ABSTRACT

WHEELER, SAMUEL RAMON. Using Choice to Uncover the Role of Gender Stereotypes in High School Physics Assignments: Examining Students’ Interests, Beliefs, Conceptual Understanding and Motivations. (Under the direction of Dr. Margaret R. Blanchard).

The demand for Science, Technology, Engineering, and Math (STEM) skilled workers is outpacing the rate at which they are produced from universities in the United States (US); this is particularly true for female students in the physical sciences. The gender gap for interest in STEM subjects is not present in students in the early grades. Yet, studies demonstrate that from the time a girl enters school in kindergarten until the time she begins her senior year of high school, chances are she will have lost much of that interest in STEM subjects as compared to her male peers. Indeed, only about 36% of undergraduate STEM degrees and 19% of undergraduate physics degrees were awarded to US women in 2015.

This study used a pre/post intervention designed to offer students choices of different contexts (biological/health, sports, and traditional) for physics problems. These choices were intended to potentially increase the interest of students, especially females, in the subject matter - with the intention of also positively impacting their achievement. Students’ interests, beliefs, conceptual understanding, and motivation toward learning physics in a high school unit on Newton’s Laws were examined before and following their completion of an online homework unit composed of these problems. This study was informed by Artino’s social-cognitive model of academic motivation and emotion, using choice in an online learning environment (WebAssign) to see if this experience would lead to different academic outcomes. Three research questions guided this study. When given assignment choices designed around gender stereotype: Which types of physics problems do males and females select? Are there any differences in achievement of males and females, and is this related to the types of physics
questions they select or other factors?; What are students’ attitudes toward, beliefs about, and interest in physics, and what accounts for any changes that occur over the unit?

Seventy-one students in high school physics classes, from five US states, participated in this mixed methods study. Homework problems created on WebAssign were designed, based on the literature, to investigate the role that the context of a physics question has on the type of physics problems male and female students prefer. Three contexts were used: traditional, biological/health, and sports. Fifteen written questions and six questions using a video format made up the intervention. After answering a question, students were prompted to explain their reason for choosing that version of the problem. All of the homework problems were scored, most of which had two or three parts. Students were allowed to re-do a homework problem, for a maximum of five ‘tries.’ The online program also kept track of the order of the choices made by students and the amount of time they spent on the homework problems. Participants were given the Force Concept Inventory (FCI) to evaluate students’ conceptual knowledge, and the Colorado Learning Attitudes about Science Survey (CLASS) to measure changes in attitudes, both pre-and post-intervention.

Compared with males, females saw improvements from pre to post measure in the Sense Making category of the CLASS, but saw decreases in attitudes on items used in the Problem Solving, Problem Solving Confidence, Conceptual Understanding, and Real World and Personal Interests categories. Females showed gains in trusting their calculations, compared with male students, if the calculation gave a result that was different from what they initially expected, but females also were less likely to expect that physics equations would help their understanding and that they were just for calculations. Males saw a decrease in being satisfied with working on a problem until they understood why it worked the way it does, as compared with their initial
attitude. However, students reported interest in the context was a major factor in their reasons for selecting the questions they chose. While female students showed significant improvement on the FCI as compared with males, certain aspects of females’ attitudes towards physics decreased.

It was hoped that the intervention would address students’ interest in physics, as measured on the CLASS, yet that for the most part did not happen. However, the intervention did lead to gains on sense making for the females, but not the male students. And students scored highly on the homework assignment, which were closely correlated with the FCI scores. Thus, the intervention, at least for the females, increased their achievement on the FCI, and all students seemed to enjoy the choice and engaging with the video problems. Suggestions for future studies are shared.
Using Choice to Uncover the Role of Gender Stereotypes in High School Physics Assignments: Examining Students’ Interests, Beliefs, Conceptual Understanding and Motivations

by
Samuel Ramon Wheeler

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APPROVED BY:

_______________________________
Dr. Margaret R. Blanchard
Committee Chair

_______________________________
Dr. Sarah Carrier

_______________________________
Dr. Robert Beichner

_______________________________
Dr. Aaron Clark
DEDICATION

To my father who unknowingly started me on this path, and to my mother who has always believed in my dreams even the ones I haven’t dreamt yet.
BIOGRAPHY

I was born in 1968 in Waynesville, North Carolina and grew up in western North Carolina where I lived for much of my life. I was blessed to have a loving family with grandparents and great-grandparents living next door, who always encouraged me in all things science and to explore and tinker as much as I wanted. My love for science continued throughout elementary school into high school. During my senior year of high school, I was faced with a decision that would affect the rest of my life.

I was offered two full college scholarships: a full Navy ROTC scholarship, and the new NC Teaching Fellows Scholarship but due to the required commitments of each, I could choose only one. I had been in ROTC throughout high school and was familiar with the program and enjoyed it greatly, and I was excited to explore the opportunities that the program would offer me in college and beyond. The Teaching Fellows program was something that caught my family’s attention and they strongly encouraged me to take the Teaching Fellows scholarship, which I reluctantly did. The irony of life is that the eighteen-year old makes decisions that the forty-year (+) old must live with.

I always had a passion for science, particularly physics, and decided to double major in Physics and Science Education when I started my freshman year at NCSU in 1987. The Teaching Fellows program required a major in Education, but I had always wanted to go into Physics, so the double major was, in a way, an insurance policy in case the whole teaching thing (which I wasn’t thrilled about) didn’t pan out. The Physics program was challenging and fun and the Education program was surprisingly enjoyable too; although, especially after completing student teaching, it was not a field I saw myself entering.
When I graduated from NCSU, I was determined that I was not going to teach, but attend graduate school instead; however, the lack of planning on my part left me with few options and no money. I moved back to western North Carolina and took a long-term substitute position at Smoky Mountain High School in Sylva, NC as a math teacher. Unfortunately that teaching experience didn’t ignite anything in me to make me want to continue that career path.

I applied to graduate school at Western Carolina University. With my background in physics, I quickly got a teaching assistantship in the Physics department and decided to major in Biology with an emphasis in Biophysics. However, that program didn’t materialize the way I had envisioned it, and I found myself missing the problem-solving aspect of pure Physics. Since the university was small, they didn’t offer a graduate degree in Physics, so I decided to transfer over into the Applied Mathematics program. In 1995 I graduated from Western Carolina University with an MS in Applied Mathematics and a minor in Biology still never intending to enter the teaching field.

Once I graduated, life snapped me into adulthood. I received a letter from the Teaching Fellows program saying that I either had to pay back my scholarship plus interest over the time of my deferment, or begin teaching immediately. As a result, my professional teaching career began a few months after I graduated, in Marshall, NC where I attempted to teach introductory physical science classes, biology, earth/environmental sciences, and chemistry on a cart roving from room-to-room. After five years teaching in the mountains I finally paid off my teaching obligation to the state of North Carolina, and decided to pursue bigger opportunities by moving back to Raleigh where I began teaching physics at Southeast Raleigh Magnet High School (SRHS) all while planning my exit from the career.
But here something happened and I found my niche teaching Physics. To my chagrin, I began to really enjoy teaching and I enjoyed teaching at that school. The school administration and staff were very supportive, and the students were eager to learn, I was teaching all Physics for the first time in my career, and I found many opportunities to pursue as a teacher. While teaching at SRHS, I earned National Board Certification. I also co-hosted and helped produce a live call-in television show for four years called The Math & Science Show which aired weekly on Raleigh Community Access Television. Following my success with the Math & Science Show, I was selected to be a Kenan Fellow and worked on two projects: one designed to integrate physics into the high-school classroom and the other to create an exhibit at the NC Museum of Natural Sciences on the role of carbon dioxide in climate change.

The Kenan Fellowship started me on a pattern of international travel that continues to this day. For part of my Fellowship I traveled to Belize to learn about the role of carbon dioxide in nature. Other opportunities to travel came out of my partnership with the museum and as a result, I have traveled to Alberta, Ecuador, Yellowstone, and to the Amazon River in Peru. In 2003 I was selected to be a Fulbright Memorial Fund Scholar and traveled to Japan, where I learned about their education system, government, and culture. In 2004 I was a finalist for NASA’s educator astronaut position, and while I wasn’t selected to be an astronaut, the connection I made with NASA paid off in dividends with more opportunities than I could have ever imagined. I’ve been invited to and have watched shuttle launches and taken part in an astrobiology expedition to the Mojave Desert. I also arranged for my students to talk with astronauts onboard the ISS, and I’ve designed and flown with an experiment on a zero-g flight
(onboard a specialized aircraft affectionately known as the “Vomit Comet”) where I experienced zero-g, Lunar gravity, and Martian gravity.

The hunger to go back to school returned and I knew that I would have to take more physics if I wanted to achieve my goal. So, in 2005 I began graduate work in Radiological Physics through the Illinois Institute of Technology to bolster my physics background with the goal of pursuing a PhD in some area of physics. In 2008 I had an opportunity to travel to Namibia to explore conservation efforts being done with the big cats through Miami University and the Cincinnati Zoo. This opportunity turned into an Masters of Arts in Zoology that allowed me to travel to Kenya, and Guyana to study the impact of climate change on various ecosystems helping to satisfy my desire for travel.

Though probably the most pivotal professional achievement came in 2005 when I was selected as the recipient of the Presidential Award for Excellence in Math and Science Teaching for North Carolina and traveled to Washington, DC where I met many important people, including the President of the United States and testified in on Capitol Hill in front of the House Science Committee. In 2007, I began teaching physics at Enloe High School in Raleigh where I stayed until 2012 when I was one of nineteen teachers across the country selected for the Albert Einstein Distinguished Educator Fellowship. For this fellowship, I served at the US Department of Energy in the Office of Science for a year. The fellowship opened many opportunities for me and my students including in my current job as a physics instructor at the North Carolina School of Math & Science.
ACKNOWLEDGEMENTS

I want to thank my committee chair and advisor Dr. Margaret R. Blanchard who has skillfully guided me through my program and this dissertation. She is a dedicated professional who devotes her time and energy to her students and for that I am eternally grateful. Her guidance and feedback have been essential to my success. When I first began the program, I lost two different advisors, due to a job move and retirement. After going through two advisors, I had momentarily considered the possibility that obtaining a PhD might not be in the cards for me. But Meg graciously offered to be my advisor and she took me under her wing, even knowing my track record with past advisors. While I wasn’t concerned she would lose her job (she had tenure) or that she would be retiring soon (she’s too young and has kids going to college so she needs the money), I secretly thought that she had done so only because she needed to have a food taster and/or consider adding me to her life insurance policy in case something happened to her, but her constant “go, go, go” convinced me that she was in it for the long haul.

In the end, I couldn’t have asked for a better advisor. I suppose that being a mother to two boys prepared her for being my advisor in some fashion, since she constantly held me to task and wouldn’t let me get away with anything and made sure that I met every milestone of my program whether I knew about it or not. But, I think that she secretly kept a bottle of vodka in her desk, or in her purse, ready for every time I said, “Meg, I have this opportunity…. ” Without her weekly meetings, hot tea, and her husband Jon’s quote, “The only good dissertation is a done dissertation” constantly running through my head, I couldn’t have finished. Thanks Meg.

I would like to thank Dr. Robert Beichner for being my ‘sugar daddy’ with his help in providing funding for my research project (which saved me from having to pay for it out of
pocket), for his guidance in all things physics, and for serving on my committee. I would also like to thank other members of my committee Dr. Sarah Carrier and Dr. Aaron Clark for their time and effort. I would like to thank Dr. Patricia Simmons for her help and contributions to my work and for her encouragement throughout my career.

I also want to thank Dr. Jeff Milbourne for his help with the long process of student response coding and his technical feedback. Thanks to Chris Allred and Dr. Latricia Townsend for their help and advice with all things statistics. I would like to thank June Martin for her advice and help in selecting inspiring biology examples. Without the help of Jim Von Steen, Dr. Mike Bowman, Dr. Jon Bennett, Julia Kohn, Matt Skalor, and Teresa Walker, this project would have not been a success. I would also like to thank the administration of the North Carolina School of Science and Mathematics for being flexible and understanding as I’ve traveled on this journey.

I would like to thank my fellow PhD cohorts Dr. Huei Chen Lao and Dr. Pam Phillips, both of whom provided support and strategic intelligence on the process that I’m now completing. I would also like to thank Dr. Meredith Keir for her encouragement and advice along the way and especially for being a topic of discussion that I could bring up to distract Meg from asking too many questions about my numerous opportunities. I would also like to note here that the Puerto Rican Bioluminescent Kayak Disaster of 2013 forever convinced Meg that we were never married. I would also like to thank Dr. Kristie Gutierrez and Dr. Kylie Hoyle for their help along the way.

I want to thank my daughter, Ella, who was there at the beginning of my journey to earn this degree. When she was a few weeks old, she took part in one of my first video projects for a
summer technology course. Those video projects were integral to my research, but her happy, smiling, beautiful face, and curious and vibrant personality, are essential to my soul.

Finally, they say that behind every man who thinks he’s great, is a woman rolling her eyes. I want to thank my wife Rebecca for rolling her eyes, and for her support, patience, and understanding as I’ve worked through this project. Becca, if you’re not sure who I am, I’m that guy who’s been living in the other part of the house for the past several years, the part that you don’t go into. She has a very even temperament, but I know that my pursuit of this degree has frustrated her at times since she’s issued a moratorium forbidding me to pursue any new degrees for the next five years (why would I even want to after this). However, she might change her mind now that I’m going to have more free time around the house and she’ll be able to get to know me all over again.

Early in our marriage, I told Becca that I wanted to eventually get my PhD and that doing so would open doors and opportunities that would lead to bigger and hopefully greater things. I’m not sure she believed any of that or whether I would follow through with my goals, but she stood by me without question and I wouldn’t have been able to do this without her. She has cared for me and loved me through this journey and beyond, and I couldn’t ask for anything more. I don’t deserve her, but I love her and I’m blessed to have her in my life. Thank you Becca.
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CHAPTER ONE

INTRODUCTION

As the nation has moved into the twenty first century, the demand for Science, Technology, Engineering, and Math (STEM) skilled workers is outpacing the rate at which we produce them from our universities (Wieman, 2012). Along with this gap in supply and demand, there is a gender gap for those interested in these fields which begins before students go to college (Heilbronner, 2013). However, that gap is not always present in the education pipeline. There is no gender gap in interest in STEM subjects for students in the early grades but a dramatically large gap exists by the end of high school (Baram-Tsabari & Yarden, 2011). These studies indicate that from the time a young girl enters school in kindergarten until the time she begins her senior year of high school, chances are that she will have lost much of her interest in STEM subjects as compared with her male peers.

While the gender gap of more broadly defined STEM fields is troubling, the most dramatic gender disparities are found in college engineering and physics programs. Female students tend to steer clear of taking physics courses in high school, which makes them less likely to go into a technical major in college that requires a physics background (Blickenstaff, 2005). This is especially troubling because physics is a ‘gateway’ course that students must take to go on to earn graduate STEM degrees in engineering, chemistry, or physics. Only about 36% of undergraduate STEM degrees and 19% of undergraduate physics degrees were awarded to women in 2015 (American Physical Society, 2015). Similarly, the gender gap for graduate degrees is 23% of masters’ degrees (Mulvey, 2014) and 21% of PhD’s that are awarded go to women (American Physical Society, 2015).
Much work has been done documenting and measuring the gender gap in STEM fields, but not all the underlying causes have been fully investigated. It is well documented that female role models in physics can make a positive impact on female students’ attitudes and interests in physics by providing a someone who has ‘physics identity’ for female students to observe, such as a female physics teacher, or female physicist (Hazari, Sonnert, Sadler, & Shanahan, 2010). However, the same research highlights the small number of female physics teachers and available female role models in physics. This creates a ‘chicken-and-the-egg’ paradox: female physics role models can help encourage female students’ interest in physics, but there aren’t enough females interested in physics to fill the need for role models.

Other work has been done to examine the teacher’s choice of pedagogy and the gender gap. Consistent with a constructivist epistemology, student-centered learning invites students to take an active role in their own learning and leads them to compare and contrast their prior understanding with new experiences (Bächtold, 2013). Mulhall argues that the discrepancies in a teacher’s understanding of how physics is most effectively learned translates to inadequate teaching of the subject and weak student understanding of physics concepts, including the female students. In addition, chances are that students who have these negative or less than ideal experiences may not choose to pursue the subject any further. Additional studies have focused on cultural aspects of why women are less likely to go into or stay in STEM careers (McNeely & Vlaicu, 2010). This research lists factors such as family responsibilities and lack of support when in a STEM occupation as the primary reasons why women don’t remain in STEM careers; however, other factors must be at play prior to the woman entering her career (Heilbronner, 2013).
Gender bias within physics curricula has been examined and some progress has been made to correct certain aspects of instruction that are easy to control (McCullough, 2007). For example, including pictures of female scientists in textbooks and educating teachers about the challenges that female students face demonstrated positive effects on female student interest in physics; but other areas of pedagogy, such as specifically designing curricula around female student interests, have not been fully explored (McCullough, 2004). One suggestion is for teachers to pay attention to the written and spoken language of the physics being presented in order to avoid stereotypical contexts (McCullough, 2007). McCullough (2007) suggests using specific language in examples and problems used that involve contexts that are familiar and relevant and to all students such as cars, food, and school activities. Other researchers suggest tapping into the interests of female students by integrating medical and biological fields into the traditional physics curriculum is a way to get more female students interested in physics (Gibson, Cook, & Newing, 2006). Gibson and Newing investigated trends in enrollment in medical and health physics programs at the university level in the UK. Based on the authors’ observations, they recommended using applications of medical physics curricula to bolster enrollment and retention in secondary physics courses. Gibson notes that the typical enrollment in a required university medical physics course is 50% female, but does not offer any quantitative data on why the female enrollment is so large.
Theoretical Framework

Figure 1.1. Social-cognitive model of academic motivation and emotion (adapted from Artino, 2010).

The theoretical framework (see Figure 1.1) used for this study applies a social-cognitive foundation to connect the influence of student choice, motivation, achievement emotions, satisfaction, and academic achievement together (Artino Jr, 2010). Artino used this framework to investigate the factors that influenced students’ decisions to enroll in online courses. This study was conducted at a military academy and investigated student motivational beliefs, achievement emotions, and their overall satisfaction with the course in general (Artino Jr, 2010). The author found that students who were more satisfied with their experiences with an online course were more confident in their ability to handle the course, and were more likely to prefer
taking online courses in the future. Artino concluded that higher self-efficacy and satisfaction predicts whether or not students prefer taking online courses.

Similarly, this model was used to investigate the motivational factors that influenced at risk students when they were completing a self-paced online science course, as part of a summer school remediation for students who had failed the course (Phillips, 2015). Phillips found that most students were very satisfied with the opportunity to set their own pace with learning the online material and, as a result, take control of their learning, which led to all students passing the course.

The learning environment includes such things as the assignments (e.g., WebAssign tasks given to the students) and the classroom setting itself. The instructional resources include class materials such as books, online programs (Phillips, 2015), and details about the nature of these resources (e.g., the contexts of questions the students are able to choose from and the delivery modes: written and video analysis based).

Students’ Motivational beliefs are directly linked to student self-efficacy or one’s own belief in her or his ability to perform a task (Eccles & Wigfield, 2002). According to Eccles and Wigfield, task value beliefs reflect a student’s own perception of a task’s interest and significance, which will determine his or her motivation for completing that task. Achievement emotions describe the feelings that are directly the result of achievement outcomes and activities and can be thought of either as reoccurring emotions tied into an activity or situational (Pekrun, 2006). As Pekrun describes, achievement emotions can be thought of as boredom or enjoyment experienced during learning and can be determined by self-efficacy beliefs and task value beliefs. According to this model, students who become more interested in learning will find
more value in the task and feel more confident in their ability to complete the task. The learning environment and the personal factors contribute to the academic outcomes satisfaction and instructional choices. The model predicts that students’ satisfaction and choices are linked to their motivational beliefs and socio-cultural influences through a feedback loop.

Research questions

This study took place in high school classrooms during a unit on Newton’s laws and applications of forces. Based on literature findings about the females in physics and research about what might generate more interest in physics, a homework assignment was created for a unit on the application of Newton’s Laws. Given the focus of the study, the following research questions were addressed:

1. When given assignment choices designed around gender stereotypes, which types of physics problems do males and females select?
2. Are there differences in the achievement of males and females, and is this related to the types of physics questions they select or other factors?
3. What are students’ attitudes toward, beliefs about, and interest in physics, and what accounts for any changes in these that occur over the unit?

Summary

In this chapter, students’ attitudes and performance in traditional physics classes were introduced, highlighting the disparities between the number of female students in physics and factors that may help to address these issues. A gender gap exists in the selection of STEM
courses in high school and college majors, especially in physics. The call to make physics courses relevant and more inclusive to female students’ interests have resulted in minor changes at the secondary school level, but recent work in developing undergraduate physics courses to accommodate requirements for Biology majors and Medical Physics majors demonstrate higher engagement and interest from female students than traditional courses. Artino’s (2010) social-cognitive model of academic motivation and emotion will be used to investigate factors underlying students’ choices in an online physics intervention. Research questions guiding this study address the types of physics problems that male and females select, explores differences in achievement, and investigates factors that influence beliefs, self-efficacy, attitudes, and understanding of physics, with special attention to female students.

Chapter Two gives a detailed literature review of the gender gap in physics, gender bias, student choice and interest alignment, technology, and video analysis. In Chapter Three, details the methods used for this proposed study are presented. Chapter Four provides the discussion of the results and the limitations of the study. Finally, Chapter Five summarizes the conclusions and implications of this study.
CHAPTER TWO

LITERATURE REVIEW

The need to redesign physics programs at both the undergraduate and secondary school levels has been recognized at the national level, in response to the current challenges facing physics education across the country (National Research Council, 2013). The National Research Council (2013) identified physics as the ultimate foundation of all the other branches of science, with over 500,000 students a year taking an introductory physics course. Yet, only 1% of college graduates complete a degree in physics. This report asserts that current practices aren’t serving underrepresented groups and that factors such as student motivations, attitudes, and that interest may play a role in the lack of female and minority representation in the field.

The representation of females in high school physics classrooms (in any physics course) has remained relatively constant over the past twenty years at about 47%, but that statistic is for all physics courses and the representation of females in advanced, quantitative high school physics classes is 32% (White, 2011a). According to The American Institute of Physics’ 2009 Report on High School Physics, 52% of Asian students, 41% of White students, and 25% of Black and Hispanic students have taken at least one physics course in high school (White, 2011b). We know that gender biases in the pedagogy and implementation of the curriculum as well as teacher biases influence female students’ decisions to take physics the high school; and we are also aware of the fact that physics classes tend to be a male dominated subject (McCullough, 2007). To counter this trend, some have called for the use of problems and examples in the context of female stereotypes to elicit female students’ interest and performance in the subject (McCullough, 2004).
The Gender Gap Problem in Physics Courses

The problem with few female students choosing to take advanced physics courses, let alone choosing to pursue academic and professional careers in physics is not a problem limited to the United States, but also has been documented throughout the world. A study of female high school seniors’ interest in taking physics at a university in Ghana, shows that female students have little interest in pursuing more physics once they graduate from high school (Buabeng, Ampiah, & Quarcoo-Nelson, 2012). In Scotland, females also are underrepresented in physics courses (high school or college) which Scottish researchers attribute to the ‘abstract rule’ or the traditional method of instruction which has not been shown to engage female students (Reid & Skryabina, 2003). Australia has been measuring a decline in female student enrollment in physics and advanced math courses, at the secondary and college level (Oliver, Woods-McConney, Maor, & McConney, 2017). In England, Singapore, Spain, and Mexico, among other nations, the same trend has been observed leading many to call for international action to address the issue in hopes that the trend can be reversed (Oon & Subramaniam, 2010). Not surprisingly, there is growing interest to further investigate the gender gap in STEM fields, especially in physics.

Much of the research in the gender gap has been toward the attitudes of the students in the classroom and in extracurricular settings. Student attitudes toward a subject are particularly important. Interest and positive student motivation toward STEM subjects have been linked to the use of collaborative learning and social modeling in the classroom, which promotes interest and excitement in the material (Bryan, Glynn, & Kittleson, 2011). Student self-efficacy is an important aspect of a student’s academic or science identity, which has been determined to be a
strong factor in their perseverance in physics classes (Sawtelle, Brewe, & Kramer, 2012). The authors use the definition of science identity comprised of three components: competence, performance and recognition. Sawtelle et.al. (2012) found that ‘vicarious learning experiences,’ opportunities for students to see a particular task they are expected to perform modeled for them, correlated with the development of female students’ self-efficacy. When students compared their achievement with the achievement of others, it had a positive influence on self-efficacy in learning physics in this environment. Others argue that in addition to self-efficacy and social factors, the lack of pedagogies which promote creativity and realization of curiosity are culprits for the gender gap (Hill & Rogers, 2012).

