready to throw some

Chapter 4 Free-Body Project: Name:_____ Period: _____ Date: _____

	10	9	8	7	6	0
Question 1	Question was completely and insightfully answered.	Question was completely answered.	Question was answered with one missing detail: _____	Question was partially answered. _____	Presentation hinted at an answer.	Not answered.
Question 2	Question was completely and insightfully answered.	Question was completely answered.	Question was answered with one missing detail: _____	Question was partially answered. _____	Presentation hinted at an answer.	Not answered.
Question 3	Question was completely and insightfully answered.	Question was completely answered.	Question was answered with one missing detail: _____	Question was partially answered. _____	Presentation hinted at an answer.	Not answered.
Question 4	Question was completely and insightfully answered.	Question was completely answered.	Question was answered with one missing detail: _____	Question was partially answered. _____	Presentation hinted at an answer.	Not answered.
Question 5	Question was completely and insightfully answered.	Question was completely answered.	Question was answered with one missing detail: _____	Question was partially answered. _____	Presentation hinted at an answer.	Not answered.
Question 6	Question was completely and insightfully answered.	Question was completely answered.	Question was answered with one missing detail: _____	Question was partially answered. _____	Presentation hinted at an answer.	Not answered.
Question 7	Question was completely and insightfully answered.	Question was completely answered.	Question was answered with one missing detail: _____	Question was partially answered. _____	Presentation hinted at an answer.	Not answered.
Visual Presentation	Your diagram was: 1. Clear Photograph 2. Clearly Marked Vectors 3. Vector Lengths Realistic 4. Vector Angles Realistic	Could have improved 1 of: 1. Clear Photograph 2. Clearly Marked Vectors 3. Vector Lengths Realistic 4. Vector Angles Realistic	Could have improved 2 of: 1. Clear Photograph 2. Clearly Marked Vectors 3. Vector Lengths Realistic 4. Vector Angles Realistic	Could have improved 1 of: 1. Clear Photograph 2. Clearly Marked Vectors 3. Vector Lengths Realistic 4. Vector Angles Realistic	All graphic elements could use improvement.	Disorganized or missing visual presentation.

Score

Pts	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57
%	100	99	98	96	95	94	93	91	90	89	88	86	85	84	83	81	80	79	78	76	75	74	73	71

APPENDIX C

ASSIGNMENT AND RUBRIC, TREATMENT 2

STEM LAB Names: _____

Parachute

In this lab, you will design parachute models and then improve your model to develop a parachute that has the most air resistance. You will be collaborating with your group using your google account, doing online research and completing the engineering design process.

PURPOSE

Design and model processes, materials, and equipment that might be used to construct a parachute that maximizes air resistance for a mass of 10 to 30 grams.

ENGINEERING DESIGN PROCESS

Day 1: Identify a Need What's the problem?

1.

Conduct Research What have others done? What are the constraints?

Brainstorm Solutions How can you solve the problem? Brainstorm multiple ideas.

2 . Brainstorm about how you can use the materials provided to construct a model of a parachute that maximizes air resistance. Consider how the model's shape, size, material, and tie lines will affect drag.

Select a Solution Which ideas best meet the need? Which ideas meet all your constraints? Choose the best one.

3. Write out a procedure for testing your prototype. As you plan the procedure, make the following decisions:

- Decide how you will maximize the air resistance of your parachute.
- Decide what construction techniques you will use to build your parachute.
- Decide how you will measure or determine whether your model is a success.
- Select the materials and technology that you will need for your experiment from those that your teacher has provided.
- Decide what safety procedures are necessary.

Design a Solution Describe or draw a diagram of the steps you will take to solve the problem. Make a list of what you will need to implement your solution.

4. Create a labeled diagram of your prototype, including any measurements. Have your teacher approve your plans.

Day 2:

5. Follow your plan. Obtain your materials and set up any apparatus you will need. Construct your parachute.

Test and Evaluate Test it out! Analyze your results. Were they what you expected? Think about what your results say about your plan.

6.

Data Table**(Please complete as a google spreadsheet)**

Trial					

Redesign to Improve What changes could you make that would give you better results? Make your design even better. Test it out!