Claims have been made by some researchers that the gender gap can be partially attributed to students’ previous educational background; but the gender gap persists even after factoring in the different educational background between the male and female students (Noack, 2009). Instead, Noack found that students’ initial conceptual understanding of physics topics was the best indicator of how well they performed in the class. Commonly used predictors such as age, gender, and parents’ educational have been found to have very little effect on a student’s learning conceptual physics learning gains (Noack, 2009).

The gender gap in the number of female students who pursue physics was once attributed to the assumption that it was too difficult for them (Zohar & Sela, 2003). Programs were created to remedy girls’ deficiencies in physics and mathematics by focusing on their ‘lack of various characteristics needed to succeed’ or placed “blame” on the girls for their underachievement, as Zohar and Sela explain. As research advanced in the understanding of how female students learn mathematics, more student-centered pedagogies were adopted to increase girls’ engagement in
mathematics (Boaler, 1997). The results of the efforts in mathematics have prompted similar efforts in physics to better understand what would make a physics course more appealing to female students. In the United Kingdom (UK), a study was conducted to identify those factors that would make physics more appealing to female students at the secondary level (Mitrevski & Treagust, 2011). The authors found that female physics students wanted pedagogies that connected the relevance of physics with the greater world and with their own interests.

The impact of the use of student-centered pedagogies also appear to be observable after the student is no longer exposed to them (Gibson, V., Jardine-Wright, and Bateman, 2015). The authors suggest that the way that physics assessments are written may have an impact on student performance. At first, the data appeared to show a positive influence on the performance of female students who were given exam questions that made use of “scaffolding”. An example of scaffolding physics questions on an exam is explicitly asking students to define terms, draw out diagrams, and calculate numerical answers at each step which significantly improved the performance of both genders on high school level questions. However, delving deeper into their data, Gibson et.al. found that students’ prior physics backgrounds correlated well with their exam results. Their findings imply that the students who performed better probably had a more pedagogically sound introduction to physics than did the other students.

Gender Issues in Physics

One explanation for the gender gap between the enrollment of male and female students in physics and the physical sciences points to three influences that place pressure on both genders to adhere to established stereotypes: cultural, attitudinal, and educational (Baram-Tsabari & Yarden, 2008). The cultural influences the authors discuss stem from established
societal views of the ‘male image of science’ and parental beliefs that girls aren’t as interested in science as are boys. However, the authors assert that these differences apply more to the physical sciences than to the biological sciences. Baram-Tsabari and Yarden’s (2008) explanation of attitudinal influences assert that girls don’t like science as much as boys. The authors posit that the attitudinal influences on girls could be perceptions of the impersonal nature of physical sciences, difficulty with the material, and an image of the physical sciences being a masculine field. The authors contend that the classroom environment and pedagogy can be influential in overcoming the gender gap in the physical sciences. In addition, in order to make physics a more engaging subject for girls to study, the curriculum should focus on making the subject material personally relevant to girls (Baram-Tsabari & Yarden, 2008; Murphy & Whitelegg, 2006).

Even without the external stereotypes and academic difficulties that might occur with learning physics, females’ perceptions of barriers to learning and doing physics impede their full exploration and immersion in the subjects (Grossman & Porche, 2014). Most students taking physics for the first time are in high school or are university freshmen who are transitioning from adolescence to young adulthood and sensitive to social factors. Some have offered the explanation that the gender gap in STEM is due to female student perceptions of engineers and physicists as being ‘nerdy’ and ‘reclusive’ people who have no time for interactions and relationships (Johnson, 2012).

The stereotypical image of physics is that it is for boys; however, to say that girls don’t like or aren’t interested in physics is not the case. In Scotland, studies done on students’ interest in physics topics and subjects shows that both genders are interested in learning about physical
processes, but that these interests shift as they get older (Reid & Skryabina, 2003). At the beginning of their Standard Grade (equivalent of beginning of high school in the US) physics courses boys and girls equally reported that physics was “definitely my subject,” but by the end of the course boys were much more likely to still say the same thing. From these results, the authors state that the stereotypical boy tends to prefer more abstract, rule-dominated teaching styles with references to interests in such things as boats, cars, and guns. Whereas, the stereotypical girl tends to be more interested in living things, biology, applications to daily life, and emotions of those around her (Reid & Skryabina, 2003).

The attitudes and interests of the boys in the Reid and Skryabina (2003) study deteriorated by the end of the year, however, for boys who took a subsequent 1-year course in Higher Grade. The authors found that although both girls and boys had interest in physics, boys tended to report liking physics for the problem solving and technical aspects, whereas girls were found to like physics for the beneficial social applications; however, both genders were interested in how learning physics could relate to future career choices. Reid and Skryabina conclude that something about the structure of the course was turning female students off of physics and, as a result, toward subject areas more commonly attributed to social sex role stereotypes. The authors suggest that the traditional method of instruction, which adheres to and is dominated by pedagogy that makes use of stereotypical male interests could be the reason why females are not interested in physics. Reid and Skryabina (2003) recommend that to attract more girls to physics courses, work should be done to remove these stereotypes and to make the course more appealing to female students.
Women face many hurdles and challenges to careers in physics and engineering but even girls with the highest mathematics abilities often choose to go into science fields that are already highly represented by females, such as medical and biological fields (Grossman & Porche, 2014). This begs the question: if females with the ability to succeed in physics or physics related fields aren’t going into these areas, then what is going on? Among the challenges that young women face in school are microaggressions, or brief, but frequent everyday interactions that send subtle but negative messages to them that they can’t be scientists or physicists (Grossman & Porche, 2014). Other messages that girls receive, the authors point out, is that STEM careers, including physics, aren’t compatible with female stereotypes.

Stereotype Threat (ST) is a well-studied phenomenon that occurs when “a stereotype about an individual’s social or racial group can provide a potential explanation for the person’s poor performance” (Marchand & Taasoobshirazi, 2012). This phenomenon has been studied extensively in mathematics education and is thought to be a contributing factor to the gender gap in mathematics, yet there has been little research into ST’s role in the gender gap in science and especially physics (Marchand & Taasoobshirazi, 2012). Marchand and Taasoobshirazis’ findings corroborate findings from previous studies in mathematics education that when stereotype threat has been nullified, the performance of female and male students equalizes. They point out that, besides their own study, the few research studies that have been done on ST and females in physics have been done at the undergraduate level.

Stereotype Threat (ST) is thought to be a contributing factor to creating the gender gap in mathematics and is believed to be a contributing factor in the observed gender gap in physics (Marchand & Taasoobshirazi, 2012). The authors performed one of the first studies on
stereotype threat in high school physics classrooms. Their study included 312 high school physics students from the southwestern United States who were given four problems to solve. There were three sets of instructions given to different groups of students. The first one indicated to students that the problems were based on material that they had already covered; the second indicated that males outperformed females on the problems; while the last set indicated that no gender differences were found on the tests. Their results showed that female students who had the instructions that there were no gender differences on the test did just as well as male students on the problems. The results of the investigation led Marchand (2012) to partially conclude that societal stereotypes contribute to poor performance of female students in physics classes.

The first organized focus of the problem of underrepresentation of women in advanced mathematics classes in high school and university was initiated by the National Institute of Education in 1977 (Eccles, J.S., 2011). To better understand the problem of underrepresentation of women in advanced mathematics classes, Eccles (2011) proposed a very enlightening model. Instead of looking at “why women weren’t making the same choices as men,” Eccles decided to look at the educational choices that women were making and why they were making those choices. Similarly, today we know that many women aren’t choosing to take any more physics than they must, if they take it at all. Perhaps the focus should be on how to make physics more academically appealing to female students.

*Gender Bias (Why Choose Physics from a Biology Context?)*

Gender stereotypes in K-12 education and our culture are known and well documented in the literature; to deal with these in the classroom, stereotypes and perceptions from both students
and teachers must be recognized (Leo & Cartagena, 1999). Further propagating these gender stereotypes, as the authors describe, gender bias has been observed throughout instructional materials in education, from the earliest grade levels through college. In principle, as Leo and Cartagena define, gender bias represents the context and format of presented information, while gender stereotype represents behaviors which are perceived as representing one gender or the other. Male gender bias can occur in textbooks and in curriculum through a variety of ways, such as the occurrence of men represented in examples or text, by the frequency with which the male point of view is represented, or by the propagation of stereotypes beneficial to males (Leo & Cartagena, 1999). From the perspective of both male and female students, physics tends to be personified by masculine traits, although from the teacher’s perspective physics is perceived as having characteristics from both genders (Makarova & Herzog, 2015). Until recently, stereotypical masculine interests and characteristics were widely represented in the images and language used in textbooks with references to male names and traditionally male activities and images (McCullough, 2007). In addition to the textbooks used, validated formal assessments such as the Force Concept Inventory (FCI), one of the most widely used physics concept assessments (Hestenes, Wells, & Swackhamer, 1992), is largely dominated by questions from stereotypical male contexts (McCullough, 2004). These contexts lay the foundation for gender biases, which send the message to young female students that they may lack the aptitude to do well in physics or in STEM related fields (Grossman & Porche, 2014).

To counteract the effects of these biases, researchers and educators have called for gender balanced teaching practices and textbooks (Owens, Smothers, & Love, 2003). Implementing gender balanced teacher practices requires understanding why students are interested in taking
the course. Stereotypically, male students tend to be interested in physics for the sake of physics, while female students tend to report being interested in physics for the sake of what physics can do to help humankind and other social associations (BØE & Henriksen, 2013).

There are numerous calls in the literature to reduce gender bias and stereotypes in physics courses. The interdisciplinary approach to teaching physics by incorporating life science into the curriculum is on the rise, mainly as a response to the greater demand for students to more fully understand the relevance of physics in relation to biology and chemistry (Crouch & Heller, 2014). Crouch and Heller designed a course for the growing number of life science majors who needed physics. They taught at two universities with diverse student populations over a two-semester sequence. Student attitudes about physics were measured with the Colorado Learning About Science Survey (CLASS) and found to either remain stable or improve over the course, as compared with the attitudes of students in the same course but taught without the biological context which showed a decline in positive attitudes about physics (Crouch & Heller, 2014).

The course that Crouch and Heller designed was greatly influenced by recommendations from a faculty committee based on what was judged to be important for biology majors and represents a greatly modified course over what had been traditionally taught in a university level introductory physics course. Crouch and Heller also report that one other goal of the modified course was to still deliver a “coherent view of physics as a discipline” (Crouch & Heller, 2014, p. 379). Table 2.1 lists the topics taught each semester and the relative weight of that topic compared with a traditional physics course taught at Crouch and Hellers’ respective universities. The authors also point out that forces and Newton’s laws were taught in the new course, and that the content was nearly the same as what was taught in the traditional course.
Table 2.1

Topics covered in modified introductory physics course (from (Crouch & Heller, 2014, p. 380))

<table>
<thead>
<tr>
<th>Semester</th>
<th>Topic</th>
<th>Nature of change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kinematics</td>
<td>Reduce</td>
</tr>
<tr>
<td></td>
<td>Momentum</td>
<td>Omit</td>
</tr>
<tr>
<td></td>
<td>Torque (consider statics only)</td>
<td>Reduce</td>
</tr>
<tr>
<td></td>
<td>Angular velocity, momentum, dynamics</td>
<td>Omit</td>
</tr>
<tr>
<td></td>
<td>Fluids (statics and dynamics)</td>
<td>Add</td>
</tr>
<tr>
<td></td>
<td>Drag force and motion through fluids</td>
<td>Add</td>
</tr>
<tr>
<td></td>
<td>Diffusion and osmotic pressure</td>
<td>Add</td>
</tr>
<tr>
<td></td>
<td>Thermodynamic cycles</td>
<td>Increase</td>
</tr>
<tr>
<td></td>
<td>Statistical treatment of entropy</td>
<td>Add</td>
</tr>
<tr>
<td></td>
<td>Free energy</td>
<td>Add</td>
</tr>
<tr>
<td>2</td>
<td>Geometric optics</td>
<td>Increase</td>
</tr>
<tr>
<td></td>
<td>Gauss’s Law</td>
<td>Omit</td>
</tr>
<tr>
<td></td>
<td>Electrostatics in media and in salt water</td>
<td>Increase</td>
</tr>
<tr>
<td></td>
<td>RC circuits</td>
<td>Increase</td>
</tr>
<tr>
<td></td>
<td>Induction (Lenz’s Law and Faraday’s Law only)</td>
<td>Reduce</td>
</tr>
<tr>
<td></td>
<td>Inductance and inductors in circuits,</td>
<td>Omit</td>
</tr>
<tr>
<td></td>
<td>AC circuits (with alternating sources)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maxwell’s equations, calculation of induced electric or magnetic fields</td>
<td>Omit</td>
</tr>
<tr>
<td></td>
<td>Radiation-matter interactions</td>
<td>Add/Increase</td>
</tr>
</tbody>
</table>

According to Crouch and Heller, a student survey ($N = 52$) was also administered with questions about the influence of learning physics through biological examples. Specific questions in the survey asked about the impact of using biological examples in the course as opposed to non-biological examples. One asked students if “including biological examples helped me enjoy physics more than if we had used non-biological examples” of which the responses were $3.6 \pm 0.1$ on a Likert scale with 4 being “strongly agree” (Crouch & Heller, 2014, p. 384). Crouch and Heller also asked students if biological examples helped them to
understand physics more than non-biological examples which also rated highly on the scale with a 3.3 +/- 0.1 average response rate.

Medical Physics is a unique field which integrates physics and biology through the application of physics concepts to directly help people. Most Medical Physics curricula focus on the role of the physics of radiation and the electromagnetic spectra, such as x-ray tomography, positron emission tomography, nuclear medicine, and radiotherapy as well as ultrasound and Magnetic Resonance Imaging (MRI) (Gibson et al., 2006). Even though courses in Medical Physics make heavy use of sophisticated physics concepts, Gibson et al. found that enrollment in these courses and programs is high and 50% of the students in these programs are female. Because of these trends, the authors suggest that incorporating Medical Physics into traditional secondary school physics courses could result in increased enrollment and interest in pursuing further physics. The authors point out several advantages to infusing physics with examples from the medical field. These include:

- Students may bring their own experiences to class: e.g., ultrasound images, x-rays
- Frequent references in the media and popular culture
- Very visual
- Allows a connection to ethics and consideration of safety issues

Both physics and biology, at the foundational level, depend upon observations and measurements to begin to put together a model that explains the worlds they investigate (Hoskinson, Couch, Zwickl, Hinko, & Caballero, 2014). In response to the growing trend at many major universities to develop introductory physics courses specifically for life science
majors, Hoskinson et al. recommended that the integration of biology and physics begin by recognizing the similarities of the two disciplines instead of the differences.

Research into understanding specific science topics that girls find the most interesting list topics associated with biology as the most engaging and relatable to students (Mitrevski & Treagust, 2011). In a survey given to 103 girls aged 14-17 in Australia, Mitrevski and Treagust found the top four most interesting science topics they introduced to females were genetics, fighting diseases, workings of the heart, and respiration, while the least interesting topics were all traditional physics topics: magnetic fields, light waves, and circuits. Furthermore, the authors report that girls weren’t sure about the relevance of physics to their daily lives or its relevance to their environment or community. Mitrevski and Treagust conclude that one of the remedies for lack of female interest in physics is to create curricula that relate physics issues to health applications and other topics related to the human body.

*Interest Alignment*

Alignment of physics curricula with student interests has been shown to produce measurable achievement gains when compared to that of students in physics courses with a traditional curriculum. A study focused on first courses in physics at the junior high level in Germany was designed to specifically target the interests of girls and the teachers’ interests while remaining faithful to the required course topic list (Hoffmann, 2002). Hoffmann’s study involved an intervention that combined three different treatments: curriculum development according to specific interests of girls; strategies for teachers to check their own classroom behavior; and switching between teaching single gender and coeducation classrooms compared with coeducational classrooms only. Hoffman developed teaching materials for five units by
modifying the existing content to be more aligned with the interests of girls based on the students’ previous experiences and interests and the attributes listed. Hoffman’s criteria for modifying a physics course for female students are as follows:

- Is there an opportunity to marvel?
- Is there a link to prior experiences for both boys and girls?
- Can first-hand experiences be constructed?
- Are discussions and reflections on the social importance of science encouraged?
- Does science appear in an application-oriented context?
- Are references made to the human body?

Hoffman worked with the cooperating teachers to develop strategies to incorporate gender-specific pedagogies through teacher-centered reflective practices, and proposed that teachers also consider the aspects criteria for modifying a physics course when creating their lessons. The study included an intervention with the teachers to get them to reflect on their own gender biases while teaching to get them to better develop positive physics-related self-concepts in girls.

Hoffman gave pre and post interests-in-physics questionnaires at the beginning of the school year and at the end of the school year to students in both the control and the experimental groups. The questionnaire was developed by the author and consisted of 88 items that combined eight different topics of physics with different general categories such as technical devices that students encounter, the impact of physics on society, and the laws governing how physics can be used to make calculations. The results of this study show that as the instruction continued, girls
became as motivated as the boys toward the physics instruction and more motivated than girls in the control group who received the traditional instruction according to Hoffmann’s attitudes instrument. Hoffmann also found that the greatest achievement occurred in single gender classrooms or partially single-gendered classrooms. While Hoffmann’s study incorporated the interest alignment of female students with physics concepts, the contribution of this portion of the intervention to the results is difficult to ascertain since the greatest outcomes for female students occurred in partially single-gender settings. The study concluded that curriculum that was modified to incorporate female student interests in physics did serve to increase female students’ self-concepts toward physics or a student’s perceptions of their own ability and competence in physics (Hoffmann, 2002).

Others have investigated the effect that merging student interest with the physics curricula has on motivation to learn. One study found that by incorporating topics and phenomena that students do not encounter in everyday life into the physics curricula, students become more interested in the physics concepts (Badri, Mazroui, Al Rashedi, & Yang, 2016). Badri’s et al. (2016) study found that females were more interested in phenomena that could not be easily explained by high school physics, while males were more interested in traditional phenomena such as mechanical equipment and lasers.

**Choice**

The effect of choice on student performance and engagement in the classroom has been a subject of investigation for some time, but the debate about the efficacy of choice has not been settled (Flowerday, Schraw, & Stevens, 2004). Many of these investigations begin with the premise that giving students opportunities to make choices in their learning will lead to the
students performing better on the tasks and being more engaged with the task in general stemming from intrinsic motivation to do that task (Patall, E.A., 2013). According to self-determination theory, an individual’s intrinsic motivation to engage in a task stems from three basic needs: the need for competence, relatedness, and autonomy (Ryan & Deci, 2000). Giving students choice in their assignments or classroom is thought to be a key factor in supporting and fostering the criteria of intrinsic motivation (Patall, E.A., Harris; Wynn, Susan R. 2010). Other research has found that instruction using choice works best under certain circumstances and conditions instead of open ended approaches (Patall, E.A., Cooper, & Robinson, 2008).

An investigation into whether students’ interests have an influence on how they choose, when given the option, and what effect that has on their performance was conducted using three different scenarios for comparison (Patall, E.A., 2013). In this investigation, the first part had participants read a series of situations and made choices about the tasks described in the story based upon their interests. Patall (2013) reported for this part of the investigation that participants were more likely to make a choice about a task if they have a personal interest in it somehow. In her second scenario, Patall found that participants who were already interested in a concept or topic showed more motivation and better performance on the task when given the opportunity to choose. But for those who expressed no interest in the task, choice had no effect on their performance or motivation outcomes. In the final scenario, Patall found that when students took part in a boring task, having a choice resulted in increased feelings of interest and value in the task. If no choice was given, students only reported being more motivated to complete the task if it was interesting to them. Overall, Patall (2013) found that to obtain the
optimum benefits of choice, the interests of the person doing the choosing and the design of the
task should be considered first.

A study on the effects of choice of topic and situational interest on students’ attitudes
and performance when engaging undergraduate students in a reading assignment found that
situational interest had more effect on engaging students with the task than did choice or topic
(Flowerday et al., 2004). In the first experiment, students were given two tasks to choose to
close: either writing an essay or completing a crossword puzzle; or they were assigned one of
these tasks after reading a story. In the second experiment, differences in student performance
and interest were investigated by examining the results of students in a self-paced study session
and students in a researcher-paced study session. The study found that student interest in the
task influenced what type of task they selected and that students who had a low level of interest
switched to a new task (Flowerday et al., 2004). Cognitive engagement was not improved by
choice but choice did have a positive impact on affective engagement with the task, and students
who had no choice reported that they worked harder than others (Flowerday et al., 2004).
Flowerday also found that choice had a negative impact on deeper learning and interpretation of
the assigned readings. When students chose the content they were working on they performed
poorly on their content essays as compared with students who did not chose (Flowerday et al.,
2004). Based on these findings, Flowerday concluded the following: situational interest
influences student attitudes and has a lesser effect on student engagement; interest in the topic
may act as a hook to catch students’ attention but situational interest may keep students
interested; and in the study’s experiments, choice was not found to significantly influence
attitude or engagement (Flowerday et al., 2004).
In a study using an undergraduate survey course in computer science, students were given choices in the homework assignments they were asked to complete as a final project (Fulton, 2011). Students were observed to enjoy the course more because of the choice in the final project, but the authors believe the students who chose the easier assignment did not acquire the same level of understanding of the content as those who chose the more challenging assignment. The authors noted that students who chose the more challenging project gained programming experience by doing the project and performed better in the course overall as compared with those who chose the easier project.

The question of whether offering a choice to students results in positive outcomes in student performance, interest, and motivation is a question that is recognized as having many variables and that fine-tuning of the scenario is required to create a meaningful learning experience (Katz & Assor, 2006). Previous studies show that when students are given choices in a “complex learning environment” with many variables and factors, that students tend to rely on simple decision-making strategies that don’t demand much from the student in the way of cognitive effort and don’t result in gains in performance outcomes (Bereby-Meyer, Assor, & Katz, 2004). In contrast, Bereby-Meyer et al. found when the learning environment is simple and students’ choices are limited, students make choices that lead to better results and gains in learning outcomes. Choice was found to be a motivating factor when the choice satisfied the students’ psychological needs (competence, relatedness, and autonomy), as described in self-determination theory, were accounted for in the learning environment (Katz & Assor, 2006). Katz and Assor comment that for choice to be beneficial to the learner, factors such as the context in which the choice is provided must be considered, and for choice to be motivating,
students’ needs, background, and abilities should also be factored in. Others have reached a similar conclusion; in order for choice to be a motivating factor within the lesson, the choice should be meaningful, relevant, and enhance the competence of the student (Evans & Boucher, 2015).

Motivation

Motivation is a well-studied area of human psychology that is interconnected with educational research. Highlighted as central to the core principles of Self-Determination Theory (SDT), one of the leading theories of human motivation often applied to educational research, is the distinction between autonomous and controlled motivation (Deci, 2008). Controlled motivation depends on external regulation of a person’s behavior, such as through the process of receiving a reward or a punishment, which results in the person experiencing pressure to behave in a certain way (Deci, 2008). Autonomous motivation integrates intrinsic motivation along with external motivation that comes from when a person has made a connection with an activity that they can associate and identify with on a personal level (Deci, 2008). Curriculum designed around these concepts of motivation have been shown to be successful at enhancing students’ motivation about a topic by giving students the opportunity to find some part of the lesson to be excited to be involved with (Loukomies et al., 2013).

Many studies have examined the factors that influence female student motivations towards physics. Early exposure to STEM activities and family influences have been found to contribute to long term female student motivation to pursue a professional career in STEM fields (Talley & Martinez Ortiz, 2017). Other studies have found that teachers with rich content knowledge backgrounds and the enthusiasm teachers have towards teaching result in positive
gains in student motivation in physics (Keller, Neumann, & Fischer, 2017). One recent study showed that female students’ motivation to study and do well in physics is not due to just one factor, but several which include a combination of teachers, supportive and knowledgeable teachers, engaging pedagogy, the school’s science culture, and social interactions with family and peers (Oliver et al., 2017). Students’ motivation in physics has recently been shown, in another study, to be positively related to the task-value they see in the physics they are doing and that student interest in the science being studied would influence their motivational trajectory in the course (Wang, Chow, Degol, & Eccles, 2017). Similar results were found in a Croatian study which suggested that a key motivational factor for female students was the utility value students put into physics (Jugović, 2017).

Eccles Expectancy Value Model of achievement related choices is another motivational model often used and integrates an individual’s value of how important, interesting, and beneficial an academic undertaking may be with how much they directly expect to succeed in that task (Plante et al., 2013), (J. Eccles, 2011). Achievement value, referred to as the subjective task value, portion of this model is defined through four mechanisms: attainment value, intrinsic value, utility value, and cost (Eccles & Wigfield, 2002). Eccles (2002) described the attainment value as an individual’s belief in how well they will do on a task as well as one’s own expectations on efficacy. Intrinsic value reflects the gratification that an individual gets from a task, while utility value indicates how well the task connects with other goals not directly associated with the immediate task at hand. Cost, as Eccles described it, ties into the negative expenditures of engaging in the task such as time, stress, effort, sacrifices due to the task, and so on.
These models converge on the concept that students’ perceptions about themselves and the tasks at hand play a central role in their sustained motivation throughout the lesson or course. Students’ perceptions of their abilities in science are correlated with their performance on standardized tests and their self-concept aligns with their STEM career goals (Nagengast & Marsh, 2012). Research in students’ motivations in the physical sciences has shown that by understanding the relationships between students’ self-concept and task values the motivational outcomes can be affected (Wang, Chow, Degol, & Eccles, 2017). Wang et al. identified seven different “motivational trajectories” associated with students’ self-concept ability and task values associated with physics that were positively identified with science career aspirations, taking advanced science courses, and achievement in science classes.

Research has shown that females are ahead of or equal to males in performance on standardized science assessments and psychological exams during the early years of their education, but the gap widens dramatically by graduation (Owens et al., 2003). But the gap is not due to lack of ability; female students who take physics in high school are just as likely to succeed in the course as male students (National Research Council, 2013). Rather, research tends to support the idea that the gender gap in physics is due to issues of motivation, interest, and other affective qualities (National Research Council, 2013). Other studies point to the female success in physics and other physical science subjects as linked to family support and career options and interests that fuel female students’ persistence in physics (Talley & Martinez Ortiz, 2017). All these studies point to the need to make physics courses more engaging to female students as well as being more ‘people-oriented’ and making the curricula more connected to everyday life (Mujtaba & Reiss, 2014). These findings point to the need to change
the experiences of students in traditional physics courses from the way it is taught to the nature of the material being used.

**Videos and Video Analysis**

Videos and video analysis technology as pedagogical tools in physics were introduced over twenty-five years ago to more effectively teach kinematics and help students better understand the physics of motion (Beichner, 1988). Video based technology can be a powerful way for the teacher to bring the real, ‘everyday world’ into the classroom and enhance students’ ability to see science in their daily lives (Beichner, 1999). Incorporating video technology into the physics classroom has been found to increase student excitement and engagement with the material being presented (Lee & Sharma, 2008). Lee and Sharma reported that students were highly engaged and excited by a video investigation of the Meissner Effect, in which a magnet is levitated above a superconductor. Students asked a wide range of questions, and many remained after class to continue the inquiry, suggesting a relationship between the way students are engaged, the amount of student learning, and the level of student interest and attitudes toward their investigation (Lee & Sharma, 2008). When students play an active role over their own learning, their attitudes toward learning, and toward science tend to be positively affected as well (Brass, Gunstone, & Fensham, 2003).

Using visual representations in physics aren’t new; physics students and teachers alike can tell stories of stick figures, free body diagrams, and chalkboard cartoons used as an intermediate step between understanding the physical situation and applying mathematics to solve the problem (Bing & Redish, 2009). Drawings and diagrams have always been helpful
teaching strategies, but today’s technologies afford the learner and the teacher greater access into developing better models to address conceptual misunderstandings. Aside from stick figures and chalkboard cartoons, still photographs have been used to help make learning physics easier. In particular, photographs have been used in inquiry driven physics lessons and in constructivist settings to effectively identify and correct student misconceptions about Newton’s 3rd Law (Eshach, 2010).

The use of pictures and multimedia representations in the learning process is a well-studied phenomena, in some cases has produced mixed results as to the effectiveness of visual representations in the learning process (Ainsworth, 2006). Early research claimed that visual and multimedia material would be more of a distraction to students from the more important material if it were just applied for cosmetic purposes (Rieber, 1994). But as instruction became more integrated with technology, multimedia representations have been added to instruction with the hopes of grabbing students’ attention and appealing to their attitudes and therefore encouraging them to engage with the material and learn (Titus, 1998).

The use of pictures and illustrations as aids with student learning appear to be most successful when the image and the information from the text are integrated, and the complexity of the diagrams influences the outcome (Mason, Pluchino, Tornatora, & Ariasi, 2013). Mason et al. (2013) used eye-tracking software to investigate whether the use of an illustrated text led to better learning than plain text alone. They found that for a factual knowledge assessment, readers with text and illustrations did better than readers with text only. A similar study investigated the use of text-to-diagram referencing compared with the use of text only and found that students who used diagrams along with text performed better than students who just read the
text only on the understanding of simple facts (Jian & Wu, 2015). These studies suggest that the use of diagrams and pictures could help students process the information and better understand what they are reading (Jian & Wu, 2015).

Once new technology became commonplace and easy to use, the use of videos as pedagogical tools was the next logical step from diagrams and photographs and was originally seen as a way to introduce concepts to students that would motivate them to explore the concept further, to understand more, and to examine “what if” questions - therefore allowing them time to bridge the gap between the abstract and the concrete (Zollman & Fuller, 1994). With the rise of computers, the internet, and modern digital camera technologies, video use in the classroom has taken on a new role in learning by giving students the power to conduct their own investigations (Beichner, 1996).

The power of video as an instructional tool has matured and enhanced with the development of video analysis software such as Vernier’s Logger Pro © and Pasco’s © commercial versions, as well as open source freeware such as Tracker (D. Brown & Cox, 2009), and VideoPoint or other technologies developed specifically for the physics classroom (Beichner, 2006). Therefore, instead of videos being used in classrooms for dispensing facts and instruction or as supplemental sources of information, students now can use them as primary learning tools. For example, students can now model air resistance through investigating the motion of falling coffee filters, or they can observe the conservation of momentum through the analysis of 2-dimensional collisions and the center-of-mass frame of reference (Brown, D., & Cox, 2009).
Beichner (1988) was a pioneer in this field, having invented the first program that allowed this type of educational video analysis to be done with computers. Research on the effect of using video analysis in high school and undergraduate physics classrooms shows that integrating video analysis into the curriculum improved students’ abilities to understand kinematics graphs (Beichner, 1996). This technology provides students with the ability to collect real-time data, which can motivate them to want to learn the underlying physics concepts and also provide a way for them to more easily clarify and correct their misconceptions about motion (Beichner, 1999). Work done by Struck and Yerrick (2010) reinforce Beichner’s findings. Struck and Yerrick compared the conceptual understanding of students who used video analysis as the sole lab technology with the conceptual understanding of students who used traditional hands-on probe-ware to record and analyze data. The findings reinforced Beichner’s work, that video analysis based projects more effectively promote student comprehension and understanding of kinetics (the physics of motion) as compared with just using probe-ware alone in the lab.

Video technology use is evolving from analysis of simple kinematic systems to the analysis of previously unavailable situations (e.g., video footage of a rocket launch) which can be imported for analysis (Beichner, 1999). Prior to the use of this technology, beginning physics students would have only been presented these examples through problems and examples in their textbook or notes during lectures. However, the technology has matured, giving students the ability to examine situations and phenomena first hand. For example, work has been done to create artificial videos (videos made from animation software) of physics that are difficult or impractical for many students to observe under typical high school laboratory conditions, such as the Milikan Oil-Drop experiment or similar situations (Gallis, 2010).
Video technologies have allowed students to study other phenomena that are difficult to observe and make measurements on. In a recent study, videos were made of a familiar Lenz’s law demonstration, in which a magnet drops through a long, non-magnetic metal tube and slows down due to forces created because of induced current. Students could then analyze the motion to find the braking force and make measurements of several different types of metals and compare the measured terminal velocities using video analysis (Molina-Bolivar & Abella-Palacios, 2012).

Another common physics problem that students encounter in their textbooks and in introductory physics courses is the confusing concept of centripetal versus the pervasive, but misdirected ‘centrifugal force’ and the Coriolis force. The usual approach to teaching these concepts has been through diagrams and drawings and simple lab activities, but video analysis technology now allows the direct quantitative analysis of the concepts through observations of both the rotating and relative non-rotating systems (Wagner, Altherr, Eckert, & Jodl, 2006). This example is a testimony to the power of the video technology because it demonstrates not only how motion depends on the observer’s frame of reference, but also that the student can now make measurements in both frames of reference at the same time.

Digital camera technology now has advanced to the point that powerful, relatively affordable high-speed cameras are now being used by students to perform analyses on phenomena that were virtually impossible to observe in the average high school physics lab before video technology matured. In one school in the Czech Republic, students used high speed cameras to conduct a variety of investigations on phenomena such as the oscillating light output of an incandescent light bulb, the formation of a water drop, the motion of an oscillating tuning
fork, and falling weights connected by a spring among others (Koupil & Vícha, 2011). These photographic techniques allowed students to slow down fast motion enough to understand what was happening, and to collect measurements as appropriate.

Video analysis technology allows the investigation of concepts that are difficult to explore under normal laboratory conditions. In a study by Phommarach, Wattanakasiwich, and Johnston (2012) video analysis software was used to analyze high speed videos of various hollow and solid cylinders that were rolling down an incline at the critical angle for static friction between a steel and wood surface (Phommarach et al., 2012).

High speed cameras can also be used to study events that occur too quickly to see with the naked eye or with normal speed cameras. In this example, model rockets were launched and video recorded at high speed using a relatively inexpensive Casio EXILIM camera (Desbien, 2011). Desbien then provided the video clips for his conceptual physics classes so that they could analyze the rockets for acceleration. The conceptual physics students found the acceleration of the rocket by finding the slope of the velocity-time graph; more advanced students analyzed more complicated systems that have variable accelerations or test out their own hypotheses.

Another powerful and practical application that video analysis provides is the ability of students to investigate assumptions that they have made about their model. In a study by Gates (2011) students were able to closely watch the motion of a ball after it bounced off of a wall and find that their initial assumptions of the ball having a constant rebound velocity was incorrect. The technology allows for a more detailed examination of the problem and creates a teachable moment.
Video analysis technology also has the powerful advantage of allowing students to explore several variables simultaneously on the same video. For example, in a study of the physics of bungee cords and bungee jumping, students were able to directly measure the position, velocity, and acceleration of the mass on the end of the cord and make conclusions about the forces and momentum experienced by a person engaged in the sport (Heck, Uylings, & Kędzierska, 2010).

Video analysis software and video technology has been used to explore the differences between the performance of radio controlled airplanes as compared with the performance of a real-life Cessna using video analysis technology (Tarantino & Fazio, 2011). Students found significant differences between the results from the model and the real airplane and those differences were attributed to the different aerodynamic properties between the model and full-scale airplane. Perhaps the most beneficial aspect to utilizing video technology in the physics classroom is the power the video analysis software provides to the students to make discoveries based on evidence and their own findings (Wee, Chew, Goh, Tan, & Lee, 2012). As Wee et al. point out, the technology allows students to begin with incomplete models and refine those models to better understand the situation they are investigating. As students refine their understanding of the data they have collected and create more accurate physical models, they will also be pushed to become better at conducting these kinds of investigations and become more comfortable with making discoveries.

Summary

A large gender gap exists between the number of females and males who earn degrees in physics and in the number of females who take physics in high school. Many factors contribute
to the gender gap such as cultural issues like stereotype threat and gender stereotype, but other factors that can be controlled in the classroom contribute as well. Factors such as understanding female students’ motivations and interests can be better used to help these students do better in the course and help them develop more of an affinity for the subject. The incorporation and integration of examples from the biological sciences and medicine into high school and college physics curricula, has been shown to increase female student engagement and interest in the subject by highlighting the relevance of the subject into more affective domains. The role of student choice in the classroom and how it benefits the student is not fully understood, but students who have limited choice in the types of assignments show higher gains in the course than students who have unrestricted choice in their assignments. Student performance in physics is closely tied into student motivation, which has been found to be influenced by the learning tasks students are involved with. Video analysis technology is a powerful and engaging pedagogy in physics that allows students to directly investigate phenomena that they would otherwise have no way of examining. Chapter Three will detail the methods used for this study.
CHAPTER THREE

METHODS

This study is a mixed-methods investigation designed to help us understand more about the role of choice, gender stereotypes, and gender biases in student interest and performance in physics, particularly for female students. Several different instruments were used to investigate the variables. One instrument to present choice (see Appendix D) was developed to determine which of three different contexts that students prefer when presented with a problem on a physics concept. The Force Concept Inventory (FCI), and the Colorado Learning Attitudes towards Science Survey (CLASS) were used in this investigation. The study followed the experimental design shown in Figure 3.1.

Figure 3.1. Experimental design.
The elements of the experimental design shown in Figure 3.1 are described in this chapter.

Participants

Seventy-three student participants, twenty-one females (40.4%) and thirty-one males (59.6%) representing eight different schools from five US states took part in this study (48.6% white, 30.6% Asian, 11.1% Hispanic, 1.4% Native American, 1.4% African American, 2.8% other, 4.2% no response). The students were all currently enrolled and taking either honors physics or AP Physics at their schools. All the students had completed a unit on Newton’s Laws and their applications prior to this study. The Internal Review Board (IRB) at the university (NCSU) approved the proposed study on February 10th, 2016, Protocol #6552. See Appendix A.

IRB Consent Forms

Once IRB approved this study, a letter was sent out to each school’s administration and cooperating teacher. Permission for the research to be conducted in the school was sought from principals and any administration at the district level that was needed. Students were given a consent form and a letter to take home to their parents explaining the research and the student’s role in the research inviting them to participate. The letter consisted of the project description and an invitation for both students and parents. The signed written consent form was returned by the student to the teacher. The cooperating teacher returned all the signed forms to the author. Teachers were also asked to complete a signed consent forms for their part in the study and these were returned to the researcher with the student forms. Teachers were provided with self-addressed stamped envelopes to return all the materials.
Recruitment

Teachers were recruited through personal contacts, the AP Physics Readers list-serves, and professional organization websites (e.g. AAPT, NSTA, NCSTA, etc.) and asked to participate in the study. Upon completion of the study, the teachers were provided with written solutions to each question within the problem set. Participating teachers who complete the full investigation and returned all the requested information were given a $75 Amazon.com gift card at the end of the study. Students who completed the study were given a $10 Amazon.com gift card and extra credit as determined by their teachers.

Contextual Problem Set and Method of Delivery

The sets of physics problems used in this study were delivered to the students through the online homework delivery system WebAssign (www.webassign.net). WebAssign is an integrated online homework delivery system originally developed by Aaron Titus and Larry Martin to allow homework problems to be assigned to students in a multimedia format (Beichner, 2006). This system is a “fully customizable online instructional system” that “instantly assesses individual student performance” (WebAssign, 2015).

The problems used were created to investigate the role that the context of a physics question has on which type of physics problem students prefer, specifically from a standpoint of student gender. The WebAssign problem set instrument consists of a total of twenty-one problem sets made up of sixteen written problems, and five video analysis problems. Each written problem set contains three questions of equivalent difficulty and covering the same physics concept but of different contexts. The video analysis problems also each contain three
questions of equivalent difficulty but from different contexts. The questions were validated and vetted by current physics teachers as described in detail below.

Each problem set consists of the same fundamental physics problem but from the perspective of three different format contexts or biases. The first context is the traditional or classic physics “particle” problem which depicts simple objects with little real life day-to-day relevance. The second question is presented in the context of sports, reflecting examples from baseball, basketball, extreme sports, etc. The third format presents the question from a biological context where each question is presented from the standpoint of an example from nature, biology, or human physiology/health. Students were presented with the choice of one of three different scenarios to select one from. For example, the student was told the question is about the concept of net forces and asked which context they wish to choose to investigate the concept: mass & spring, the high jump, or the baby bird. Figure 3.2 shows the actual view in WebAssign that the student would see.

![Student View of Question Contexts](image)

*Figure 3.2. Student View of Question Contexts.*

The problems were designed to fit into any two-week investigation of Newton’s Laws and forces, but all the participating teachers had already completed this unit by the time of this study. Teachers assigned the problem sets to their students as part of the normal classroom
homework process and most used this as review before the AP exam. The problem set also includes a video analysis section where the questions are presented in the form of an event captured on video so that the students must analyze the video for the data needed to solve the problem. The same three contexts (classic, sports, and biology/health) used in the written problems will be used with the problems using the video analysis. No other variations on the video versions are presented.

Students were asked to report their gender, and other demographic identifying information to track pre/post measures. The teachers were free to give students extra credit in their classes as they determined was appropriate for the work given. In either case of the written or video formats, participants were asked to choose one context per question to answer.

After the students had completed the question, they were asked to write a short description (also in WebAssign) of why they chose that question context over the other choices. In addition to the student description, WebAssign allows easy tracking of student performance on the problems and the context type selected. Teachers were asked to submit examples of questions and problems they used when teaching this unit. These examples were categorized based on their alignment with the same classic, sports, and/or biological/medical physics categories described above and analyzed to see if the nature of the examples given in class impacted other measured outcomes.

*Newton’s Laws and their Applications*

This investigation focused on students in high school honors and AP Physics courses. These courses are traditionally the courses in which students first study Newton’s Laws in great
depth and detail (Walker, 2007). Newton’s Laws and their applications were chosen as the topic to investigate the effects of contexts for several reasons. The topics of Newton’s Laws and their applications are among the most fundamental and commonly taught concepts in high school physics courses (Walker, 2007). This unit of introductory physics is also a well-researched unit with reliable instruments available to measure student conceptual understanding of the principles and student attitudes (Hestenes et al., 1992). Generally, the curricula of the introductory high school physics course cover the topic of Newton’s Laws very thoroughly and early in the course in order to serve as the foundation for learning other physics concepts (Walker, 2007). For example, like many other states the high school physics curriculum in North Carolina starts with the study of linear and two-dimensional motion, and then proceeds to Newton’s Laws and their applications with the following objectives:

- **Analyze forces and systems of forces graphically and numerically using vectors, graphs and calculations.**
- **Analyze systems of forces in one dimension and two dimensions using free body diagrams.**
- **Explain forces using Newton’s Laws of motion as well as the universal law of gravitation.**
- **Explain the effects of forces (including weight, normal, tension, and friction) on objects.**
- **Analyze basic forces related to rotation in a circular path (centripetal force)**
- **Analyze motion in one dimension using time, distance, displacement, velocity, and acceleration.**
- **Analyze motion in two dimensions using angle of trajectory, time, distance, displacement, velocity, and acceleration** (North Carolina Department of Public Instruction, 2017).

The Next Generation Science Standards, used by many states and districts, also highlight the importance of student understanding of Newton’s Laws with the objectives of the standards pertaining with forces and motion:

- **HS-PS2-1 Analyze data to support the claim that Newton’s second law of motion describes the mathematical relationship among the net forces on a macroscopic object, its mass, and its acceleration** [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.](Achieve Inc, 2015).

*Development, Validation and Vetting of Physics Problem Set*

Any high school or college introductory physics textbook that contains a unit on Newton’s Laws and forces provides a rich source of questions and concepts that can be mined for use in the classroom and modified for various uses such as quizzes, tests, homework, and lab problems. The questions that this study used were inspired by problems from various physics textbooks such as Walker’s *Physics* (2007), Halliday, Resnik, and Walker’s *Fundamentals of Physics* (2005), Serway and Faughn’s *Holt Physics* (1999), Giancoli’s *Physics: Principles with Applications* (2004), and Paul Hewitt’s *Conceptual Physics* (2002).
The questions used in this study were written in order to convey the situation in each problem and the related information given as clearly as possible, while also maintaining an appropriate balance between the number of words and sentences used (Miller, 2015). Advice was also taken from Miller’s (2015) work with the Duke Initiative in Survey Methodology to keep the relative frequency of numerical values used in each question balanced between the questions in each set. This was done to prevent any bias a reader may have toward a question with fewer or more numerical values.

To ensure that the three versions of each homework question was equivalent in difficulty and covered the same physics topics and concepts, all three versions of the problems were sent out to two physics instructors (PhDs who’ve taught college physics) and six high school physics teachers (who were not part of the study). Evaluators were asked to evaluate the questions from the perspective of comparing them to the types of problems that would be appropriate to give students taking a high school honors physics course or an AP Physics 1 course (both courses are algebra based, introductory courses). The problem sets were sent out to the evaluators in the form of a Google Form which allowed easy collection of their feedback and comments and was relatively easy to disseminate (see Appendix A for the evaluation form sent to physics teachers). The questions sent out did not contain any photographs or gender specific language or identifiers.

Each question was validated in the context of the other two problems in the set. Evaluators were asked to examine each question and to determine if the following criteria were consistent between the questions within each set: level of difficulty; common concept addressed; and written clarity of the question. The validation scale is a Likert format for the three criteria:
level of difficulty (1=easy; 2=moderate; 3=difficult); content alignment (1 = not aligned; 2=somewhat aligned; 3=completely aligned); question clarity (1=clearly written; 2=somewhat clearly written; 3=not clearly written). Evaluators left open-ended feedback on the clarity of the question and any issues or concerns that might arise because of the wording. Additionally, evaluators left general comments pertaining to the question sets. Results of the vetting and validation process were used to refine the questions on the instrument so that questions in each set of three were equivalent in their level of difficulty, address the same physics concepts, and were clearly written. For example, feedback on one question included comments such as “I think it would be interesting/relevant to ask questions about situations where the purpose is for someone to experience an acceleration…” and “e can be confused with the base of the natural log”, and “…might be rewritten as ‘A Wolf spider with mass of 7.0 e -5 kg is climbing up on its thread toward a tasty fly...’”. These comments and feedback were utilized to make the questions clearer and more streamlined into the questions that make up the third WebAssign problem.

Readability of the questions was analyzed using the Flesch reading ease test and the Flesch-Kincaid grade level readability test (Kincaid, 1975). Both tests use the total number of words in the question, the number of sentences, and the number of syllables in their respective formulas. The score calculated by using the Flesch reading ease test formula indicates the relative understandability of the text (Glynn, 2012) (Kincaid, 1975). The reading ease score of the questions in the problem set was taken from the average of the three contexts (traditional-82.9; biology-82; sports-85) an 83.3, indicating that the questions were easily readable by 13 to 15-year-old students (grades 8-10). The Flesch-Kincaid grade level readability test uses the same variables to produce a value that is equivalent to the approximate US grade level (Kincaid,
1975), (Glynn, 2012). The average value of the questions in this instrument indicate that the questions are being presented on a sixth-grade reading level. Thus, the reading comprehension of the questions should not be a factor in students being able to solve the problems.

**WebAssign and Video Analysis**

WebAssign (www.webassign.net) is the online delivery method that was selected to administer the problem set to the students in this study. WebAssign was developed as an online homework delivery system designed to allow homework problems to be assigned to physics students over the internet, in a multimedia format (Beichner, 2006). This system is a “fully customizable online instructional system” that “instantly assesses individual student performance” (WebAssign, 2015). The technology reduces teacher grading and gives students immediate feedback on their assignments (Bonham, Beichner, Titus, & Martin, 2000).

WebAssign is now a for-profit company that serves teachers of physical and mathematical sciences courses, ranging from secondary school settings to the university, as well as courses in accounting, biology, engineering, social studies, and statistics. Instructors may either purchase question banks with pre-written problems associated with a specific textbook, or they may create their own using WebAssign’s online question editor. For physics teachers and instructors, WebAssign provides banks of free questions from released New York Regency exams, AAPT Physics Olympiad exams, OSU clicker questions, and the Force Concept Inventory. An extensive Instructor’s help guide which includes examples, questions, and step by step tutorials to help anyone make the questions. The question editor provides the instructor with the ability to add videos to the questions and other animation or visuals. The question editor was the tool used to create the questions used in the assignment for this study.
Integrating Video Analysis into WebAssign

Using Vernier’s Logger Pro software, Camtasia Studio 8®, and YouTube; WebAssign was used to deliver the homework problems to the participating high school physics students. The process of creating, analyzing, importing, and embedding the video clips was the same for each context. Initially, several videos were chosen based on the initial vetting process’s criteria of what best represents the physics concept being addressed and then categorized into one of the three contexts described above. Videos were found by searching for various physics related concepts on YouTube or they were used created ‘in-house’ by the author and the author’s students or others at the author’s school. Videos were chosen to represent a variety of different concepts such as circular motion, braking forces, frictional forces (see Table 3.1 for a list of videos used and the concept addressed).