Data Table **(Please complete in the same google spreadsheet)**

Trial					

Communicate Share your results with others throughout the design process and get their feedback. Report on your final design.

ANALYSIS

1. **Summarizing Data** Summarize your findings and observations. How did your model perform in your tests? Were you able to improve its performance after modifications?

2. **Identifying Cause and Effect** Describe how each design component of your parachute might have contributed to its air resistance.

3. Describing Events Share your results with your classmates. How did each group's design affect the time it took their parachute to fall?

CONCLUSIONS

1. **Drawing Conclusions** What conclusions can you draw from your results? Did you learn anything from other groups' results that could improve your parachute's performance?

2. **Evaluating Models** Was your prototype a good model for showing what methods or materials could maximize the air resistance of a parachute? Explain why or why not, and give examples of what might be missing from your model.

STEM Lab Parachute Rubric

Name: _____

Top Collaboration Points: +4
Best Time Points: +4

Rubric Total: ____/80
Final Grade: ____/80 = _____%

Element	10	9	8	7	6	0
Engineering Design Process Problem Definition	Launch and material constraints fully identified. Reliable sources cited for parachute designs.	Launch and material constraints identi fied. Sources cited for parachute designs.	Missing the following detail. _____	Missing the following _____ _____	Element minimally addressed.	Element Omitted/ Incorrect
Engineering Design Process Brainstorm/ Solution Selection	Thorough brainstorm addressed model's shape, size, material, and tie lines. Selection cited clear reasons for choice.	Brainstorm addressed model's shape, size, material, and tie lines. Selection cited reasons for choice.	Missing the following detail. _____	Missing the following _____ _____	Element minimally addressed.	Element Omitted/ Incorrect
Engineering Design Process Solution Design	You created a professional and dimensioned drawing and a wrote a procedure with all required elements.	You created a dimensioned drawing and a wrote a procedure with all required elements.	Missing the following detail. _____	Missing the following _____ _____	Element minimally addressed.	Element Omitted/ Incorrect
Engineering Design Process Build a Prototype	You built a parachute that met your criteria in accordance with your plans and then rebuilt in response to your testing data and observation.	You built a parachute that met your criteria and then rebuilt in response to your testing data and observation.	Missing the following detail. _____	Missing the following _____ _____	Element minimally addressed.	Element Omitted/ Incorrect

Data Analysis Preliminary	You created a data table that included masses, distance, times, velocities, forces and additional calculations of your own choosing that enhanced understanding. Variables and units correct. Description of changes if needed.	You created a data table that included masses, distance, times, velocities, forces Variables and units correct. Description of changes if needed.	Missing the following detail. _____	Missing the following _____ _____	Element minimally addressed.	Element Omitted/
Data Analysis Final	You added data after revisions to your parachute and described how your data and calculations changed in response to your modifications. **Or you justified why no modifications were necessary.**	You added data after revisions to your parachute and described how your data response to your modifications.	Missing the following detail. _____	Missing the following _____ _____	Element minimally addressed.	Element Omitted/ Incorrect
Analysis	Analysis questions were answered addressing how each design element impacted your results specifically referencing your data.	Analysis questions were answered addressing each design element and its impacted your results.	Missing the following detail. _____	Missing the following _____ _____	Element minimally addressed.	Element Omitted/ Incorrect
Conclusion	Answers to conclusion questions showed insight into your parachute, the model's created by others and referenced improvements to your design or justified why your model was optimal.	Answers to conclusion questions referenced your parachute, the model's created by others and referenced improvements to your design or justified why your model was optimal.	Missing the following detail. _____	Missing the following _____ _____	Element minimally addressed.	Element Omitted/ Incorrect

APPENDIX D

PRE-TREATMENT SURVEY

Edit this form

Physics Survey October

Please choose the answer to each question below based on your plans, experiences and attitudes as of today. Your participation in this survey is voluntary.

* Required

Part I *

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1.I plan to pursue a career in Science, Engineering, Mathematics or Technology	○	○	○	○	○
2. I look forward to taking college science classes.	○	○	○	○	○
3.I look forward to taking physics in college.	○	○	○	○	○
4. I feel confident that my high school science experiences have prepared me for college success.	○	○	○	○	○

5.What are your plans after graduation? *

Check all that apply

☐ Immediate Employment

- [ ] Associates Degree
- [ ] Technical Degree
- [ ] Four year College
- [ ] Military

6. Please describe your career plans. *

Part II *

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
7.Concepts I learn in physics apply to my everyday life.					
8. I could see myself as a scientist or engineer.					
9. Compared to my classmates, I am more likely to assume a leadership roll while doing a science lab or science project.					
10. I like to figure out how things work.					