Table 3.1

<table>
<thead>
<tr>
<th>Video</th>
<th>Physics Concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loop-the-loop with ball (Traditional)</td>
<td></td>
</tr>
<tr>
<td>Damien Walters Running Loop-the-loop (Biology)</td>
<td>Centripetal Force</td>
</tr>
<tr>
<td>Terry Grant Sports Car Loop-the-loop (Sports)</td>
<td></td>
</tr>
<tr>
<td>Arrow in Ballistics Gel 9 (Sports)</td>
<td></td>
</tr>
<tr>
<td>787 Landing/braking (Traditional)</td>
<td>Average Stopping Force</td>
</tr>
<tr>
<td>Jumping Frog &amp; landing (Biology)</td>
<td></td>
</tr>
<tr>
<td>Activity</td>
<td>Force Measurements</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>-------------------------------------------</td>
</tr>
<tr>
<td>Ballistics Cart &amp; Ball Bearing (Traditional)</td>
<td></td>
</tr>
<tr>
<td>Salmon Jumping Upstream (Biology)</td>
<td>Average Landing Normal Force</td>
</tr>
<tr>
<td>Car Jumping (Sports)</td>
<td></td>
</tr>
<tr>
<td>Pendulum Swing (Traditional)</td>
<td>Centripetal Force</td>
</tr>
<tr>
<td>Roller Coaster (Sports)</td>
<td></td>
</tr>
<tr>
<td>Corona Arch Swing (Biology)</td>
<td></td>
</tr>
<tr>
<td>Ball Drop (Traditional)</td>
<td></td>
</tr>
<tr>
<td>Highest Human Vertical Jump (Sports)</td>
<td>Normal Force at Landing</td>
</tr>
<tr>
<td>Dolphin Vertical Jump (Biology)</td>
<td></td>
</tr>
<tr>
<td>Baseball Leaving Bat (Traditional)</td>
<td></td>
</tr>
<tr>
<td>Leopard Jump (Biology)</td>
<td>Normal Force</td>
</tr>
<tr>
<td>Bicycle Jump (Sports)</td>
<td></td>
</tr>
</tbody>
</table>

Creating video analysis questions for use in WebAssign was an involved process and careful selection of the videos was important to get the best data possible so that the physics concept was clearly displayed. Once identified, the selected video was downloaded and imported into Camtasia Studio 8®, a video editing software package. The videos were then edited to find a clip that best represented the desired concept that was easiest to analyze with the video analysis software (see Figure 3.3). The clips also had to be of a short enough time so that only the targeted physics concept was seen and efficiently analyzed. Videos were chosen so that the action was in the plane of the screen and the viewer had as close to a fully perpendicular
point of view as possible. In some situations, the videos were cropped and a digital zoom was used to center the image and to render the clearest view possible. These steps made the video easier to analyze for accurate results. In certain clips, the original video speed was reduced to best analyze the motion and for the students to more easily use those clips, the new time scale was incorporated into the video analysis so that the students wouldn’t have to factor that into their work on the solution.

*Figure 3.3. Editing of Video Clip in Camtasia Studios 8®.*

**Analysis**

Once the target video clip was edited and prepared by the author using Camtasia 8®, it was saved as an mp4 file and imported into Logger Pro 3.8.6.1 for analysis. Logger Pro is a proprietary data-collection software package created and sold by Vernier Software and Technology (www.vernier.com). The author’s initial step in analyzing the image began with determining the distance scale represented in the video. For some of the videos, the scale was provided or could be easily found online. For example, in Figure 3.3 above, the video that was used was of the Corona Arch in Utah which has a publicized height that can be found on the
Bureau of Land Management’s website (http://www.blm.gov/). However, some videos did not provide the scale, and an estimate was made by the author based on the subject itself, or an object in the same plane of the picture as the subject. The author utilized the scale feature in Logger Pro, by activating the scale button, and then with the mouse, right-clicked on the starting point where the scale is to be set and then moved the cursor to the end-point of the scale and right-clicked there. A prompt was displayed and the actual, real-world, measurement depicted in the video was entered by the author along with the corresponding correct units (meters were used for these videos).

Once the scale was determined and entered, a point of origin was selected in the video so that the subsequent data points represented the proper direction. The data points were plotted by advancing the video, frame by frame, and using the plot feature in Logger Pro until the desired motion was complete and the video and the data plot were synchronized (if they weren’t so initially). A curve fit was then added once the data points were plotted and displayed. The displayed curve fit was chosen based on the phenomena being investigated and the concepts that were intended for the students to learn. In most cases either a linear fit or a quadratic fit were the most appropriate for the situations being addressed by the problems. The windows displayed on the Logger Pro page were arranged so that all the information was clearly displayed and presented. Figure 3.4 shows the finished video analysis product after a video of a landing plane has been inserted and analyzed by a group of students.
After the analysis was completed in Logger Pro, a new video clip of the original video being analyzed had to be created. Using the screen capture feature of Camtasia Studios 8®, a video was created by the author of the completed data analysis and video page (see Figure 3.5). As the video ran, the displayed results were then edited, saved and uploaded to YouTube.
Creating Questions in WebAssign

Once the video was created, analyzed, and prepared for export by the author, it was embedded into a WebAssign question. Questions were created by using the question editor. To create a successful question, it was helpful to consult WebAssign’s extensive ‘Instructor Help’ section, which describes how to create questions for various subjects (chemistry, math, and physics) as well as how to create different formats of questions (multiple choice, short answer, and numerical response). Some experience writing computer code is helpful, but not necessary. Question templates and sample questions were provided, as were video tutorials.

The general format of the video questions created for this study consisted of three student steps: 1) analyze the video for a specific variable, such as a final speed, or an acceleration from the slope of the line and the regression analysis; 2) calculate a quantity such as a force based on the data mined for step 1; 3) explain why she/he chose that video context (traditional, sports,
biological/health) to complete. [Note: these choices were not labeled, so it was up to the student to interpret the context of the question.]

The questions were coded in WebAssign’s editor by the author (see Figure 3.6) which prompts the user to enter in the name of the question and the type of question being created. The editor consists of a window where the computer code for the question was written. The code includes the full question as it is intended to be presented. Below the question editor window is the answer editor window which corresponds to the questions created in the window above. Below in the answer editor, the correct answer (numerical or otherwise) was entered to set up WebAssign’s automatic scoring feature. WebAssign has a feature that allows the creator of the question to create variables within the problem that are randomized for each student. This feature ensures that every student working on the same problem will have unique numerical values that they must use to solve the problem. If the questions utilize the randomization feature for the variables, the user must enter in the equation, linked to the randomized variables in the problem, which provides the correct answer in the answer editor window.
To create the items, the author used WebAssign’s “Instructor Help” online manual (under the ‘Create Questions’ tab there is a section labeled ‘Format Questions’) which described the steps to add multimedia and add links to external resources (such as YouTube; see Figure 3.6). There is an extensive library of free questions and the underlying code. The code was copied, or modified by the author to create some of the written and video questions (see Figure 3.7).
It is important to discuss the tolerance parameters of each question here. Students may round numerical values differently than the instructor intends, such as with the acceleration due to gravity which could take on values ranging from 9.8 m/s², 10 m/s², 9.81 m/s², and so on. In the everyday classroom setting this is usually nothing more than an annoying habit that can be overlooked; in WebAssign, a student could be doing the problem correctly, but have their answer scored as incorrect. This could cause students to get frustrated with the problem or WebAssign if they thought they were solving the problem correctly but it was counted wrong. This issue can be addressed through the tolerance of the question. The tolerance allows for a range to be set around the correct numerical answer so that small variations in significant digits and rounding won’t affect a student’s score. Figure 3.7 shows the question editor window and below that the answer editor window. The numbers next to the -tab- command are the tolerance ranges for each answer. These should be set by the instructor who creates the question, keeping in mind the
nature of the assignment and the students. In Figure 3.8 under the circle, the correct answer is set as <eqn $acc> and the tolerance is set as 3.

![Figure 3.8. Coded Question and Answer in WebAssign Editor.](image)

The questions that were created for this study took advantage of one of WebAssign’s most powerful features; the ability to create questions using randomized variables. This feature helps to individualize each student’s question so that each student must perform calculations
using the numbers provided in their problem to get the correct solution. This feature was used in both the written questions and the video analysis questions created for this study. Since the video data couldn’t be randomized, other variables such as mass, a secondary distance, velocity, etc. were randomized for each question. In Figure 3.7 the command ‘randnum (190,210,1)’ is being used to generate a value for a mass used in the question. The value of the mass would be between 190 and 210 (kilograms were the units used) and each random value would be automatically generated by the program in this range, with a step no larger than 1.

Once the question is coded, the author tested the problems to make sure that every part was working properly. The editor provides a view of the question through the Question Previewer feature (see Figure 3.9) and when ready, the user can enter their answers in the boxes provided and click on the ‘submit’ button to test it out. Any randomized variables will appear in red in the question and will change each time the question is attempted. The video should also be examined in the test window so that the information needed for the question is visible. If the resolution of the information from the regression line is not visible, then the video should be magnified in the video editor to ensure the information is viewable to the student.
Following a successful test of the question, it can then be added to an assignment and distributed to the students as needed.

**Survey Instruments**

**Colorado Learning Attitudes about Science Survey (CLASS)**

Students were given the Physics version of the Colorado Learning Attitudes about Science Survey (CLASS) (see Appendix B) to measure their beliefs and attitudes about physics prior to and after the delivery of the WebAssign instrument. CLASS was chosen for several reasons. It is a vetted, validated, and reliable attitudes survey with a version specifically designed for students taking physics that has been shown to be robust across a wide range of distributions (Wendy K Adams, Perkins, Dubson, Finkelstein, & Wieman, 2004; W. K. Adams et al., 2006). Adams et al. designed the CLASS with seven predetermined constructs and, of those,
there are two that specifically measure student perceptions about the real-world connections that physics has and student interests in physics (W. K. Adams et al., 2006). Historically, as Adams points out, the results from CLASS has shown considerable differences in the constructs of real world connections and personal interest in the responses by male and female students in introductory college physics courses. Finally, CLASS is freely available online (https://www.colorado.edu/sei/surveys/Faculty/CLASS-PHYS-faculty.html) and easy to adapt and deliver through WebAssign. The authors give permission for personal use on the website.

**Force Concept Inventory (FCI)**

Conceptual understanding of Newtonian concepts was measured, before and after the delivery of the problem sets, by using relevant items from the Force Concept Inventory (FCI) (see Appendix C). The FCI was developed in the early 1990’s by physics educators who saw the need to more fully understand student misconceptions in order to design more effective introductory physics courses (Hestenes et al., 1992). The Force Concept Inventory was designed specifically around what the authors called “commonsense alternatives” to actual Newtonian physics since, as Hestenes, Wells, and Swackhamer (1992) found, many students coming into introductory physics courses fail to grasp Newtonian concepts but instead rely on their own misconceptions and beliefs that do not match scientific explanations. The authors also point out that this chronic conceptual misunderstanding is due to the way that physics is taught. The FCI has been validated and has been found to be a reliable tool for identifying how much students understand about the physics concepts of Newton’s Laws and forces (Hestenes et al., 1992).
Summary

In this chapter the description of how the participants were recruited was discussed and the development process of the conceptual problems was described. The validation and vetting process of the contextual problems were discussed. The development of the video analysis problems and the written problems was explained and how they were edited in WebAssign was detailed. Then the CLASS (Wendy K Adams et al., 2004) was discussed and how it was going to be used to measure changes in students’ attitudes and interests toward physics. The FCI (Hestenes et al., 1992) was described and how it was used to evaluate students’ understandings of physics concepts centered around Newton’s Laws. In Chapter Four, the findings will be presented followed by a discussion in Chapter Five and conclusions and implications from this study in Chapter Six.
CHAPTER FOUR

FINDINGS

In this chapter, the findings will be presented beginning with the choices students made when selecting physics problems and their rationale for these selections. Next, students’ achievement on the Force Concept Inventory (FCI) will be presented and whether or not they had growth from pre to post inventory and whether their achievement was linked to the context of physics problems that they selected. Finally, students’ attitudes toward, beliefs about, and interests in physics will be presented based on results from the physics version of the Colorado Learning Attitudes About Science Survey (CLASS), both pre and post intervention, and whether there are relationships to achievement or choice.

Physics Problem Set: Contexts Selected by Students

The physics problem set for this study, on WebAssign, consisted of twenty-one problems. Fifty-two student participants, twenty-one females (40.4%) and thirty-one males (59.6%) completed ninety percent or more of the problems in the assignment. The ninety percent threshold was chosen examining the data and the responses given in the WebAssign assignment set. The majority of the fifty-two students completed all twenty-one problems, with only a few students leaving two or fewer problems blank. A total of twenty out of the one-thousand ninety-two responses assigned on homework questions were left blank and were not used in the study. Students who left the questions blank were not penalized.

The breakdown of the context choices made by students can be seen in Table 4.1. The value listed for students described as “1st Choice Combo” were students who answered questions
in more than one of the possible contexts but whose first choice was counted here. Students were asked to complete one context choice per problem, and reminded that they did not receive any extra credit for completing additional versions of the problem, but most students completed a second context, by choice.

Table 4.1

*Student Choices of Question Context by Gender*

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of Students</th>
<th>Traditional Contexts Chosen</th>
<th>Biology Contexts Chosen</th>
<th>Sports Contexts Chosen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>%</td>
<td>Total</td>
<td>%</td>
</tr>
<tr>
<td>Female</td>
<td>21</td>
<td>154</td>
<td>34.9</td>
<td>166</td>
</tr>
<tr>
<td>Male</td>
<td>31</td>
<td>253</td>
<td>38.9</td>
<td>216</td>
</tr>
<tr>
<td>Female 1\textsuperscript{st} Choice Combo</td>
<td>11</td>
<td>83</td>
<td>32.9</td>
<td>100</td>
</tr>
<tr>
<td>Male 1\textsuperscript{st} Choice Combo</td>
<td>21</td>
<td>168</td>
<td>38.1</td>
<td>147</td>
</tr>
<tr>
<td>Female No Combo</td>
<td>9</td>
<td>71</td>
<td>37.6</td>
<td>66</td>
</tr>
<tr>
<td>Male No Combo</td>
<td>10</td>
<td>85</td>
<td>40.5</td>
<td>69</td>
</tr>
</tbody>
</table>

Note: Each row may not add up to 100% because some of the options were not selected, although this only represents fewer than 2% of the choices.

Table 4.1 represents the number of each context chosen by each student group. The groups were categorized by gender (male and female) and then by the number of question contexts students chose to complete. For example, 21 female students made choices on 21 questions for a total of 441 possible selections; 31 males had 21 choices and 651 possible selections. The difference between the total possible number of selections and the actual number
of selections recorded are due to students who did not complete a question and is reflected by the note indicating that fewer than 2% of the questions were answered.

The groups above were separated into student groups that either attempted only one question context or attempted a second or third question context for each problem. Table 4.1 presents the initial context choice that was made by either group. “Female 1st Choice Combo” refers to female students who chose to complete a second question context, but whose first choice was one of the three contexts listed in Table 4.1. Similarly, “Female No Combo” refers to female students who chose one question and did not attempt a second question context.

Overall, the female group was more likely to choose the biology context (37.6%) over the traditional or sports context, as compared with the total male group, who chose the biology context 33.2% of the time ($p = 0.038$). In the “Female 1st Choice Combo” category, female students were more likely to choose to do the biology context (39.7%) over the other contexts as well as choosing biology more often than the male students who also chose to complete a second question (males’ selection of biology as part of a combo, 33.3%). The trend did not continue for the female students who did not choose to complete a second question; rather, this group chose the traditional context (37.6%) more often than they did the biology (34.9%) or sports context (25.9%). Each male group chose the traditional contexts (males with combo 38.1%; males without combo 40.5%) over the other two, with approximately the same rate (biology-with combo 33.3%; without combo 32.9%; sports-with combo 27.4%; without combo 26.2%). Less than two percent of the questions were not answered by each group and did not significantly affect the total.
**Student Rationale**

The motivations for all the student’s choices were measured qualitatively through their written responses in WebAssign. After completing each question, students were asked to give the reason why they chose the particular question context by writing a short answer response in WebAssign. As described in the Methods, codes were developed by reading through the student responses and creating categories that corresponded to their explanations. Once the initial categories (# you started with) were developed, they were collapsed into similar categories (5) by the author. Coding of all responses were conducted blinded to any demographic information of the students. An independent physics education researcher took students’ responses and coded them using the five codes. The author and second researcher coded the entries independently and then compared their results. Differences between the results were discussed and resolved after careful evaluation and refinement of the coding scheme in which two of the codes (3-random choice and 4-no preference) were collapsed into one. After the refinements, the final inter-rater reliability was found using Cohen’s kappa to be 0.875 (87.5%) agreement. The responses were coded using the following key:

- 1- Interest
- 2- Familiarity of the problem
- 3- Random Choice
- 4- No preference
- 5- Easy, straightforward, etc.
The response totals were calculated for both males and females and are presented in Table 4.2. Five male students indicated in their responses that they chose a question because they were looking for a challenge. This was initially coded as a -5 (the opposite of easy). However, this number represented only fourteen responses out of the total 787 male responses given, or 1.78%. Therefore, these responses were removed from the totals of the male students from the ‘Easy, Straightforward’ category, and is denoted by the *.

Table 4.2

*Student rationale for context choices, by gender (in percentage)*

<table>
<thead>
<tr>
<th></th>
<th>Interest</th>
<th>Familiar</th>
<th>Random/No Preference</th>
<th>Easy, Straightforward</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>34.3</td>
<td>17.6</td>
<td>15.0</td>
<td>32.6</td>
</tr>
<tr>
<td>Male</td>
<td>45.2</td>
<td>12.3</td>
<td>15.6</td>
<td>25.0*</td>
</tr>
</tbody>
</table>

Table 4.2 shows males were most likely to choose a question because they were interested in it. However, while the main reason females gave for choosing a question was interest, they almost equally selected a question because they perceived it to be easy or straightforward.

Figure 4.1 shows the breakdown (by percentage) of the categories students labeled their context choices.
As described earlier, students were not directed nor expected to complete a second question from the same problem set. In fact, the directions given at the beginning of the assignment stated that students would not earn extra points for doing additional problems. However, many students did choose to investigate multiple contexts associated with each problem. The percentage of students who chose combinations for each of the six video question contexts are displayed in Figure 4.1, by gender. Figure 4.2 shows the percentage of students who chose combinations for each context for the nineteen word problems.
Figure 4.2. Percentage of video questions combinations selected by gender.

Figure 4.3. Percentage of word problem combinations selected by gender.
Figures 4.2 and 4.3 show the actual number of combinations chosen, by gender, for each question. There were eight questions that had more combinations of contexts selected than the other questions. Two of these were word problems and six were video questions. Questions 5V, 10V, 15V, 16V, 20V, and 21V are questions in which the question was presented in the form of a video that was used as a part of the question’s data analysis. Problem 5V deals with circular forces (ball in loop, running man in loop, car in loop); problem 10V is a problem about friction/resistive forces (arrow in gel, plane landing, frog jumping); problem 15V deals with normal forces (ballistics cart, salmon jump, car jump rope); 16V deals with circular forces (pendulum swing, roller coaster, human arch swing); 20V deals with normal forces (ball drop, standing jump, dolphin jump); and 21V also deals with normal forces (baseball & bat, leopard jump, mountain bike jump). Word problems 3 and 13 were the word problems with the most number of multiple contexts chosen. Problem 3 was a word problem dealing with tension in a taut line (spider & thread; mountain climber & rope; elevator & cable), and problem 13 dealt with the normal force of an object and the ground (rocket lift off; kitten jump; standing high jump).

Sample student written responses are presented in Table 4.3 that explain why students chose the context they did. Under the question context column, the question number is shown with a (V) if the question was a video question, followed by either a (t, b, and/or s) to represent the question context. The contexts shown were chosen because there was equal feedback from male and female students. The percentages in the far-right column represent the breakdown of students by gender who chose to do these question contexts.
Table 4.3

Sample male and female student responses for choosing video and word problems.

<table>
<thead>
<tr>
<th>Question (Context)</th>
<th>Student Response</th>
<th>% of gender who chose this question</th>
</tr>
</thead>
</table>
| 5V(t)              | M  ● Imagining yourself being the one to run the loop-the-loop makes the problem easier to think about.  
                  ● The ball in a loop seemed kind of boring, and the car in a loop isn't that impressive, but a human running in a perfect loop is pretty cool.  
                  ● I enjoyed seeing the 5 second video and was motivated to actually complete the problem because of it.  
                  ● This problem seemed more interesting than the other ones did  
                  F  ● Because it's more impressive than the others, and cool to watch and think about.  
                  ● ITS GOT A HUMAN and its cool! I think I did it the correct way and I have looked through my notes to find it.  
                  ● This is so cool!!! I wish I could run this loop tbh  
                  ● The context of this problem was more interesting.  | 57.1                               |
| 10V(s)             | M  ● I chose this problem because it is on a topic that interests me.  
                  ● I found it most interesting  
                  ● I choose this because I shoot bow and arrow sometimes and I thought it was cool.  
                  ● The context was interesting, as I have not seen an object slow in its velocity due to a solid.  | 62.5                               |
|                    | F  ● I like frogs.  
                  ● I like to deal with constant acceleration and position  
                  ● A jumping frog is easy to picture.  
                  ● I feel more confident calculating parabolas.  | 37.5                               |
| 15V(t/b)           | M  ● It seems most like the problems I've done before.  
                  ● I like LoggerPro. Easy to use and this looks simple  
                  ● The graph made it easy to utilize the values in the problem.  
                  ● We've done ballistic cart analyses in class before.  | 66.7                               |
|                    | F  ● I chose this problem because the physics involved with the salmon jump apply to real world issues.  
                  ● Fish are pretty cool and more exciting than carts.  
                  ● Fish are interesting, especially jumping ones. Asian Carps are powerful jumpers, and sometimes they cause severe injuries when they hit people while jumping.  | 33.3                               |
| Table 4.3 Continued |
|---------------------|------------------|------|
| 16V(t) M | ● *It's the most like previous problems I've done.*  
 ● *We've done pendulum analyses in some of my other classes before.*  
 ● *Pendulums remind me of a swing which I can relate to.*  
 ● *We did a lab like this in class!*  
 | F | ● *I remember doing a demonstration similar to this problem.*  
 ● *I'm good at solving pendulum problems usually.*  
 ● *This graph in this question looked the nicest. Other than that, there was really no other reason.*  
 ● *Type of mechanics I am most familiar with.*  
 | 54.5 |
| 20V(t) M | ● *This version is the most like previous problems I've done.*  
 ● *We've done ball drop problems in class before.*  
 ● *Seemed clear and simple; the example is a simple ball being dropped.*  
 ● *I have dropped a ball plenty of times and is easy for me to interpret.*  
 | F | ● *This seemed like the most straightforward and simple of the three questions.*  
 ● *It was the easiest to understand.*  
 ● *The question was straight-forward and simple.*  
 ● *Long ball problems make sense to me.*  
 | 71.4 |
| 21V(b) M | ● *Leopards are more interesting to me.*  
 ● *Because big cats are interesting and I enjoy learning about them.*  
 ● *I like questions involving animals it seemed the most interesting.*  
 | F | ● *Easiest to visualize.*  
 ● *I chose this problem because leopards are cooler than bikes and baseball.*  
 ● *This video was interesting.*  
 ● *I like leopards and this reminds me of previous problems.*  
 | 83.3 |
| 3(b) M | ● *The problem, as I read it, was extremely straightforward and I knew what I needed to do to solve it immediately.*  
 ● *This question applied physics to a context in a different area of science, which I found interesting.*  
 ● *I chose this version because it sounded the coolest.*  
 ● *I thought that incorporating "spider" and "fly" made it interesting.*  
 | F | ● *This problem was straightforward and easy to understand.*  
 ● *The context was interesting.*  
 ● *Animals make the problem more relatable and "friendly of sorts".*  
 ● *I like spiders, so the name of this questions stood out to me.*  
 ● *I thought it was pretty easy.*  
 | 75 |
Table 4.3 Continued

<table>
<thead>
<tr>
<th>13(t)</th>
<th>M</th>
<th>Rockets are cooler than kittens or people.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>● Rockets are interesting and we launched model rockets in class</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● I was interested in the question which involved rockets</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● It seemed the most interesting</td>
</tr>
<tr>
<td>F</td>
<td></td>
<td>I remember doing a problem similar to this for homework.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● I really love kittens, so this problem was more interesting for me than the rest.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● Rockets are probably the best example of physics in action.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● I have a weakness for cuddly kittens.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● The question is, how can anyone NOT choose a question about cuddly kittens?</td>
</tr>
</tbody>
</table>

Note: M = male; F = female.

The main reasons offered for choosing a context, for both males and females, was interest in the context and the “cool” factor of the video. These rationales given by students seem to have led them to select multiple videos to watch, and then to collect the data needed to complete additional problems (from a different video context). For example, students wrote explanations for their choices such as they “love kittens (both males and females)” or have a “weakness for cuddly kittens (females)” or that they “like spiders (females).”

**Number of Submissions on Problems**

**Choice Trends**

The trends in students’ choices of context were examined to get a better understanding of how students’ interests changed over the course of the project. Students were given five chances to correctly answer each question that they chose, regardless of the context. Four trends were examined: female students choosing more than one context; female students choosing only one context; male students choosing more than one context; and male students choosing only one context.
Females who chose to complete multiple contexts tended to select more traditional contexts throughout the project and fewer sports contexts, while their choices of the biology context remained relatively constant. Females who chose only one context tended to select more biology contexts and fewer traditional contexts across the project, while the number of sports contexts remained stable. Males who selected multiple contexts tended to select more biology contexts and fewer sports questions while the number of traditional contexts remained relatively stable. Males who chose only one context tended to select more traditional questions and tended to select slightly fewer sports and biology contexts across the duration of the project.

The total number of each combination for males was seventy-one and the total number for females was thirty-seven. The breakdown of each category by percentage was found recorded in Table 4.4. Twenty-one (68%) male students and eleven (52%) female students chose more than one context to complete.

Table 4.4

<table>
<thead>
<tr>
<th>Context pairs selected, by gender (percentage)</th>
<th>Traditional/Biology %</th>
<th>Traditional/Sports %</th>
<th>Biology/Sports %</th>
<th>All Contexts %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>22</td>
<td>30</td>
<td>22</td>
<td>27</td>
</tr>
<tr>
<td>Male</td>
<td>24</td>
<td>21</td>
<td>28</td>
<td>27</td>
</tr>
</tbody>
</table>
Overall, males selected more context pair choices than females, however, there were more male participants than female participants. When looking at the percentage of choices per gender, 52% of females chose multiple contexts and 68% of males did. The highest rate of context pair choices for female students was the Traditional/Sports context pair choices. Male students’ highest rate of choice for context pairs was for Biology/Sports. Both females’ and males’ second highest combination was completing every context in the problem.

Several questions were rarely chosen by students for a second context. Questions 9, 14, 17, and 19 each were selected two or fewer times as a second context. Question 9 is a conceptual question about Newton’s First law in which the numbers in the question were irrelevant to the final answer. In each context for this item, the subjects (bighorn sheep butting heads, soccer players colliding, or cars colliding) are given and the students are asked to find the sheep, soccer player, or car that experiences the greater impact force. The remaining questions all deal in some way with applications of Newton’s Second Law, which details the definition of a net force acting on an object. Question 14 asks students to find a height reached by a spring/frog/basketball player after applying a force to the ground. Question 17 focuses on the circular forces experienced by a hamster/circus performer/ball. Question 19 addresses the concept of kinetic friction experienced by a downhill skier/box/penguin. The one theme common to the last three questions is each of these questions require the application of Newton’s Second Law to solve for the unknowns. While in the first question, 9, students unfamiliar with the concept might think they needed to apply Newton’s Second law to solve the problem. Each question had a high average percentage correct score: question 9- 100%; question 14-94%; question 17-97%; and question 19-84%.
Order of Choice

The order of student choice was examined between the possible pair combinations that a student could make. The order of the choices being made was examined to see if there were any patterns in how students selected a second context or if there were any changes between the first selection and the second. Table 4.5 shows the choice combination with the average number of correct responses and the number of submissions for each context for all students.

Table 4.5

Question Choice Combination for All Students (by Average Values)

<table>
<thead>
<tr>
<th>Choice Pair</th>
<th>n</th>
<th>First Choice</th>
<th>Second Choice</th>
<th>Last Choice (for ‘All’ Category)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>% correct</td>
<td>% correct</td>
<td>% correct</td>
</tr>
<tr>
<td></td>
<td></td>
<td># submissions</td>
<td># submissions</td>
<td># submissions</td>
</tr>
<tr>
<td>Bio-Sports*</td>
<td>18</td>
<td>77.8</td>
<td>52.8</td>
<td>1.67</td>
</tr>
<tr>
<td>Sports-Trad</td>
<td>16</td>
<td>59.4</td>
<td>56.3</td>
<td>3.19</td>
</tr>
<tr>
<td>Trad-Bio</td>
<td>14</td>
<td>85.7</td>
<td>46.4</td>
<td>2.57</td>
</tr>
<tr>
<td>Trad-All</td>
<td>14</td>
<td>85.7</td>
<td>42.9</td>
<td>2.57</td>
</tr>
<tr>
<td>Bio-Trad</td>
<td>11</td>
<td>80.3</td>
<td>45.5</td>
<td>2.27</td>
</tr>
<tr>
<td>Bio-All</td>
<td>11</td>
<td>81.8</td>
<td>27.3</td>
<td>3.00</td>
</tr>
</tbody>
</table>
Table 4.5 Continued

<table>
<thead>
<tr>
<th>Sports-Bio</th>
<th>10</th>
<th>60.0</th>
<th>3.70</th>
<th>45.0</th>
<th>2.50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trad-Sports</td>
<td>10</td>
<td>80.0</td>
<td>2.8</td>
<td>15.0</td>
<td>1.1</td>
</tr>
<tr>
<td>Sports-All</td>
<td>4</td>
<td>62.5</td>
<td>4.25</td>
<td>50.0</td>
<td>3.50</td>
</tr>
<tr>
<td>Average (unweighted)</td>
<td>74.8</td>
<td>2.84</td>
<td>44.9</td>
<td>2.43</td>
<td>27.6</td>
</tr>
</tbody>
</table>

*Note: For all choice pairs, the one listed first was the first choice, and the one listed second was the second choice.

The “percent correct” value (the student’s score on the questions) represented in Table 4.5 by % correct, was found by treating each question as having a total number correct value of 1. Each subsequent part of a question correctly answered was given a value representing the fraction of the total correctly answered parts possible. If a question had two parts and if a student did not get a part correct then the total percentage correct would be a 50.0, and so on, if the question had more than two parts. Students were allowed a maximum of five submissions for each part of each question before the program locked them out from any further attempts. The data in Table 4.5 was not broken down by gender because of the limited number of responses by gender in each context pair category. Students results used in this section represent students who chose to do more than one context per problem, but they may only have made that choice for one of the twenty-one total problems on the assignment and not in every question on the assignment. Even though a context pair category may have multiple responses, only one or two female responses may have been submitted.
The data from Table 4.5 shows that students who chose more than one context scored higher on their first-choice context than any of their other choices, regardless of the context pair category. These students also used more submissions on the first context for every context pair, except the Bio-All, Sports-Trad, and Bio-Trad context pairs. Table 4.6 shows the number of correct responses and submission for each choice, by gender.

Table 4.6

Average Score of Responses and Submissions by Gender.

<table>
<thead>
<tr>
<th>Gender</th>
<th>First Choice</th>
<th></th>
<th>Second Choice</th>
<th></th>
<th>Last Choice (for ‘All’ Category)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% correct</td>
<td># submissions</td>
<td>% correct</td>
<td># submissions</td>
<td>% correct</td>
<td># submissions</td>
</tr>
<tr>
<td>Female</td>
<td>85.1*</td>
<td>2.11</td>
<td>40.5</td>
<td>2.30</td>
<td>33.3</td>
<td>2.89</td>
</tr>
<tr>
<td>Male</td>
<td>69.5</td>
<td>3.22***</td>
<td>47.2</td>
<td>2.49</td>
<td>25.0</td>
<td>2.55</td>
</tr>
</tbody>
</table>

Note: *p ≤ .05. **p ≤ .01. ***p ≤ .001

Data Table 4.6 represents the average number of correct responses and the number of submissions by gender for each subsequent context choice. The means were compared using two-sample t-tests assuming unequal variances. Females who chose multiple contexts per question had significantly more correct responses on their first choice and achieved that with significantly fewer submissions than male students who also chose to complete multiple contexts.
The data were analyzed to see if students were more likely to get questions correct if they chose more than one context. Student responses were broken into two groups: the group that completed multiple contexts and the group that only chose to complete one context. Table 4.7 shows the average percentage of correct responses and the average number of submissions by question context for the four groups of students: females who chose a combination; males who chose a combination; females who didn’t choose a combination; males who didn’t choose a combination. These averages below are from every student’s results on each question they responded to.

Table 4.7

Average score of responses and submissions by category.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Traditional Contexts</th>
<th>Biology Contexts</th>
<th>Sports Contexts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% correct</td>
<td>#Submissions</td>
<td>% correct</td>
</tr>
<tr>
<td>Females who chose a combination</td>
<td>73.7</td>
<td>2.24</td>
<td>83.1</td>
</tr>
<tr>
<td>Males who chose a combination</td>
<td>74.9</td>
<td>2.292</td>
<td>76.3</td>
</tr>
<tr>
<td>Females who did not choose a combination</td>
<td>59.9</td>
<td>3.17</td>
<td>86.9</td>
</tr>
<tr>
<td>Males who did not choose a combination</td>
<td>85.1</td>
<td>1.80</td>
<td>91.3</td>
</tr>
</tbody>
</table>

From Table 4.7 we see that for every gender and group, students scored highest on the biology contexts than any other context. This trend follows with the traditional context which is
the second highest score correct for every gender and group, and then the sports contexts which has the lowest score correct for each gender and group. The number of submissions does not follow such a simple pattern, but the general trend is that questions that have more submissions indicated that student stayed with the problem longer, while fewer submissions indicated the student either got the problem correct quicker or gave up on the problem earlier. For both groups of female students, the number of submissions for the biology context is smaller compared with the other contexts. The high score on the biology contexts and the low number of submissions indicate that female students had an easier time with the biology context questions than the other contexts.

To determine the significance of these differences, analyses were conducted to see if students were more likely to answer a question correctly if they completed a question combination than if they did not (see Table 4.7). The mean percentages of their questions (from table 4.7) were compared using two-sample t-tests, assuming unequal variances and the results are displayed on Table 4.8. Highlighted terms indicate which subject group had the higher context scores.

Table 4.8

<table>
<thead>
<tr>
<th>Groups Compared</th>
<th>% Correct</th>
<th># Submissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p-value</td>
<td>p-value</td>
</tr>
<tr>
<td>Trad Male no combo vs</td>
<td>4.88e5***</td>
<td>4.96e8***</td>
</tr>
<tr>
<td>Female no combo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bio Male no combo vs Male with</td>
<td>0.0001***</td>
<td>0.016*</td>
</tr>
<tr>
<td>combo</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4.8 Continued

<table>
<thead>
<tr>
<th>Context Combination</th>
<th>p-value</th>
<th>E-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sports Male no combo vs Female no combo</td>
<td>0.0012**</td>
<td>$8.01e^{-5}$***</td>
</tr>
<tr>
<td>Trad Male no combo vs Male with combo</td>
<td>0.009**</td>
<td>0.001***</td>
</tr>
<tr>
<td>Sports Female no combo vs Female with combo</td>
<td>0.017*</td>
<td>$8.52e^{-7}$***</td>
</tr>
<tr>
<td>Trad Female no combo vs Female with combo</td>
<td>0.02*</td>
<td>0.00016***</td>
</tr>
<tr>
<td>Bio Male with combo vs Female with combo</td>
<td>0.036*</td>
<td>$1.27e^{-5}$***</td>
</tr>
<tr>
<td>Bio Male no combo vs Female no combo</td>
<td>0.281</td>
<td>0.016*</td>
</tr>
<tr>
<td>Bio Female no combo vs Female with combo</td>
<td>0.299</td>
<td>0.00037***</td>
</tr>
</tbody>
</table>

Note. *p ≤ .05. **p ≤ .01. ***p ≤ .001

Males who chose not to complete combinations of contexts had significantly higher scores, and used significantly fewer submissions on the traditional context than females who chose no combinations. This indicates the male were repeating their attempts on that question less than the females. Since the males had a higher score and uses fewer submissions than the females, the males seemed to have found this question easier than the females.

Males who chose only one context also used significantly fewer submissions on the traditional context questions than males who chose multiple contexts and females who did not. For the biology context, males who did not choose many contexts scored significantly higher on the problems than males with combinations and used significantly fewer submissions to answer the problems. On the sports context, males who did not choose multiple contexts scored
significantly higher and used significantly fewer submissions than females who did not choose to complete multiple contexts.

Females who chose to complete multiple contexts had significantly higher scores on the sports contexts and used significantly fewer submissions than females who did not choose combinations. Females with combinations had significantly higher scores on the traditional contexts and used significantly fewer submissions than females who did not choose combinations. For the biology contexts, females who chose to do combinations of contexts had significantly higher scores on the problems and used significantly fewer submissions to complete the problems than males who chose to complete combinations.

To see if there were any differences between performance on the video questions, the results for just the video context questions were found and separated by gender and then by whether the student had chosen to do a combination of contexts or not. Table 4.9 displays the average decimal percentage correct that each group got and the average number of submissions by context.

### Table 4.9

*Average Percentage of Responses Correct and # Submissions by Category of Video Questions.*

<table>
<thead>
<tr>
<th>Gender</th>
<th>Traditional Contexts Video</th>
<th>Biology Contexts Video</th>
<th>Sports Contexts Video</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% correct</td>
<td>#submissions</td>
<td>% correct</td>
</tr>
<tr>
<td>Females Total</td>
<td>66.0</td>
<td>3.02</td>
<td><strong>69.8</strong></td>
</tr>
<tr>
<td>Males Total</td>
<td>71.5</td>
<td>2.52</td>
<td><strong>73.0</strong></td>
</tr>
</tbody>
</table>
Table 4.9 Continued

<table>
<thead>
<tr>
<th></th>
<th>% Correct</th>
<th>p-value</th>
<th># Submissions p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females who chose a combination</td>
<td>72.6</td>
<td>2.58</td>
<td>71.1</td>
</tr>
<tr>
<td>Males who chose a combination</td>
<td>71.0</td>
<td>2.58</td>
<td>67.3</td>
</tr>
<tr>
<td>Females who did not choose a combination</td>
<td>57.1</td>
<td>3.57</td>
<td>73.5</td>
</tr>
<tr>
<td>Males who did not choose a combination</td>
<td>78.0</td>
<td>2.16</td>
<td>88.2</td>
</tr>
</tbody>
</table>

The means from Table 4.9 were compared using two-sample t-tests assuming unequal variances. The $p$-values found of the comparisons were categorized and placed into Table 4.10 based on the context addressed. Highlighted terms indicate which subject group had the higher context scores.

Table 4.10

*Significant Differences in Response Score and Submissions Video Format.*

<table>
<thead>
<tr>
<th>Video Format</th>
<th>% Correct</th>
<th>p-value</th>
<th># Submissions</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bio Male no combo vs Male with combo</td>
<td>0.0068**</td>
<td>0.458</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sports Female no combo vs Female with combo</td>
<td>0.025*</td>
<td></td>
<td>0.0013**</td>
<td></td>
</tr>
<tr>
<td>Trad Male no combo vs Female no combo</td>
<td>0.044*</td>
<td></td>
<td>0.002**</td>
<td></td>
</tr>
</tbody>
</table>
Table 4.10 Continued

<table>
<thead>
<tr>
<th>Context</th>
<th>Comparison</th>
<th>p Value 1</th>
<th>p Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trad</td>
<td>Female no combo vs</td>
<td>0.092</td>
<td>0.0185*</td>
</tr>
<tr>
<td></td>
<td>Female with combo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bio</td>
<td>Male with combo vs</td>
<td>0.275</td>
<td>0.0067**</td>
</tr>
<tr>
<td></td>
<td>Female with combo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bio</td>
<td>Female no combo vs</td>
<td>0.393</td>
<td>0.0374*</td>
</tr>
<tr>
<td></td>
<td>Female with combo</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. *p ≤ .05. **p ≤ .01. ***p ≤ .001

Males who did not choose to complete combinations of contexts had significantly higher scores on the biology context problems than males who chose to complete combinations. Males with no combinations had significantly higher scores on the traditional problems and used significantly fewer submissions on these problems than females who did not choose to complete combinations. Females who chose combinations scored significantly higher on the sports problems and used significantly fewer submissions than females who did not choose to do multiple contexts. Females who chose to complete combos used fewer submissions than males with combinations and females with no combinations on biology context questions and fewer submissions than females with no combinations on traditional context questions.

The written questions were isolated and the results of the average percent correct score and the average number of submissions were found for each context category. The results are displayed in Table 4.11.
Table 4.11

Average Percentage of Responses Correct and # Submissions by Category of Word Problems.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Traditional Contexts Written</th>
<th>Biology Contexts Written</th>
<th>Sports Contexts Written</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% correct</td>
<td>#submission s</td>
<td>% correct</td>
</tr>
<tr>
<td>Females who chose a combination</td>
<td>81.8</td>
<td>2.09</td>
<td>86.8</td>
</tr>
<tr>
<td>Males who chose a combination</td>
<td><strong>81.0</strong></td>
<td>2.23</td>
<td>79.5</td>
</tr>
<tr>
<td>Females who did not choose a combination</td>
<td>64.8</td>
<td>3.04</td>
<td><strong>92.6</strong></td>
</tr>
<tr>
<td>Males who did not choose a combination</td>
<td><strong>92.4</strong></td>
<td>1.59</td>
<td>91.3</td>
</tr>
</tbody>
</table>

The means from the video questions Table 4.10 were compared with the means of the written questions from using two-sample t-tests assuming unequal variances. The p-values found of the comparisons were categorized and any significant differences found were placed into tables 4.11 based on the context addressed. Bold terms indicate which subject group had the higher context scores.

Table 4.12

Significant Differences in Response Score and Submissions by Written vs Video Format.

<table>
<thead>
<tr>
<th>Written/Video Format</th>
<th>% Correct</th>
<th># Submissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p-value</td>
<td>p-value</td>
</tr>
<tr>
<td>Trad Male no combo writ vs Male combo vid</td>
<td><strong>5.46e-05</strong>*</td>
<td>2.87e-6***</td>
</tr>
<tr>
<td>Group</td>
<td>Comparison</td>
<td>p-value 1</td>
</tr>
<tr>
<td>------------------------------</td>
<td>-----------------------------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Bio Male</td>
<td>no combo writ vs Male combo vid</td>
<td>1.96e-05***</td>
</tr>
<tr>
<td>Sports Female</td>
<td>no combo vid vs Female combo writ</td>
<td>0.00057***</td>
</tr>
<tr>
<td>Sports Male</td>
<td>no combo writ vs Male combo vid</td>
<td>0.000682***</td>
</tr>
<tr>
<td>Sports Male</td>
<td>no combo writ vs Male no combo vid</td>
<td>0.00209**</td>
</tr>
<tr>
<td>Bio Female</td>
<td>combo writ vs Female combo vid</td>
<td>0.0045**</td>
</tr>
<tr>
<td>Bio Male combo writ vs Male</td>
<td>combo vid</td>
<td>0.0115*</td>
</tr>
<tr>
<td>Sports Female</td>
<td>no combo writ vs Female no combo vid</td>
<td>0.0134*</td>
</tr>
<tr>
<td>Bio Female</td>
<td>no combo writ vs Female combo vid</td>
<td>0.0165*</td>
</tr>
<tr>
<td>Trad Female</td>
<td>combo writ vs Female no combo vid</td>
<td>0.017*</td>
</tr>
<tr>
<td>Sports Male combo writ vs Male combo vid</td>
<td></td>
<td>0.0191*</td>
</tr>
<tr>
<td>Sports Male combo writ vs Male no combo vid</td>
<td></td>
<td>0.0194*</td>
</tr>
<tr>
<td>Trad Male</td>
<td>no combo writ vs Male no combo vid</td>
<td>0.0287*</td>
</tr>
<tr>
<td>Trad Male combo writ vs Male</td>
<td>combo vid</td>
<td>0.031*</td>
</tr>
<tr>
<td>Bio Female</td>
<td>no combo writ vs Female no combo vid</td>
<td>0.052</td>
</tr>
<tr>
<td>Bio Female combo writ vs</td>
<td>Female no combo vid</td>
<td>0.0621</td>
</tr>
</tbody>
</table>
Table 4.12 Continued

<table>
<thead>
<tr>
<th>Condition</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bio Male combo writ vs Male no combo vid</td>
<td>0.129</td>
<td>0.0052**</td>
</tr>
<tr>
<td>Bio Male no combo writ vs Male no combo vid</td>
<td>0.347</td>
<td>0.00058***</td>
</tr>
<tr>
<td>Sports Female no combo writ vs Female combo vid</td>
<td>0.4</td>
<td>0.00122**</td>
</tr>
</tbody>
</table>

Note. *p ≤ .05. **p ≤ .01. ***p ≤ .001

To better analyze the data, the results of Table 4.12 were divided into four categories based on who had the higher scores: males with combos; males without combos; females with combos; females without combos.

Males with combos (those who chose to complete multiple contexts) did significantly better on the word problems in all three contexts than they did on the video questions for all three contexts. Males who chose combos in the written sports and biology contexts did significantly better than males who did not choose combos who did the sports and biology video questions.

Males without combos (those who only did one context per question) did significantly better on the traditional, and sports word problems than they did on the traditional, and sports contexts of the video questions. Males without combos did significantly better on the word problems of the traditional, and sports contexts, compared with males who chose combos did in the traditional, and sports contexts.

Females who chose to do combos did significantly better in the biology word problems than they did in the biology video problems. Females who chose to complete combos in the sports and traditional word problems, did significantly better than females who chose no combos.
did in the video questions of those contexts. Females who chose to do combos in the biology word problems used significantly fewer submissions than females who did not choose combos used on the video questions.

Females who did not choose combos did significantly better on the sports word problems than they did on the sports video problems. Females who did not choose a combo did significantly better on the biology word problems than females who chose combo did on the biology video problems. Females who did not choose a combo used significantly fewer submissions on the biology word problems than they did on the biology video questions. Females who did not choose a combo used significantly fewer submissions on the sports word problems than females who did combos used on the video questions.

The average male and female performance on the written and video questions were compared using two-sample t-tests assuming unequal variances. The p-values found of the comparisons were examined and any significant differences found were placed in Tables 4.13 according to context. The highlighted terms indicate the group that had the higher scores and/or higher number of submissions used.

Table 4.13

*Significant Differences in Male vs Female Average Scores and Submissions by Context, Written vs Video Format.*

<table>
<thead>
<tr>
<th>Traditional Written/Video Format</th>
<th>Traditional % Correct $p$-value</th>
<th>Traditional # Submissions $p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trad <strong>Male no combo</strong> writ vs Female no combo writ</td>
<td>8.8e-05***</td>
<td>6.29e-07***</td>
</tr>
</tbody>
</table>
Table 4.13 Continued

<table>
<thead>
<tr>
<th>Sports Male no combo writ vs Female no combo writ</th>
<th>0.0031**</th>
<th>1.15e-5***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trad Male no combo vid vs Female no combo vid</td>
<td>0.0439*</td>
<td>0.00208**</td>
</tr>
<tr>
<td>Bio Male combo writ vs Female combo writ</td>
<td>0.0631</td>
<td>0.00875**</td>
</tr>
<tr>
<td><strong>Bio Male combo vid vs Female combo vid</strong></td>
<td>0.275</td>
<td>0.00665**</td>
</tr>
<tr>
<td>Bio Male no combo writ vs Female no combo writ</td>
<td>0.448</td>
<td>0.0169*</td>
</tr>
</tbody>
</table>

Note. *p ≤ .05. **p ≤ .01. ***p ≤ .001

On the traditional word problems, males who did not choose multiple contexts scored significantly higher and used fewer submissions than did females who did not choose multiple contexts. On the traditional video questions, males who chose one context scored significantly higher and used fewer submissions than females who chose one context.

No significant differences in WebAssign scores were found between the written and video question format for the biology context for either males or females. Males who chose multiple contexts used significantly more submissions on the biology written questions than females who chose multiple contexts. Males who did not choose multiple contexts used significantly fewer submissions on the written biology questions than females who only completed one context. Males who chose to do multiple contexts used significantly more submissions on the biology video questions than females who did multiple contexts. Males who only chose one context scored significantly higher and used fewer submissions on the written sports questions than females who only chose one context.
Achievement of Males and Females, and Choice

Achievement was defined in this study by raw improvement on the post FCI compared with the pre FCI. Students were given the FCI as a pre and post assessment on their conceptual understandings of Newton’s Laws and their applications. Seventy-three participants (48.6% white, 30.6% Asian, 11.1% Hispanic, 1.4% Native American, 1.4% African American, 2.8% other, 4.2% no response) completed the pre-survey and fifty-six took and completed the post-survey. Fifty-four students, twenty-two females (40.7%) and thirty-two males (59.3%), who completed the pre-survey also completed the post-survey and the WebAssign assignment set. Only the results of these fifty-four students were used in the analysis and the other responses were discarded since only complete sets of pre/post measures along with the complete assignments provided useful data on the changes in attitudes, interests, and performance.