Part III *

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
11. It is important to me to get a good grade in					

physics.					
12. It is important to my parents that I get a good grade in physics.	○	○	○	○	○
13. Students are successful in science due to their talent.	○	○	○	○	○
14. Students are successful in science due to their effort.	○	○	○	○	○

15. Please describe what you most want to get out of your physics class. *

Part IV *

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
16. I prefer to learn new concepts from my experiences.	○	○	○	○	○
17. I prefer to learn new concepts from reading.	○	○	○	○	○
18. I prefer to learn new concepts by listening to a lecture or discussion.	○	○	○	○	○
19. I prefer to learn new concepts by watching a video or demonstration.	○	○	○	○	○
20. It is important					

to me to see examples of how to solve problems in physics.					
21. It is important for me to apply concepts to be successful in physics.					

22. Name *

Lastname, Firstname please

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APPENDIX E

INTERVIEW QUESTIONS

Interview Questions:
Thank you for agreeing to participate in this interview. I want you to know that your participation is voluntary in no way effects your grade in physics. If you do not wish to answer a question just let me know.
PRE-TREATMENT

1. Please describe your favorite memory from science in elementary school or if you can't think of one, describe your favorite learning experience in elementary school.
Probe: This could be an activity done with after-school activity
2. Same for middle school
3. And high school
4. Growing up do you recall doing science experiments or activities with your family or other non-school community members? If so who did you do an experiment with and what was it?
Probe: Think about birthday presents, activities on family vacations, museums, or outdoor activities
5. Growing up do you recall an automotive, building, sewing or home-repair project with your family or other community member? If so describe who and what.
Probe: Grandparent? When visiting other family, or club activity
6. Do you and your family discuss science in the news, read science books or magazines together? If so, give an example. If not, describe what you read and discuss?
7. Have you discussed your physics class with someone not in the class in the last two weeks? If so who and what?
8. When you don't understand a science topic, who do you go too? Is this the same person you seek out for other subjects?
9. Is there additional information about your science background that hasn't come up that you might like to share?
POST-TREATMENT
10. Overall: Do you feel your confidence in understanding the concepts of future physics courses has increased, decreased or stayed the same? To what do you attribute the change?
11. Rank your confidence in your ability to understand physics concepts on a scale of 1-5 with five being the highest.
12. Do you feel your confidence in doing an excellent job on projects in this class has increased, decreased or stayed the same? To what do you attribute the change?
13. Rank your confidence in your ability to do an excellent job on projects on a scale of 1-5 with five being the highest.
14. Do you feel that your confidence in doing an excellent job on tests in this physics class has increased, decreased or stayed the same? To what do you attribute the change?
15. Rank your test taking confidence on a scale of 1-5 with five being the highest.
16. Please comment on your memories of completing the Free-Body Project and the impact it had on your conceptual understanding of physics and your confidence in doing physics.
17. Please comment on your memories of the presentations of the Free-Body Project and the impact it had on your conceptual understanding of physics and your confidence in doing physics.
18. Please comment on your memories of completing STEM parachute project and the impact it had on your conceptual understanding of physics and your confidence in doing physics.

19. Please comment on your memories of completing the Free-Body Project and the impact it had on your conceptual understanding of physics and your confidence in doing physics.
20. How would you change either project to improve the experience for students next year?

APPENDIX F

IRB EXEMPTION

MONTANA STATE UNIVERSITY

INSTITUTIONAL REVIEW BOARD

For the Protection of Human Subjects
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MEMORANDUM

TO: Dawn Peterson and Walt Woolbaugh

FROM: Mark Quinn, Chair Mark Quinn

DATE: December 15, 2014

RE: *"The Effect of Integrating Project-Based Learning and Engineering Design into Physics Instruction* [DP121514-EX]

The above research, described in your submission of December 15, 2014, 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.