Of those fifty-four responses, two students’ responses that were less than 10% complete were removed, leaving a total of fifty-two students’ data in the sample. The results of the pre and post FCI scores were checked for normality using the Shapiro-Francia test and the Shapiro-Wilk test in the statistical analysis package STATA, which showed the pre and post FCI data were normally distributed. The FCI results were organized by gender and the pre and post results were compared within each group using a paired t-test for unequal variances (Table 4.14).
Table 4.14

Pre/Post FCI Comparisons Within Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-FCI Avg</th>
<th>Post-FCI Avg</th>
<th>Δ Avg</th>
<th>t</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female-CAucasian</td>
<td>14.9</td>
<td>17</td>
<td>2.1</td>
<td>-3.12</td>
<td>9</td>
<td>0.0062**</td>
</tr>
<tr>
<td>Female-Minority</td>
<td>16.9</td>
<td>19.3</td>
<td>2.4</td>
<td>-1.78</td>
<td>10</td>
<td>0.053</td>
</tr>
<tr>
<td>Male</td>
<td>20.56</td>
<td>20.25</td>
<td>-0.3125</td>
<td>0.4856</td>
<td>31</td>
<td>0.3153</td>
</tr>
<tr>
<td>Male-CAucasian</td>
<td>19.4</td>
<td>18.9</td>
<td>-0.5</td>
<td>1.74</td>
<td>17</td>
<td>0.288</td>
</tr>
<tr>
<td>Male-Minority</td>
<td>22.8</td>
<td>22.7</td>
<td>-0.1</td>
<td>0.146</td>
<td>12</td>
<td>0.443</td>
</tr>
</tbody>
</table>

Note. *p ≤ .05. **p ≤ .01. ***p ≤ .001

When compared as a total group, females showed significant gains in their post FCI score as compared with their pre FCI score. When analyzed by ethnicity, Caucasian females showed significant increases in their post FCI score as compare with their initial score. However, minority female students showed no significant gains from pre to post FCI. Males as a total group showed no significant changes between their pre and post scores. When analyzed by ethnicity group, neither Caucasian nor minority group had any significant differences from pre to post measure.

Comparisons were made between the female and male groups. The results were analyzed using a two-sample t-test assuming unequal variances and summarized below in Table 4.15.
Table 4.15

*Pre/Post FCI Comparisons Female to Male*

<table>
<thead>
<tr>
<th>Group</th>
<th>Female Avg</th>
<th>Male Avg</th>
<th>t</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-FCI</td>
<td>16.86</td>
<td>20.56</td>
<td>-2.254</td>
<td>46</td>
<td>0.0145*</td>
</tr>
<tr>
<td>Avg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-FCI</td>
<td>18.43</td>
<td>20.25</td>
<td>-1.027</td>
<td>47</td>
<td>0.1549</td>
</tr>
<tr>
<td>Avg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. *p ≤ .05. **p ≤ .01. ***p ≤ .001

Males’ pre-FCI scores (20.56) were significantly higher than the females (16.86) in the pre-FCI, but the gap was closed by the post-FCI (females 18.43; males 20.25; p = 0.1549).

Female and male groups were sub-divided into Caucasian and minority groups to examine differences in achievement between the ethnic groups based on self-report. All non-Caucasian students were placed into the minority group due to the small number of the different ethnicities. Values were compared using a two-tailed t-test assuming unequal variances and the results are shown in Table 4.16.

Table 4.16

*Pre/Post FCI Comparisons Comparison by Gender and Ethnicity*

<table>
<thead>
<tr>
<th></th>
<th>Female-Caucasian</th>
<th>Male-Caucasian</th>
<th>T</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-FCI Avg</td>
<td>14.9</td>
<td>19.4</td>
<td>-1.97</td>
<td>23</td>
<td>0.030*</td>
</tr>
</tbody>
</table>

*Note: p ≤ 0.05.*
Table 4.16 Continued

<table>
<thead>
<tr>
<th></th>
<th>Post-FCI Avg</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female-Minority</td>
<td>Male- Minority</td>
<td>Male- Minority</td>
<td>Male- Minority</td>
</tr>
<tr>
<td>Pre-FCI Avg</td>
<td>16.9</td>
<td>22.8</td>
<td>-2.22</td>
<td>17</td>
</tr>
<tr>
<td>Post-FCI Avg</td>
<td>19.3</td>
<td>22.7</td>
<td>-1.20</td>
<td>21</td>
</tr>
</tbody>
</table>

Note. *p ≤ .05. **p ≤ .01. ***p ≤ .001

Caucasian male students had a significantly higher pre-FCI score than did Caucasian female students. No significant differences were found between Caucasian male and female students’ post-FCI scores. Minority male students had significantly higher pre-FCI scores than minority female students, but that gap was not found on the post-FCI.

Comparisons were made within groups to better understand if any differences between students who chose to do combinations of questions differed in achievement on the FCI as compared with students who only chose one context. The pre-FCI scores (with combo 16.91; without 14.67; p = 0.221) of both female groups were compared and no significant differences were found between female groups and no significant differences were found between their post-FCI scores (with combo 19.25; without 16.78; p = 0.197). The pre-FCI scores (with combo 19.81; without 23; p = 0.086) of both male groups were compared and no significant differences were found between the male groups and no significant differences were found between their post-FCI scores (with combo 19.62; without 22.3; p = 0.168).
The growth of each group was defined as the change in score from pre to post FCI score and the results were compared using a two-sample t-test, assuming unequal variances. Females demonstrated significant positive growth (with $p = 0.00285$) with a net gain of 1.571 points on the post FCI as compared with a net decrease of male scores of -0.3125 from the pre-FCI to the post-FCI.

Fifteen female students and twelve male students were identified as improving their scores by at least one point. The pre and post FCI scores of the female students and the male students who were identified as showing growth, were compared using a two-tailed t-test assuming unequal variances and the results summarized below in Table 4.17. One male student who was omitted scored a perfect score on the pre-FCI and received a perfect score on the post-FCI.

Table 4.17

<table>
<thead>
<tr>
<th>Group</th>
<th>Female</th>
<th>Male</th>
<th>T</th>
<th>Df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(one-tailed)</td>
</tr>
<tr>
<td>Pre FCI</td>
<td>14.8</td>
<td>20.17</td>
<td>-2.098</td>
<td>21</td>
<td>0.0240*</td>
</tr>
<tr>
<td>Post FCI</td>
<td>18.4</td>
<td>22.83</td>
<td>-1.867</td>
<td>21</td>
<td>0.0379*</td>
</tr>
</tbody>
</table>

Note. *$p \leq .05$. **$p \leq .01$. ***$p \leq .001$

Looking only at students who experienced raw growth from the pre to the post-FCI, males began with significantly higher scores than females on the pre FCI and had significantly higher scores than females on the post FCI.
The pre and post scores of the female group that showed growth were analyzed for significant differences as well as the male group that showed growth. The results are shown in Table 4.18.

Table 4.18

Comparisons of Pre and Post FCI Scores for Growth Groups Only

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre FCI</th>
<th>Post FCI</th>
<th>T</th>
<th>Obs</th>
<th>p (one-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>14.8</td>
<td>18.4</td>
<td>-1.731</td>
<td>15</td>
<td>0.0472*</td>
</tr>
<tr>
<td>Male</td>
<td>20.2</td>
<td>22.8</td>
<td>-0.951</td>
<td>12</td>
<td>0.176</td>
</tr>
</tbody>
</table>

Note. *p ≤ .05. **p ≤ .01. ***p ≤ .001

Females showed a significant gain from their pre-FCI score to their post score, however no significant differences were found between the males’ pre and post FCI score.

The raw FCI growth between groups who chose to complete multiple contexts and those who did not were analyzed. No significant differences were found in the FCI growth between either males or females regardless of choice of multiple contexts or not.

FCI Achievement: Correlation Analyses with Time on Task and Choice

Achievement was defined in this study by raw improvement on the post FCI compared with the pre FCI. More female students (71.4%) showed growth on the post FCI than male students (37.5%). The number of students’ first choice contexts were recorded and compared with raw FCI growth and the total time they spent on WebAssign to investigate if there were any relationships. A correlation matrix of the regression analyses was created using Excel, between
the variables for all students: time on WebAssign; RCI raw growth; # traditional choices; # sports choices; and # biology choices.

For all students, a moderate correlation (0.411) was found between the time spent on completing the WebAssign homework problems and the raw growth on the post FCI. Raw growth on the FCI was found to have a weak correlation with the number of sports context choices (0.144) made and the number of biology context choices (0.287) made. The correlation between the raw growth on the FCI and the time spent on WebAssign suggests that, overall, students who worked for longer periods of time on the homework assignment had more growth on the FCI. For all female students there was a weak correlation (0.116) between time spent on WebAssign and FCI growth, and a moderate correlation of (0.521) for males between time spent on WebAssign and FCI growth.

The responses were then sorted by gender of students who made growth on the FCI and the variables were compared with raw FCI growth and time using a correlation matrix for regression to investigate whether time spent on task differed for male and female students who showed growth on the FCI. For female students who showed growth on the FCI, there was a moderate correlation between their FCI raw growth and the number of sports contexts chosen (0.223). However, there was virtually no correlation between the raw FCI growth and the time spent doing the WebAssign homework (-0.061) for female students who experienced FCI growth. In contrast, male students who showed growth on the FCI, showed a very strong correlation between the time spent doing the WebAssign homework and the raw FCI growth (0.723). This correlation was in stark contrast to the lack of correlation between the same variables of the female students. When investigating a possible connection between the choice
of context and FCI score, males with growth showed a weak correlation between the number of sports contexts chosen and FCI raw growth (0.273) and virtually no correlation between biology contexts chosen (0.06) and the raw FCI growth. Male students exhibited a moderately negative correlation between the number of traditional context choices made and the FCI raw growth (-0.347).

Comparison of WebAssign and FCI Results

After the initial pre-attitude and concept inventory, the participants were given the WebAssign intervention. The scores of the fifty-two students (twenty-one females and thirty-one males) who completed the WebAssign problem set, and the pre and post FCI measures, were compared for correlations in FCI results, FCI raw growth, and time spent on WebAssign.

The results above show that there were strong correlations between their WebAssign score and their post FCI score for both male students and female students, overall. Females’ scores had a correlation of 0.68 and males’ scores had a correlation of 0.75. This trend held up when comparing WebAssign scores to students’ raw post FCI scores who experienced growth on the FCI. For females who experienced growth, the correlations were strong (0.725), males who experienced growth also had a strong correlation between WebAssign scores and post FCI scores (0.640).

Male and female students were separated out into subgroups according to those who chose to do multiple contexts per question and those who only did one context per question and each sub-group was examined for correlations between time spent on WebAssign, FCI raw growth, and FCI scores. Females ($n=12$) who chose multiple contexts showed a moderate
negative correlation between their score on WebAssign and FCI raw growth (-0.350) and virtually no correlation between time and FCI raw growth (0.0925). Females (n = 9) who chose only one context per question had a weak negative correlation between their score on WebAssign and FCI raw growth (-0.253) and a weak correlation between time spent on WebAssign and FCI growth (0.162). For male students, this trend was different. Males (n = 21) choosing multiple contexts had a moderate correlation between their WebAssign score and FCI raw growth (0.326) and a strong correlation between the total time spent on WebAssign and FCI raw growth (0.529). Males (n = 10) who chose only one context had a strong positive correlation between their WebAssign score and FCI raw growth (0.848) and a moderate correlation between time spent on WebAssign and FCI raw growth (0.447).

Next, the WebAssign scores and the FCI scores of the minority students were compared to see if there was any correlation. Twenty-four of the fifty-two students (46%) self-identified as minority (9.61% Hispanic, 32.7% Asian, 1.92% Native American, 1.92% other). Because of the small sample size, all the minority students were compared together and then grouped according to gender for comparison. The WebAssign scores and the FCI values for Caucasian students were analyzed for comparison. Twenty-eight students, ten females and eighteen males, self-selected as Caucasian (White, non-Hispanic).

The scores of minority students had virtually (0.005326) no correlation between FCI growth and WebAssign scores, while Caucasians had a weak correlation (0.160) between the measures. However, there was a strong correlation (0.699) between the post FCI score and the total WebAssign score for minority students. This was comparable to the correlation shown by Caucasian students of 0.755.
The strong correlation between the post FCI score and the WebAssign score for female minority students (0.669) was similar to the strong correlation found for Caucasian female students (0.662). Female minority students had a moderately negative correlation between FCI raw growth and their WebAssign score (-0.401) while female Caucasians showed virtually no correlation (0.0291) between the scores.

Minority male students’ scores were moderately correlated (0.443) between FCI growth and WebAssign scores, while male Caucasians’ scores had a moderate correlation of 0.330. Minority male students had a strong correlation (0.705) between the post FCI score and their WebAssign score, while Caucasian male students had strong correlation of 0.795. Therefore, overall, students who scored well on the WebAssign problem sets also scored well on the FCI.

Student Interests and Context Choice

Students were asked to list their interests outside of the classroom as part of the initial demographic survey. These interests were sorted and categorized according to the following breakdown: 1-sports; 2-volunteering/service; 3-academic competitions; 4-music/arts; 5-research; 6-hobbies; 7-academic clubs; and 8-cultural clubs.

From the original group of student participants, twenty-nine male students responded and fourteen female students completed this portion of the survey. Six female students and three male students left the question about extracurricular interests blank on their surveys. Student responses were used only if they completed both the interest question and the assignment. These students’ interest responses were coded according to the categories above and totaled and sorted according to students who chose more than one context to answer and students who only
answered one context per problem. From this sample, fifteen students (female n = 3; male n = 12), completed more than one context per question. Twenty-eight students (female n = 11; male n = 17), only chose and completed one context per problem. The breakdown of interests for all students are displayed in Figure 4.4.

**Figure 4.4.** Breakdown of student interests.

Figure 4.4 shows that the student participants had a wide range of interests. The main extracurricular interest for both male and female students was sports. This category included both team sports, and individual sports such as martial arts or gymnastics. One noteworthy difference with stated interests was that only female students indicated they were involved with some sort of research outside of the regular academic setting, while male students listed no interest in extracurricular research. Students could list as many or as few extracurricular interests as they wanted. No constraints were placed on the responses and students could type in whatever interests they desired, including indicating multiple interests.
Student performance on the FCI was compared with their coded written responses indicating their interests. Table 4.19 shows the breakdown of the students’ interests (by percentage) according to gender for groups who showed growth or loss on the FCI.

Table 4.19

<table>
<thead>
<tr>
<th>Rationale for Context Choice</th>
<th>Interest</th>
<th>Familiar</th>
<th>Random/No Preference</th>
<th>Easy/Straightforward</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gains M &amp; F</td>
<td>51.8</td>
<td>14.8</td>
<td>14.8</td>
<td>18.5</td>
</tr>
<tr>
<td>Losses M &amp; F</td>
<td>47.8</td>
<td>4.35</td>
<td>8.7</td>
<td>21.7</td>
</tr>
</tbody>
</table>

Note: M = Male; F = Female

For both females and males, approximately half of each group of students indicated that they made their context choice out of interest.

The coded responses for each student were totaled and the mode for that student was used to compare with the FCI gains or losses. The results showed a random distribution of gains and losses as compared with student interest. Therefore, no correlation was found between the student gains and losses from pre to post FCI when compared with student interests.

Time on Project

Student time on the entire project, from when they first took the pre-surveys to when they took the post surveys, was recorded and can be seen below in Table 4.20.
Table 4.2

*Breakdown of time spent from pre to post surveys (in days)*

<table>
<thead>
<tr>
<th># of Days</th>
<th>% Overall</th>
<th>% Female</th>
<th>% Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 3</td>
<td>14</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>14-30</td>
<td>32</td>
<td>50</td>
<td>19</td>
</tr>
<tr>
<td>30-50</td>
<td>29</td>
<td>42</td>
<td>19</td>
</tr>
<tr>
<td>&gt;50</td>
<td>25</td>
<td>8</td>
<td>37</td>
</tr>
</tbody>
</table>

Most students (86%) spent more than two weeks on the project. The average time females spent on the project was found to be (32.9 days) which was nearly identical to the time spent on the project by males (32.8 days). A t-test comparing the means shows that the average times are statistically equivalent with p = 0.98. However, one observation of the data was that the minimum time spent by females on the project was fourteen days, while several male participants spent three days or less on the project total. This indicates that the female students were not likely to rush through the project, but that some of the male students did, in fact, complete the project quickly.

*Colorado Learning Attitudes about Science Survey (CLASS)*

The pre-treatment science attitudes survey, the Colorado Learning Attitudes about Science Survey (CLASS) was given to the participants online through Qualtrics. One hundred and five participants began the survey and of those participants, fifteen submitted partial responses and did not complete all or part of the survey. The survey consists of the forty-two CLASS instrument items and seven demographics questions. Responses that were not at least
90% complete on the CLASS portion were discarded (three blank; two 7.1% complete; one 53.5% complete). Four of the partial responses submissions were nearly complete (90%+), but without identifying information, and twenty-three without informed consent. The five remaining partial responses completed all but one question (97.7% complete) and these responses were kept in the data set and analyzed, giving a total of ten partial responses that were not used. This left seventy-two verified and completed surveys.

Seventy-two students completed the pre-treatment CLASS survey and of those seventy-two, twenty-five were female and forty-seven were male. One question in the CLASS instrument was designed to indicate whether students were randomly entering responses or if they were reading the questions and answering appropriately. This question was Q34 “We use this statement to discard the survey of people who are not reading the question. Please select agree-option 4 (not strongly agree) for this question to preserve your answers.” Only one student, a male student, did not respond with a 4 and that student’s responses were discarded and not used in the study. Thus, a total of seventy-one responses, from twenty-five females and forty-six males, from the pre-CLASS survey were used in this study and analyzed. The total average score and the average scores for the female and male participants can be seen in Table 4.23. A total of twenty-eight students, fifteen males and thirteen females completed both the pre and the post CLASS survey and their results were used and analyzed for changes in attitudes. The findings of these twenty-eight students are shown as the ‘completed-pre’ and ‘completed-post’ labels in the table. Of the forty-two items used on the CLASS, fourteen items were not assigned to the CLASS categories and subsequently not used in this study.
Cronbach’s alpha coefficient is widely used measure of the reliability of an instrument’s internal consistency to measure the intended attributes. (Davenport, Davison, Liou, & Love, 2015). Cronbach’s alpha follows a general scale which indicates the degree of internal consistency: $0.9 \leq \alpha$ excellent; $0.8 \leq \alpha < 0.9$ good; $0.7 \leq \alpha < 0.8$ acceptable; $0.6 \leq \alpha < 0.7$ questionable; $0.5 \leq \alpha < 0.6$ poor; $\alpha <$ unacceptable (Davenport et al., 2015) (Cronbach, 1951).

Alpha correlations were run on each sub category of the pre-CLASS results, using the statistical software package STATA, and the results are given in Table 4.21.

Table 4.21

<table>
<thead>
<tr>
<th>CLASS Category</th>
<th>Cronbach’s Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Interests</td>
<td>0.7666</td>
</tr>
<tr>
<td>Real World Connections</td>
<td>0.7180</td>
</tr>
<tr>
<td>Problem Solving</td>
<td>0.7681</td>
</tr>
<tr>
<td>Problem Solving Confidence</td>
<td>0.6454</td>
</tr>
<tr>
<td>Problem Solving Sophistication</td>
<td>0.8108</td>
</tr>
<tr>
<td>Sense Making</td>
<td>0.7322</td>
</tr>
<tr>
<td>Conceptual Understanding</td>
<td>0.6689</td>
</tr>
<tr>
<td>Applied Conceptual Understanding</td>
<td>0.7154</td>
</tr>
</tbody>
</table>

Each category displays internal consistency per their results for Cronbach’s alpha. Six of the eight categories rate good or acceptable, and two categories rated questionable.

The CLASS instrument consists of eight sub categories: personal interest; real world connections; problem solving; problem solving confidence; problem solving sophistication; sense making; conceptual understanding; and applied conceptual understanding.
The follow-up post-CLASS survey was given to the students after they had completed the WebAssign homework assignments. Thirty-nine students took the post-CLASS survey following the treatment. The same criteria used for accepting responses for the pre-CLASS were used for determining use for the post-CLASS. Of the thirty-nine, one student answered only three of the forty-two questions (7.1% response rate) and that student’s responses were not used in the final analysis. One student answered forty of the forty-two questions (a 95.2% response rate) and that student’s responses were kept in for the final analysis. Two other students answered forty-one of the forty-two responses (97.6% response rate) and their responses were also kept for the final analysis. Thirty-eight responses were found to be complete enough to use for the final analysis and every student in this group had turned in all the proper permission forms and had completed the WebAssign homework. This group consists of twenty-one males and seventeen females. Of those thirty-eight, twenty-eight complete both the pre and post FCI and the WebAssign problems. To more fully understand the impact of the treatment on students’ attitudes, beliefs, and interest in physics only these twenty-eight students’ pre and post CLASS responses were used in the final analysis. The final group of twenty-eight students were made up of fifteen males and thirteen females and their results were used for the post-CLASS analysis. Male and female responses on the post-CLASS survey were compared using a two-sample t-test with unequal variances with Microsoft Excel. The results of the pre and post-CLASS findings are displayed for each category in Table 4.22- Table 4.29.

The personal interest sub category consists of six questions from the survey. Results from the Personal Interest category can be seen in Table 4.22.
Table 4.22

*Personal Interest Pre and Post Values*

<table>
<thead>
<tr>
<th>Question</th>
<th>Female Average</th>
<th>Male Average</th>
<th>df</th>
<th>T</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q3 I think about the physics I experience in everyday life.</td>
<td>Pre 3.69</td>
<td>4.13</td>
<td>23</td>
<td>1.23</td>
<td>0.115</td>
</tr>
<tr>
<td>Post 3.69</td>
<td></td>
<td>3.93</td>
<td>24</td>
<td>-0.722</td>
<td>0.239</td>
</tr>
<tr>
<td>Q11 I am not satisfied until I understand why something works the way it does.</td>
<td>Pre 4.23</td>
<td>4.2</td>
<td>25</td>
<td>1.71</td>
<td>0.454</td>
</tr>
<tr>
<td>Post 4</td>
<td></td>
<td>4</td>
<td>26</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>Q14 I study physics to learn knowledge that will be useful in my life outside of school.</td>
<td>Pre 3.69</td>
<td>4.07</td>
<td>24</td>
<td>1.02</td>
<td>0.158</td>
</tr>
<tr>
<td>Post 3.385</td>
<td></td>
<td>3.8</td>
<td>23</td>
<td>-1.4</td>
<td>0.0882</td>
</tr>
<tr>
<td>Q26 I enjoy solving physics problems.</td>
<td>Pre 3.92</td>
<td>3.4</td>
<td>25</td>
<td>-1.36</td>
<td>0.093</td>
</tr>
<tr>
<td>Post 3.62</td>
<td></td>
<td>3.6</td>
<td>23</td>
<td>0.039</td>
<td>0.484</td>
</tr>
<tr>
<td>Q29 Learning physics changes my ideas about how the world works.</td>
<td>Pre 4.23</td>
<td>4.33</td>
<td>22</td>
<td>1.72</td>
<td>0.366</td>
</tr>
<tr>
<td>Post 3.92</td>
<td></td>
<td>4.2</td>
<td>23</td>
<td>-0.761</td>
<td>0.227</td>
</tr>
</tbody>
</table>
The results from Table 4.22 show the results of comparing male and female responses on the post-CLASS survey using a two-sample t-test with unequal variances. Statistically significant differences ($p \leq 0.05$) between male and female responses were not observed in any of the questions that pertain to the Personal Interest category. The results of the female students were compared using a paired two sample t-test for means. Significant differences ($p \leq 0.05$) between the pre (4.23) and the post (4) scores of females were found for question 31 with $p = 0.0410$ paired using two sample t-tests. The findings from this analysis show that females who completed both pre and post CLASS surveys felt less confident about applications of their reasoning skills used for physics being applicable to everyday life. Significant differences ($p \leq 0.05$) between pre (4.2) and post (4) scores for males were found for question 11 with $p = 0.0412$ paired using two sample t-tests. The findings from this analysis show that males who completed the surveys and intervention, were less likely to agree that they felt satisfied until they understood why something works the way it does after the intervention as compared with before.

Pre and post results from the Real World Connections category is shown in Table 4.23.
Table 4.23

Real World Connections, Pre and Post Values

<table>
<thead>
<tr>
<th>Question</th>
<th>Pre</th>
<th>Male Average</th>
<th>df</th>
<th>T</th>
<th>P (one-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q29 Learning physics changes my ideas about how the world works.</td>
<td>Female</td>
<td>4.23</td>
<td>22</td>
<td>1.72</td>
<td>0.359</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>4.33</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>3.92</td>
<td>23</td>
<td>-0.761</td>
<td>0.227</td>
</tr>
<tr>
<td>Q31 Reasoning skills used to understand physics can be helpful to me in</td>
<td>Pre</td>
<td>4.23</td>
<td>26</td>
<td>1.29</td>
<td>0.104</td>
</tr>
<tr>
<td>my everyday life.</td>
<td></td>
<td>4.53</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>4</td>
<td>19</td>
<td>-1.53</td>
<td>0.071</td>
</tr>
<tr>
<td>Q36 The subject of physics has little relation to what I experience in</td>
<td>Pre</td>
<td>4.31</td>
<td>25</td>
<td>0.108</td>
<td>0.457</td>
</tr>
<tr>
<td>the real world.</td>
<td></td>
<td>4.33</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>4.31</td>
<td>25</td>
<td>0.108</td>
<td>0.457</td>
</tr>
<tr>
<td>Q38 To understand physics, I sometimes think about my personal experiences and relate them to the topics being analyzed.</td>
<td>Pre</td>
<td>3.31</td>
<td>21</td>
<td>2.00</td>
<td>0.029*</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>3.46</td>
<td>25</td>
<td>-1.47</td>
<td>0.077</td>
</tr>
</tbody>
</table>

Note: *p ≤ .05. **p ≤ .01. ***p ≤ .001

On the Real World Connections subscale, males (4.14) had a significantly (p = 0.029) higher pre intervention score on question 38 as compared with females (3.31). This indicates that males were more likely to tie in their own personal experiences when analyzing a physics topic than females. But that difference was closed by the end of the intervention since the post scores of males and females for that question are not significantly different. Significant differences (p ≤ 0.05) between the pre (4.23) and the post (4) scores of females were found for question 31 with p = 0.0410 paired using two sample t-tests. The findings from this analysis show that females who completed both pre and post CLASS surveys felt less confident about
applications of their reasoning skills used for physics being applicable to everyday life after the intervention. No significant differences between males pre to post scores were found.

Pre and post results for the Problem Solving category are shown in Table 4.24.

Table 4.24

*Problem Solving Pre and Post Values*

<table>
<thead>
<tr>
<th>Question</th>
<th>Female Average</th>
<th>Male Average</th>
<th>df</th>
<th>T</th>
<th>P (one-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q13 I do not expect physics equations to help my understanding of the ideas; they are just for doing calculations.</td>
<td>Pre 3.92</td>
<td>3.93</td>
<td>25</td>
<td>0.035</td>
<td>0.486</td>
</tr>
<tr>
<td></td>
<td>Post 4.23</td>
<td>3.6</td>
<td>26</td>
<td>1.77</td>
<td>0.044*</td>
</tr>
<tr>
<td>Q16 If I get stuck on a physics problem on my first try, I usually try to figure out a different way that works.</td>
<td>Pre 4</td>
<td>4.13</td>
<td>22</td>
<td>0.562</td>
<td>0.290</td>
</tr>
<tr>
<td></td>
<td>Post 4.31</td>
<td>4</td>
<td>26</td>
<td>1.60</td>
<td>0.060</td>
</tr>
<tr>
<td>Q17 Nearly everyone is capable of understanding physics if they work at it.</td>
<td>Pre 4.15</td>
<td>3.73</td>
<td>26</td>
<td>-1.08</td>
<td>0.146</td>
</tr>
<tr>
<td></td>
<td>Post 3.92</td>
<td>4.07</td>
<td>23</td>
<td>-0.478</td>
<td>0.319</td>
</tr>
<tr>
<td>Q26 I enjoy solving physics problems.</td>
<td>Pre 3.92</td>
<td>3.4</td>
<td>25</td>
<td>-1.36</td>
<td>0.093</td>
</tr>
<tr>
<td></td>
<td>Post 3.62</td>
<td>3.6</td>
<td>23</td>
<td>0.039</td>
<td>0.484</td>
</tr>
<tr>
<td>Q27 In physics, mathematical formulas express meaningful relationships among measurable quantities.</td>
<td>Pre 4.15</td>
<td>4.47</td>
<td>25</td>
<td>1.54</td>
<td>0.068</td>
</tr>
<tr>
<td></td>
<td>Post 4.15</td>
<td>4.53</td>
<td>25</td>
<td>-2.24</td>
<td>0.017*</td>
</tr>
</tbody>
</table>
Table 4.24 Continued

<table>
<thead>
<tr>
<th>Question</th>
<th>Pre</th>
<th>Post</th>
<th>t</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q35 I can usually figure out a way to solve physics problems.</td>
<td>3.30</td>
<td>3.46</td>
<td>21</td>
<td>1.34</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q41 If I get stuck on a physics problem, there’s no chance I’ll figure it out on my own.</td>
<td>3.54</td>
<td>3.85</td>
<td>26</td>
<td>-1.71</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q43 When studying physics, I relate the important information to what I already know rather than just memorizing it the way it is presented.</td>
<td>3.69</td>
<td>3.69</td>
<td>25</td>
<td>-0.121</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Note. *p ≤ .05. **p ≤ .01. ***p ≤ .001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Females had a significant decrease in their responses for question 17 from pre (4.15) to post (3.92) CLASS with $p = 0.0410$. No significant difference was found between pre and post values for any item of the Problem Solving category for males. Females and males had significant differences in post-CLASS scores for three questions that make up the Problem Solving category. In question 13 females (4.23) had a higher score indicating that they had lower expectations that physics equations can help their understanding of physics concepts than males (3.6) with ($p = 0.044$). In question 27, females (4.15) were less likely to think that mathematical formulas express meaningful relationships among measured quantities ($p = 0.017$) than male students (4.53). In question 35 females (3.46) were less confident that they were able to usually figure out a way to solve physics problems ($p = 0.049$) than male students (3.93).

Pre and post results for the Problem Solving Confidence category are shown in Table 4.25.
Table 4.25

*Problem Solving Confidence Pre and Post Values*

<table>
<thead>
<tr>
<th>Question</th>
<th>Female Average</th>
<th>Male Average</th>
<th>df</th>
<th>T</th>
<th>p (one-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q16 If I get stuck on a physics problem on my first try, I usually try to figure out a different way that works.</td>
<td>Pre 4</td>
<td>4.13</td>
<td>22</td>
<td>0.562</td>
<td>0.290</td>
</tr>
<tr>
<td></td>
<td>Post 4.31</td>
<td>4</td>
<td>26</td>
<td>1.60</td>
<td>0.060</td>
</tr>
<tr>
<td>Q17 Nearly everyone is capable of understanding physics if they work at it.</td>
<td>Pre 4.15</td>
<td>3.73</td>
<td>26</td>
<td>-1.08</td>
<td>0.146</td>
</tr>
<tr>
<td></td>
<td>Post 3.92</td>
<td>4.07</td>
<td>23</td>
<td>-0.478</td>
<td>0.319</td>
</tr>
<tr>
<td>Q35 I can usually figure out a way to solve physics problems.</td>
<td>Pre 3.30</td>
<td>3.8</td>
<td>21</td>
<td>1.34</td>
<td>0.097</td>
</tr>
<tr>
<td></td>
<td>Post 3.46</td>
<td>3.93</td>
<td>26</td>
<td>-1.71</td>
<td>0.049*</td>
</tr>
<tr>
<td>Q41 If I get stuck on a physics problem, there’s no chance I’ll figure it out on my own.</td>
<td>Pre 3.54</td>
<td>3.8</td>
<td>26</td>
<td>0.683</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>Post 3.85</td>
<td>3.47</td>
<td>24</td>
<td>1.09</td>
<td>0.143</td>
</tr>
</tbody>
</table>

Note: *p ≤ .05. **p ≤ .01. ***p ≤ .001

The Problem Solving Confidence category shares question 17 and 35 with the Problem Solving category, and females showed a significant decrease in their responses for question 17 from pre to post CLASS with \( p = 0.0410 \). No significant differences were found between pre and post values for any item of the Problem Solving Confidence category for males. In question 35, females (3.46) were less confident than males (3.93) that they were able to usually figure out a way to solve physics problems \( (p = 0.049) \).
Table 4.26 shows the pre and post data for the Problem Solving Sophistication category.

Table 4.26

<table>
<thead>
<tr>
<th>Question</th>
<th>Female Average</th>
<th>Male Average</th>
<th>Df</th>
<th>T</th>
<th>(p) (one-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q5 After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.</td>
<td>Pre: 3.23</td>
<td>Pre: 3.4</td>
<td>23</td>
<td>0.423</td>
<td>0.338</td>
</tr>
<tr>
<td></td>
<td>Post: 3.08</td>
<td>Post: 3.6</td>
<td>26</td>
<td>-1.39</td>
<td>0.088</td>
</tr>
<tr>
<td>Q22 If I don't remember a particular equation needed to solve a problem on an exam, there's nothing much I can do (legally!) to come up with it.</td>
<td>Pre: 3.23</td>
<td>Pre: 3.2</td>
<td>25</td>
<td>-0.070</td>
<td>0.472</td>
</tr>
<tr>
<td></td>
<td>Post: 3.54</td>
<td>Post: 3.07</td>
<td>26</td>
<td>1.13</td>
<td>0.133</td>
</tr>
<tr>
<td>Q23 If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.</td>
<td>Pre: 3.08</td>
<td>Pre: 3.13</td>
<td>25</td>
<td>0.137</td>
<td>0.446</td>
</tr>
<tr>
<td></td>
<td>Post: 3.31</td>
<td>Post: 2.87</td>
<td>26</td>
<td>1.26</td>
<td>0.109</td>
</tr>
<tr>
<td>Q26 I enjoy solving physics problems.</td>
<td>Pre: 3.92</td>
<td>Pre: 3.4</td>
<td>25</td>
<td>-1.36</td>
<td>0.093</td>
</tr>
<tr>
<td></td>
<td>Post: 3.62</td>
<td>Post: 3.6</td>
<td>23</td>
<td>0.039</td>
<td>0.484</td>
</tr>
<tr>
<td>Q35 I can usually figure out a way to solve physics problems.</td>
<td>Pre: 3.30</td>
<td>Pre: 3.8</td>
<td>21</td>
<td>1.34</td>
<td>0.097</td>
</tr>
<tr>
<td></td>
<td>Post: 3.46</td>
<td>Post: 3.93</td>
<td>26</td>
<td>-1.71</td>
<td>0.049*</td>
</tr>
<tr>
<td>Q41 If I get stuck on a physics problem, there’s no chance I’ll figure it out on my own.</td>
<td>Pre: 3.54</td>
<td>Pre: 3.8</td>
<td>26</td>
<td>0.683</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>Post: 3.85</td>
<td>Post: 3.47</td>
<td>24</td>
<td>1.09</td>
<td>0.143</td>
</tr>
</tbody>
</table>

Note: *\(p \leq .05\). **\(p \leq .01\). ***\(p \leq .001\)
No significant differences were found between the pre to post data of the findings for this category, Problem Solving Sophistication, for either the females or the males. A significant difference between the post question, 35 (an item used in problem solving confidence as well) was found between females and males ($p = 0.049$), which indicates that males felt more confident that they can usually figure out a way to solve physics problems, as compared with females.

Table 4.27 shows the pre and post data for the Sense Making category.

Table 4.27

*Sense Making, Pre and Post Values*

<table>
<thead>
<tr>
<th>Question</th>
<th>Female Average</th>
<th>Male Average</th>
<th>df</th>
<th>T</th>
<th>$p$ (two-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q11 I am not satisfied until I understand why something works the way it does.</td>
<td>Pre 4.23</td>
<td>4.2</td>
<td>25</td>
<td>1.71</td>
<td>0.454</td>
</tr>
<tr>
<td></td>
<td>Post 4</td>
<td>4</td>
<td>26</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>Q24 In doing a physics problem, if my calculation gives a result very different from what I’d expect, I’d trust the calculation rather than going back through the problem.</td>
<td>Pre 3.77</td>
<td>3.67</td>
<td>25</td>
<td>-0.328</td>
<td>0.373</td>
</tr>
<tr>
<td></td>
<td>Post 4.33</td>
<td>3.33</td>
<td>19</td>
<td>2.41</td>
<td>0.010*</td>
</tr>
<tr>
<td>Q25 In physics, it is important for me to make sense out of formulas before I can use them correctly.</td>
<td>Pre 4</td>
<td>3.93</td>
<td>23</td>
<td>-0.226</td>
<td>0.412</td>
</tr>
<tr>
<td></td>
<td>Post 4.73</td>
<td>3.73</td>
<td>26</td>
<td>0.886</td>
<td>0.192</td>
</tr>
<tr>
<td>Q33 Spending a lot of time understanding where formulas come from is a waste of time.</td>
<td>Pre 4.23</td>
<td>4.2</td>
<td>25</td>
<td>-0.111</td>
<td>0.456</td>
</tr>
</tbody>
</table>
### Table 4.27 Continued

<table>
<thead>
<tr>
<th>Question</th>
<th>Pre</th>
<th>4.15</th>
<th>3.933</th>
<th>22</th>
<th>1.05</th>
<th>0.152</th>
<th>Post</th>
<th>3.46</th>
<th>3.2</th>
<th>26</th>
<th>0.593</th>
<th>0.279</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q37 There are times I solve a physics problem more than one way to help my understanding.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pre</td>
<td>3.54</td>
<td>3.27</td>
<td>24</td>
<td>-0.638</td>
<td>0.265</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.46</td>
<td>3.2</td>
<td>26</td>
<td>0.593</td>
<td>0.279</td>
</tr>
<tr>
<td>Q40 When I solve a physics problem, I explicitly think about which physics ideas apply to the problem.</td>
<td>Pre</td>
<td>3.38</td>
<td>4</td>
<td>23</td>
<td>2.71</td>
<td>0.0063**</td>
<td>Post</td>
<td>3.92</td>
<td>4.13</td>
<td>26</td>
<td>-1.10</td>
<td>0.141</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pre</td>
<td>3.69</td>
<td>4.07</td>
<td>23</td>
<td>1.45</td>
<td>0.081</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>3.69</td>
<td>3.73</td>
<td>25</td>
<td>-0.121</td>
<td>0.452</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: *p ≤ .05. **p ≤ .01. ***p ≤ .001

On question 40, females (3.38) were significantly less likely ($p = 0.0063$) to explicitly think about which physics to apply to a problem than were males (4) in the pre intervention measure. However, females made significant gains ($p = 0.014$) on question 40 from pre (3.38) to post (3.92) intervention, indicating that they were more likely to think explicitly about the physics they needed to apply to a problem and no significant differences were found between male and female post scores on this question. Males had a significant decrease ($p = 0.0412$) from pre to post measure on question 11, indicating that they were less concerned about being satisfied until they understand the way something works. Females (4) had a significantly higher ($p = 0.010$) post measure score than males (3.33) on question 24, indicating that they were more
likely than males to trust a calculation if it was very different from what they expected and less likely to go back through and rework the problem.

Table 4.28 shows the pre and post data for the Conceptual Understanding category.

### Table 4.28

**Conceptual Understanding, Pre and Post Values**

<table>
<thead>
<tr>
<th>Question</th>
<th>Female Average</th>
<th>Male Average</th>
<th>df</th>
<th>T</th>
<th>df</th>
<th>P (one-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1 A significant problem in learning physics is being able to memorize all the information I need to know.</td>
<td>Pre 3.31</td>
<td>2.8</td>
<td>25</td>
<td>-1.31</td>
<td>25</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>Post 3.23</td>
<td>3.4</td>
<td>26</td>
<td>-0.396</td>
<td>26</td>
<td>0.347</td>
</tr>
<tr>
<td>Q5 After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.</td>
<td>Pre 3.23</td>
<td>3.4</td>
<td>23</td>
<td>0.423</td>
<td>23</td>
<td>0.338</td>
</tr>
<tr>
<td></td>
<td>Post 3.08</td>
<td>3.6</td>
<td>26</td>
<td>-1.39</td>
<td>26</td>
<td>0.088</td>
</tr>
<tr>
<td>Q6 Knowledge in physics consists of many disconnected topics.</td>
<td>Pre 3.69</td>
<td>4.07</td>
<td>25</td>
<td>1.08</td>
<td>25</td>
<td>0.146</td>
</tr>
<tr>
<td></td>
<td>Post 3.85</td>
<td>4.13</td>
<td>22</td>
<td>-1.23</td>
<td>22</td>
<td>0.115</td>
</tr>
<tr>
<td>Q13 I do not expect physics equations to help my understanding of the ideas; they are just for doing calculations.</td>
<td>Pre 3.92</td>
<td>3.93</td>
<td>25</td>
<td>0.035</td>
<td>25</td>
<td>0.486</td>
</tr>
<tr>
<td></td>
<td>Post 4.23</td>
<td>3.6</td>
<td>26</td>
<td>1.77</td>
<td>26</td>
<td>0.045*</td>
</tr>
</tbody>
</table>
Table 4.28 Continued

<table>
<thead>
<tr>
<th>Question</th>
<th>Pre</th>
<th>Post</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q22 If I don't remember a particular equation needed to solve a problem on an exam, there's nothing much I can do (legally!) to come up with it.</td>
<td>3.23</td>
<td>3.07</td>
<td>0.070</td>
<td>0.472</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>26</td>
<td>1.13</td>
<td>0.133</td>
</tr>
<tr>
<td>Q33 Spending a lot of time understanding where formulas come from is a waste of time.</td>
<td>4.23</td>
<td>4.2</td>
<td>-0.111</td>
<td>0.456</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>22</td>
<td>1.05</td>
<td>0.152</td>
</tr>
</tbody>
</table>

Note: *p ≤ .05. **p ≤ .01. ***p ≤ .001

No significant differences were found between pre and post measure of female scores or between pre and post male scores for the Conceptual Understanding category. Females (4.23) had a significantly higher ($p = 0.045$) post-measure score on question 13 than did males (3.6). This indicated that females were more likely to believe that physics equations would not help their understanding of the physics concepts and that the equations were just for doing calculations.

Pre and post measure data for the Applied Conceptual Understanding category are found in Table 4.29.
Table 4.29

**Applied Conceptual Understanding, Pre and Post Values**

<table>
<thead>
<tr>
<th>Question</th>
<th>Female Average</th>
<th>Male Average</th>
<th>df</th>
<th>T</th>
<th>p (two-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1 A significant problem in learning physics is being able to memorize all the information I need to know.</td>
<td>Pre 3.31</td>
<td>2.8</td>
<td>25</td>
<td>-1.31</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>Post 3.23</td>
<td>3.4</td>
<td>26</td>
<td>-0.396</td>
<td>0.347</td>
</tr>
<tr>
<td>Q5 After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.</td>
<td>Pre 3.23</td>
<td>3.4</td>
<td>23</td>
<td>0.423</td>
<td>0.338</td>
</tr>
<tr>
<td></td>
<td>Post 3.08</td>
<td>3.6</td>
<td>26</td>
<td>-1.39</td>
<td>0.088</td>
</tr>
<tr>
<td>Q6 Knowledge in physics consists of many disconnected topics.</td>
<td>Pre 3.69</td>
<td>4.07</td>
<td>25</td>
<td>1.08</td>
<td>0.146</td>
</tr>
<tr>
<td></td>
<td>Post 3.85</td>
<td>4.13</td>
<td>22</td>
<td>-1.23</td>
<td>0.115</td>
</tr>
<tr>
<td>Q8 When I solve a physics problem, I locate an equation that uses the variables given in the problem and plug in the values.</td>
<td>Pre 1.92</td>
<td>2.07</td>
<td>18</td>
<td>0.538</td>
<td>0.299</td>
</tr>
<tr>
<td></td>
<td>Post 1.85</td>
<td>1.93</td>
<td>26</td>
<td>-0.401</td>
<td>0.346</td>
</tr>
<tr>
<td>Q22 If I don't remember a particular equation needed to solve a problem on an exam, there's nothing much I can do (legally!) to come up with it.</td>
<td>Pre 3.23</td>
<td>3.2</td>
<td>25</td>
<td>-0.070</td>
<td>0.472</td>
</tr>
<tr>
<td></td>
<td>Post 3.54</td>
<td>3.07</td>
<td>26</td>
<td>1.13</td>
<td>0.133</td>
</tr>
</tbody>
</table>
Q23 If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.08</td>
<td>3.13</td>
<td>25</td>
<td>0.137</td>
<td>0.446</td>
</tr>
<tr>
<td></td>
<td>3.31</td>
<td>2.87</td>
<td>26</td>
<td>1.26</td>
<td>0.109</td>
</tr>
</tbody>
</table>

Q41 If I get stuck on a physics problem, there is no chance I'll figure it out on my own.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.54</td>
<td>3.8</td>
<td>26</td>
<td>0.683</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>3.85</td>
<td>3.47</td>
<td>24</td>
<td>1.09</td>
<td>0.143</td>
</tr>
</tbody>
</table>

Note: *p ≤ .05. **p ≤ .01. ***p ≤ .001

No significant differences were found between pre and post intervention scores for females and no significant differences were found between pre and post intervention scores for males on any of the questions in the Applied Conceptual Understanding category. No significant differences were found comparing female and male scores.

Comparisons of CLASS, FCI, and Choice

The results of the CLASS results revealed significant differences in attitudes of female students, from pre to post measure, specifically in the categories measuring attitudes associated with problem solving. Those findings were analyzed more closely for differences in attitudes and performance based on the context choice (traditional, biology, sports). The students’ choices of context, for their first choice in the case of multiple contexts chosen, were counted and the context choice that was selected the most was used to assign students to their primary choice group. Except for one student whose primary group was sports, the other students chose either the traditional or biology context. This student was assigned to a primary group based on his
second most frequently selected context. Similarly, two other students had ties in the frequency of contexts selected and the ties were broken by examining the frequency of contexts for their second choice.

The post-data from all eight of the sub-categories of the CLASS were compared for cases where females showed significant differences in either direction. The mean scores of the traditional and biology post scores of each group were examined. These data were compared between the female group that consistently chose the traditional context and the female group that consistently chose the biology context were compared using two-sample t-tests assuming unequal variances. The sample size is made up of seven females whose choice trend is biology, and five females whose choice trend is traditional. The results are displayed in Table 4.30.

Table 4.30

<table>
<thead>
<tr>
<th>Traditional vs Biology Context Group CLASS Category Comparisons Post</th>
<th>Sub Category</th>
<th>Mean Traditional Post</th>
<th>Mean Biology Post</th>
<th>t</th>
<th>Df</th>
<th>p (one-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Problem Solving Sophistication</td>
<td>3.1</td>
<td>3.69</td>
<td>2.39</td>
<td>8</td>
<td>0.022*</td>
</tr>
<tr>
<td></td>
<td>Applied Conceptual Understanding</td>
<td>3.15</td>
<td>3.46</td>
<td>2.01</td>
<td>5</td>
<td>0.050*</td>
</tr>
</tbody>
</table>

Note. *p ≤ .05. **p ≤ .01. ***p ≤ .001

Female students who chose the biology contexts had significantly higher scores in the Problem Solving Sophistication and Applied Conceptual Understanding categories as compared with females who chose the traditional context more often.
The pre data for the sub-categories of the CLASS where significant differences were found were compared for differences of student attitudes before the students completed the WebAssign problem sets. This data was analyzed the same way as the post data and the results are displayed in Table 4.31.

Table 4.31

*Traditional vs Biology Context Group CLASS Category Comparisons Pre*

<table>
<thead>
<tr>
<th>Sub Category</th>
<th>Mean Traditional Pre</th>
<th>Mean Biology Pre</th>
<th>t</th>
<th>Df</th>
<th>p (one-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem Solving Sophistication</td>
<td>2.9</td>
<td>3.69</td>
<td>2.05</td>
<td>8</td>
<td>0.037*</td>
</tr>
<tr>
<td>Applied Conceptual Understanding</td>
<td>3.17</td>
<td>3.12</td>
<td>-0.219</td>
<td>9</td>
<td>0.416</td>
</tr>
</tbody>
</table>

Note: *p ≤ .05. **p ≤ .01. ***p ≤ .001

Comparing the pre intervention CLASS data shows that females who chose biology contexts more often had significantly higher scores than females who chose traditional contexts for the Problem Solving Sophistication category, but no significant difference was found between their scores on the Applied Conceptual Understanding category.

The FCI post scores and the FCI growth between the two female groups were compared for differences using a two-sample t-test assuming unequal variances. The data and results of the test can be seen in Table 4.32.
Table 4.32

<table>
<thead>
<tr>
<th>Sub Category</th>
<th>Mean Traditional Pre</th>
<th>Mean Biology Pre</th>
<th>t</th>
<th>Df</th>
<th>p (one-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCI Post</td>
<td>22</td>
<td>18.6</td>
<td>1.47</td>
<td>10</td>
<td>0.085</td>
</tr>
<tr>
<td>FCI Growth</td>
<td>3.57</td>
<td>1.4</td>
<td>0.935</td>
<td>7</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Note: *p ≤ .05. **p ≤ .01. ***p ≤ .001

No significant differences were found in the post-FCI scores between the two groups and no difference was found between the FCI growth between these two groups.

Correlations between the post scores from the CLASS sub-categories and the post FCI scores were made for the female biology group and the female traditional group using Excel. The findings from the correlations matrix shows that strong negative correlations exist, for females whose primary context was biology, between every sub category except Conceptual Understanding which had no correlation (0.024) and Applied Conceptual Understanding which had a strong correlation (0.514). Strong negative correlations between the post-FCI and Real World Connections (-0.828), Personal Interests (-0.578), General Problem Solving (-0.706), and Problem Solving Confidence (-0.678). Moderately negative correlations were found between Problem Solving Sophistication (-0.384), Sense Making (-0.408) and the post-FCI.

The correlations found between females whose primary context was traditional and their post-FCI scores. The correlation between Real World Connections and the post-FCI was strong (0.508) and the correlation between Personal Interests and the post FCI was strong (0.654). The correlations between Sense Making and the post FCI was weak (0.113). The correlation between Problem Solving Sophistication was very strong in the negative direction (-0.952) as was the
correlation between Applied Conceptual Understanding and post FCI (-0.988). Strong correlations were also observed between Problem Solving Confidence (-0.584) and Conceptual Understanding (-0.680).

**Summary**

In this chapter, findings related to each of the research questions were presented. The choices males and females made regarding the presented context choices were presented and the order of their choices when they chose multiple contexts were investigated. Next, the achievement of students was examined on both the problem set questions and the Force Concept Inventory (FCI). These findings were explored overall, in terms of gender, and based on whether students increased their scores or not, as well as their stated interests prior to the intervention. Finally, students’ beliefs, and attitudes as found on the Colorado (CLASS) were investigated, overall, and by gender to see how they compared and to investigate changes from pre to post intervention. In Chapter Five, these findings will be discussed.
CHAPTER FIVE

DISCUSSION

The objective of this study was to investigate whether completing a physics problem set that was designed around gender stereotypes would have any effect on student achievement, attitudes, and interest. The design of this research was informed by the social-cognitive model of academic motivation and emotion (Artino Jr, 2010). This study was centered around a problem set of twenty-one physics questions, in which each of the problems was presented as a choice of three contexts, in written and video formats. The results of the intervention were analyzed along with both pre and post intervention measures designed to detect changes related to student achievement, attitudes, choice, and conceptual understanding. This chapter is a discussion of the findings presented in Chapter Four.

Differences between Females and Males in Context Selections

The context choices made by male and female students were analyzed to answer the first research question, “When given assignment choices designed around gender stereotypes, which types of physics problems do males and females select?” Females, overall, chose biology/health contexts more often than the other two contexts, traditional and sports, than did male students. Male students, overall, were more likely to choose the traditional context over the other two contexts. Although no other studies have done an intervention online, nor in a physics problem set, nor providing the choice of a sports context, these findings on preferred context choices are resonant with those of Baram-Tsabari and Yarden (2008). In their work, they studied the interest of females and males, of various ages, towards biology and physics and similarly found that
females were significantly less interested in physics than males, but females were significantly more interested in biology than male students. Barasam-Tsabari and Yarden’s (2008) study had children, adolescents, and adults create sets of self-generated questions that were classified according to interest in biology or physics.

An unexpected, but interesting affordance of the WebAssign technology was that students could choose one or more contexts to complete. Interestingly, students were told at the beginning of the assignment that they would not receive any extra credit for completing extra assignments. However, most students chose to answer multiple contexts (and thus, extra problems). The software allowed the researcher to track the pattern of choices of the students. Those males and females who chose to do multiple contexts within a single question were placed into sub-categories for analyses; females with combinations (“combos”) and males with combos, regardless of how many multiple contexts they chose to do. Females reported they chose a certain context for two main reasons: because they were interested in the context (34% of the time) or they because they thought the context presented looked easy (33% of the time). As a reminder, the students were asked to select the question context prior to seeing the actual physics question. That is, a student might have chosen a “cuddly kitten” (interest) or a “the ball drop” (easy) prior to actually seeing and then attempting the problem, which they could view after this selection.

The trend of context choices over time, for females with combos, shows that they had a constant rate of selecting biology contexts throughout the project, a slightly increasing rate of selecting traditional contexts, and that they chose sports contexts at a decreasing rate from the beginning of the project to the end. Females who chose to do multiple contexts were more likely
to choose to complete traditional-sports combinations or answer all contexts followed by
traditional-biology, and biology-sports combinations which were selected at equal rates.
Females who chose only one context tended to choose slightly more biology questions, fewer
sports contexts, and chose traditional contexts at a relatively constant rate.

These context choices were explained by students with written comments such as, “It
looked like something we did in class,” “I like kittens,” or “It looked easy.” Female students
were equally likely to write that they chose questions because they were interested in the context,
or they thought the question was easy. Therefore, the given context of the question led to
students’ perceptions of these factors. Patall (2010) found when students had a choice of
homework, they had higher intrinsic motivation to complete the assignment and felt more
competent doing the assignment, so it is possible that this option was perceived by students as
motivating. Similar to this study, in which the researcher designed the choice options, Patall’s
(2010) study used teacher determined written assignments given to high school students, who
chose which assignment to complete, in chemistry, biology and history classes. In this study, the
choices were all related to context (biological/health, traditional, and sports).

It seems that the students’ perceptions about the choice that they made were consistent
through the end of the problem set even though several students correctly noted that the different
contexts of each question were essentially the same problem, just presented in a different
circumstance. Some students even noted that the questions were the same, but the contexts were
different. However, regardless of this observation female and male students tended to continue
to choose the same contexts until the end.
Video Questions

Compared with the written questions, male and female students were more likely to choose to complete multiple contexts with video questions. The main reason why students chose to complete a video question was because of interest in the context or the ‘cool’ factor. Students described the reasons they selected the video problems with responses such as “I enjoyed seeing the 5 second video and was motivated to actually complete the problem,” “the graph made it easy to utilize the values in the problem,” “I found it most interesting,” and “it seemed the most interesting.” The video format was more engaging to all students than the written format, according to the response rate, and the student comments reinforce that finding. Clearly video analysis problems are a format of assessment that needs further investigation.

Students were interested in the video analysis questions enough to try multiple contexts and they were interested in the written questions 3 (which dealt with tension in a taut line and included the choices of a spider & thread, mountain climber & rope, or elevator & cable), and 13 (which dealt with the normal force experienced when something hits the ground and included the choices of a rocket lift off, a cuddly kitten jump, or a standing high jump), because of the examples used in the contexts.

Female and Male Achievement Differences

To answer the question, “Are there differences in achievement of males and females, and is this related to the types of physics questions they select?” achievement in this study was measured through FCI scores and WebAssign scores. Females made significant gains in the post FCI as compared with the pre FCI, and they closed the gender gap with males by the end of the
problem set. Likewise, significant growth was observed by Caucasian female students (the measured $p$-value for minority females (0.053) was just outside of the range of significance) but both Caucasian and minority females closed the achievement gap on the post FCI with their subsequent group’s male students. Female students tended to choose biology contexts more than male students and most female students chose to complete a second context. Females did better on the biology contexts than any other context in either written or video format. Overall, students were limited to the context choice, the time they spent on the problem, and the number of submissions per problem as the only variables that they could manipulate in this study.

McCullough (2004) argues that the FCI is dominated by questions that align with stereotypical male contexts. In the findings of this study, females not only significantly improved from their pre to their post-FCI score, but their post score was statistically equal to the males’ post score. These findings and the research of McCullough (2004) suggests that the intervention was perhaps even more successful at improving female students’ conceptual understanding than first thought.

In this study, all of the choice options afforded to the students were equally difficult. This has not necessarily been the case with other studies in the literature that have also found that giving limited choice in the type of assignments or homework students can do results in greater gains on assessments. Fulton (2011) found that giving students a choice in the type of final class assignment (one defined as easier, the other more challenging), in a computer science class, resulted in lower performing students choosing an easier assignment option and therefore learning less that their peers. However, similar to this study, in a meta-study analyzing the
effects of choice in a variety of settings, Katz and Assor (2007) found that choice motivates
students when the choices are limited and aligned with student interests and goals.

In contrast to the female students, males did not show the same kinds of gains and had no
significant differences between their pre and post FCI scores, even though males had the highest
scores on the traditional context questions of the problem set. The intervention appeared to have
had a positive effect on female students’ performance on the FCI but not the males’ performance.
Why might this have happened? Even more so than the females, males were more likely to
choose a question to work on because it looked interesting to them (45%). One difference from
the females was that males who chose to do multiple contexts tended to choose traditional
contexts at a constant rate throughout the project, and they chose fewer sports contexts and
slightly more biology contexts throughout the project. Indeed, males who chose to complete
only one context tended to choose more traditional contexts from the beginning to the end of the
project, while slightly fewer sports contexts were chosen across the project, but biology contexts
were chosen at a constant rate. The most common combination of contexts were biology-sports,
then all contexts, followed by traditional-biology, and traditional-sports. These results reinforce
the findings that male students found the traditional contexts more appealing than the other
contexts.

The fact that males tended to stick with traditional contexts, which was the context they
were used to, and the fact that some males (25% of the total group) completed the entire study in
less than three days points to a supposition that they just wanted to get finished with the project
and they may have rushed through it. On the other end of the study timeline, 37% of the males
took more than fifty days to complete the project, as measured from the date they first started an
assignment to the date they completed the assignment. There wasn’t a method for tracking how long students spent on the project every day, but only the total time spent on the entire project and the dates that a student started and completed the project. The students who spent more than fifty days may have procrastinated and only completed the assignment during the last few days, after their teachers reminded them of the deadline. The majority of male students (62%) either took fewer than three days to finish or more than fifty. This last-minute push or the initial plow-through the assignment, and the playing it safe with the traditional contexts, could account for the lack of growth on the FCI. The amount of time that a student spends on an assignment is an indicator for the amount of effort a student puts on an assignment (Gershenson & Holt, 2015). Males who experienced growth on the FCI spent an average of 366.4 minutes (6.11 hours) on the WebAssign project, while males who showed no growth spent 257.4 minutes (4.29 hours) on the project. Males who showed growth spent significantly ($p = 0.0459$) more time on the WebAssign project than those who did not show growth. Furthermore, fewer males showed growth ($n = 19$) than those who did show growth ($n = 11$).

They type of context chosen seemed to have a correlation with FCI growth. The number of sports contexts chosen by female students who had growth on the FCI was weakly correlated with raw FCI growth (0.223). Males who showed growth had essentially no correlation between FCI growth and the number of biology contexts (0.060) and a weak correlation between FCI growth the number of sports contexts (0.273). Looking at the choice trends shows that males who chose more biology contexts across the scope of the project also tended to choose fewer sports contexts but chose the traditional contexts at a constant rate.
The effect of the choice in context on female students’ FCI growth can be seen in the feedback loop of Artino’s (2010) framework where positive emotions such as interest or enjoyment result in positive academic outcomes such as achievement and conceptual understanding. For males, the feedback was that they were more likely to get the traditional context problems correct compared with the other contexts which resulted in more confidence in doing the problems and more satisfaction which reinforced their choice of traditional contexts.

At first, the time spent on the assignments seemed to be an influencing factor, but under closer examination the results were revealed to be more complex. The time on the project can be explained by both the total time spent as recorded by WebAssign, and the span of time between when the student began the project and when the student completed the project. The time females tended to spend ranged from a minimum span of two weeks to a maximum of fifty days on the total project, while the span for males ranged from spending two days on the total project to fewer than fifty. No correlation was found (-0.061) between FCI growth for females who showed growth pre to post FCI and time, but for the entire group (growth, no growth, decline) of females, time was still weakly correlated with FCI growth (0.116). Time was measured by WebAssign’s internal timer which recorded how long a student spent on the project. However, the timer didn’t differentiate between the time spent on the pre and post FCI tests or the intervention. Students could have downloaded any of the word problems and worked them out by hand and then gone back into WebAssign to submit. Without additional information from the students, it’s impossible to know if they made the same sorts of “offline” choices with the problems. These limitations could have contributed to the weak correlations found, and limited the usefulness of the time on task data.
The choice to do multiple contexts, or not, had little effect on FCI scores and raw FCI growth for females, but a more substantial effect on FCI outcomes for males. Females who chose one context had a weak positive (0.162) correlation between FCI raw growth and time, whereas females who chose to do multiple contexts had virtually no correlation (0.093). Males who chose multiple contexts had a strong positive correlation (0.529) between the values, while males who only did one context had a lower, but still a moderate positive correlation (0.447) between growth and time. Males had a higher correlation between their WebAssign score and FCI raw growth. Males choosing more than one context had a moderately positive correlation (0.326), but males who only did one context had a strong correlation between their two scores (0.848). This trend is not surprising since these two groups also demonstrated positive correlations between the time they spent on WebAssign and their FCI growth. The intervention questions were open response questions and not multiple choice, so they needed to complete the problems in order to get credit instead of just checking a box. It is expected that the more time a student spends on an assignment the more their understanding will grow from exposure to the content.

There was not a significant difference between the pre and post FCI scores of males who chose to do combos versus males who chose only one context, however males who chose one context had a higher absolute score on both measures. Indeed, traditional physics courses have privileged male students (Baram-Tsabari & Yarden, 2008) who made more traditional choices, and the traditional choice also was the one more likely to correspond to an example given in the classes of the teachers who helped with this study (as explained in the Methods section).
Students who chose combos, regardless of gender, tended to do better on their first-choice context of the question. Interest in the context seemed to be more of a deciding factor for initial choice rather than the actual difficulty level. Even though the questions were essentially the same, except for the context, students were reporting one context seeming to be easier than the other. However, this was not the case since students reported on each context as they completed it. This indicates for those students who thought the question was easy, they perceived it to be easier for other reasons. Since the questions were controlled for difficulty, student interest appears to have a role in why the choice was made but also the perception of the question by the student plays a determining role as well.

Minority females showed virtually no correlation between time spent and FCI raw growth (-0.044) but Caucasian females were observed to have a stronger correlation between time and FCI raw growth (0.634). The stronger correlation between FCI raw growth and time makes sense because the longer the student is exposed to the material the more likely they will be to bring the knowledge and skills they acquire to the FCI. (Again, this study was unable to account for any ‘offline’ time that students may have used to conduct some of their work.) The sample size of Caucasian females \((n = 10)\) was virtually the same as the sample size of minority females \((n =11)\), but (as explained earlier) because of the small sample size of the different ethnic groups within the minority designation all non-Caucasians were grouped together as a whole for comparison to the Caucasian group. Furthermore, racial and ethnic differences might play a larger role in FCI growth but those questions were not addressed in this study. Further examination of a larger, diverse minority group would be recommended for full understanding of this effect on students with different ethnicities.
The Effect of Attitudes, Interests, and Choice on Performance

Choice in one’s area of interest was thought to have a correlation with female student attitudes measured by the CLASS. Female students who preferred biology themed contexts scored significantly higher on the Problem-Solving Sophistication and Applied Conceptual Understanding sub categories than did female students who preferred the traditional themed contexts. However, comparing the pre-CLASS sub-category scores with the post-scores showed little difference in the scores of each group, meaning that the difference in attitudes between the females who preferred biology themed questions and females who preferred the traditional context group was the same pre to post intervention. The lack of significant difference between the pre and post CLASS sub-category scores suggest that these attitudes may not have been the result of the choice between the contexts, but rather pre-conceived attitudes that the students of each group brought with them. No differences between the post-FCI scores or the growth experienced on the FCI between the female group that preferred biology and the group that preferred traditional contexts were found to be significant. These findings suggest that neither context choice had an effect on their conceptual understanding, but that just having a choice may be enough. Patall (2010) found that students who had a choice of homework assignments, performed better on summative assessments than students who had no choice of homework assignments. Patall’s (2010) study used high school students in six different classes, including chemistry and biology, and used teacher-made homework assignments for the students to choose from.
Written Format versus Video Format

Significant differences between the performance of male students were found between their performance on the video questions and the written questions. Males, regardless of multiple context choice or not, performed better and used fewer submissions on the written questions compared to the video questions for each context. These findings suggest that while males indicated that they enjoyed and liked the video questions more than the written questions, they did better on the written questions than they did on the video questions. Of course, the video questions were novel from what the students had seen in class, but they also required students to gather data from the video in order to try to solve the problem. Therefore, there were some additional and unfamiliar steps involved in trying to solve those problems. However, on the video biology questions, males who selected multiple contexts scored significantly higher than did males who chose only one context.

The results from the female students were not as clear. Overall, female students who did combos tended to have higher FCI scores (numerically, not significantly) and higher scores on traditional and sports questions than female students who did not choose a combo. Females who did not choose a combo tended to have higher scores on the biology contexts compared with females who chose to complete multiple contexts. The higher scores by the groups that chose to do combinations could be the result of having more practice solving the multiple questions.

Males who chose a single context scored higher and used fewer submissions on the written traditional and sports questions than did females who chose one context. Similarly, males who only chose one context did better on the traditional video questions than did females who only chose one context. The biology context was the only context where no significant
difference in WebAssign scores were found between males and females. The only significant differences found in the biology contexts between males and females were differences in the number of submissions; male students used more submissions than females on the written and biology written and video questions. In both cases of males and females, while they may have demonstrated more engagement with the video formatted questions, neither group performed better on the video questions than the written ones.

This could be due to several reasons. Two teachers reported that their students were not able to access the videos at school due to restrictions on the school’s firewall for not allowing students to access YouTube at the school. This would make it more difficult for students to get help from their teacher while they were doing the problem. But the teachers instructed the students who had home internet access to complete those questions at home. In the video questions students were expected to use data collected from the video to solve the given problems but the novelty of the format may have been more of a challenge for the students to obtain the needed information than were the written questions. While the students were all excited about the videos and interested in the premise of the question and context, their problem-solving skills may not have been as mature as expected. This explanation is reinforced by the poor ratings that female students reported on the Problem Solving contexts of the post-CLASS. Furthermore, none of the teachers reported using video analysis during their teaching and introduction of Newton’s Laws and their applications. Inexperience with the video format may have resulted in poorer performance on the problem than on the written format for all the students.
Attitudes, Interests, and Beliefs in Physics

Student attitudes, interests, and beliefs in physics were measured through pre and post CLASS surveys. The results of the male and female students were compared to better understand the gender gap and what, if any, changes occurred due to the intervention.

Changes in Female Attitudes

Female students seemed to have a wider range of changes in their attitudes about physics due to the intervention than did male students. Initially, during the pre-CLASS females and males had statistically the same scores on nearly every item on the survey except on two items. For these two items, females scored lower: one dealing with real world connections and the other dealing with sense making when it comes to physics problems. By the post-CLASS, female students had closed the gender gap on these categories and no difference was found on these questions when compared to the male responses. Because of the intervention, female students were thinking more of how the physics topics they were analyzing related to their personal experiences as compared with male students and they were more likely to consider which physics concept or idea applies to a problem than they were before the intervention. By the end of the WebAssign intervention, female students indicated that they were significantly more likely to trust their calculations and not go back through the problem than were male students. This result may be due to the nature of WebAssign and the assignment settings. WebAssign provided immediate feedback to the student and they could try each question up to five times. Compared with males, after the intervention, females were less likely to expect physics equations would help their understanding of the idea, rather reporting that equations are just there for calculations.
One observation of the females‘ data was that female students were more likely to stay with a problem and use multiple submissions as compared with males. This indicates that, nevertheless, the females persisted through the questions instead of giving up when faced with an initial set back. Grit, defined as a person’s passion and perseverance to achieve a long-term goal, contains the aspects: perseverance of effort and consistency of interest, which have been shown to predict student achievement and student study strategies (Wolters & Hussain, 2015). Wolters & Hussain (2015) investigated the role grit plays in self-regulated learning (SRL) with mostly female college students and found that grit may be associated with certain aspects of (SRL) that can help students improve academic outcomes. Although grit and perseverance were not measured in this study, females did seem to have more determination to complete the assignments than males. Future studies would be needed to determine the role and nature that grit plays in female students succeeding in physics.

Females’ scores indicated negative changes in their attitudes toward physics from pre to post intervention, primarily in the two items pertaining to CLASS categories dealing with problem-solving. Compared with their responses in the pre-CLASS, female students were less likely to think that the reasoning skills used to understand physics can be helpful in everyday life and they were less likely to believe that nearly everyone is capable of understanding physics if they worked at it. The items on the intervention weren‘t designed to deliver contexts that would be familiar to students in their everyday life; rather, they were designed to deliver the content through contexts that appealed to students based on gender stereotypes. This could explain why females were less likely to think that physics is helpful in their daily life. Many of the examples
used in the intervention questions were chosen for their appeal to students, not practicality in everyday life.

The decrease in the belief that everyone is capable of understanding physics if they work at it could be a result of the experience that the students had on the video formatted questions and with WebAssign in general. All students had lower scores on the video questions than the written questions, and some difficulty was reported by a couple of schools with the video technology. A teacher reported frustration with WebAssign not counting the students’ answers correct on the word problems, but on closer examination the teacher’s students were used to rounding their answers and as a result their answers were out of the range of the tolerance set for the problem and WebAssign was counting the submissions wrong. The teacher and students of this school were instructed not to round on the remaining questions, but to follow standard significant digits rules. Yet, it is possible that this experience contributed to students’ perceptions of their ability to understand physics, given these setbacks but no evidence was collected on these perceptions.

A study in Switzerland which surveyed male and female high school students found that females tend to have a negative view of the relationship between their gender and physics (Markarova, 2015). These findings echo what others have found and what was discussed earlier in this paper. The fact that this study saw few positive changes in female attitudes and beliefs about physics is not surprising upon further reflection. After all, many studies point to factors such as the students’ teacher, the classroom environment, female role-models, and students’ home life as major determining factors on a female’s attitudes toward a science or math subject (Meece, Glienke, & Burg, 2006).
Changes in Male Attitudes

Males had significantly higher scores than females on two questions that pertain to the problem-solving category on CLASS. Specifically, males reported that they could usually figure out how to solve a physics problem and they were more likely to believe that mathematical formulas express meaningful relationships among the variables. These changes could be due to being able to choose the context that they were most comfortable with, in this case the traditional context which was the primary context choice of males, but also because of the positive reinforcement they were receiving on their work in this context. WebAssign gave immediate feedback and allowed multiple submissions. Males who chose combinations of contexts used significantly more submissions on their first choice and numerically more submissions on their second choice than females. In other words, the combination of the technology and the opportunity to choose the context reinforced their confidence in their ability to solve physics problems. The only change in male attitudes from pre to post CLASS was the decrease in the item referring to a student’s satisfaction until they understand why something works the way it does.

Summary

Females tended to select biology contexts more than the other options and males tended to select the traditional context more than the other options, results that were consistent with contexts aligned with gender stereotypes. However, when given the option, most students chose to complete multiple contexts of the same question. Video questions were the most popular
questions for students to choose to do multiple contexts to complete. But while students enjoyed doing the video questions, they had higher scores on the word problems regardless of gender or group. Student interests seemed to play a role in which types of contexts students chose. Females made significant gains on post FCI scores, while males began with higher scores than female students, and had no significant increases on their FCI scores from pre to post. Time on WebAssign was not found to have a positive correlation on FCI growth for females, but strong correlations between WebAssign scores and post FCI scores were found for both genders. The choice of whether to do multiple contexts or to do just one context made no difference in FCI growth. By the end of the study, the data suggests females were thinking more of how to apply physics concepts to problems and how to relate physics to their own experiences, but they decreased in their confidence to solve problems. The data indicated that males gained confidence in their ability to solve problems and grew in trust of the relationship between physics formula and concepts.
CHAPTER SIX

CONCLUSION AND IMPLICATIONS

Females continue to be underrepresented in many STEM fields, but especially in physics where the number of physics degrees earned by females remains stubbornly low. Studies have shown multiple reasons for females not taking physics or pursuing physics as a career, but few have addressed the issues of female students’ interest in the high school physics curriculum. Students are more motivated if the curriculum is presented to them in the form of their interests (Talley, 2017). Researchers have found that many female students show more interest and engagement in physics when presented through contexts that they already enjoy such as with medical applications or biological contexts (McCullough, 2004), (Crouch & Heller, 2014). Through a literature review, studies have found when students have a limited choice of an assignment, their achievement increases (Bereby-Meyer, Assor, & Katz, 2004).

This study investigated the role that student choice and gender stereotypes had on students’ attitudes toward and conceptual understandings of physics. This study adapted research regarding female student interests and student choice into an online assignment designed to investigate their possible role in the attitudes, understanding, and achievement or male and female students. Artino’s (2010) social-cognitive model of academic motivation and emotion was adapted and used as a guiding framework for this study. Pre and post instruments were used to measure changes in conceptual understanding and beliefs and attitudes about physics. An intervention was created and delivered online.
Female students made gains in the FCI and achieved high scores on the intervention. These gains can be attributed to the design of the intervention, specifically the use of student choice and contexts aligned with students’ interests. However, females showed loss of confidence in some problem solving and interest aspects as measured by the CLASS.

**Implications**

Findings from this study show that student choice in a context that interests them can have a positive impact on their achievement. Specifically designing online assignments that appeal to students’ interests and giving them the choice to select the context which aligns with their interest is at the heart of this study. Student choice within an assignment is a unique approach that this study used, and one that is being adapted for other applications within education. Adaptive learning, using computers as teaching devices that adapt to the learner, is being used at the university level to help students overcome knowledge gaps in chemistry, math, and biology (Liu, 2017). Adaptive learning algorithms are being used in Massive Online Open Courses (MOOCs) and are using the game mechanics of perfectionism to increase student motivation to achievement on situational awareness training (Uskov, Howlett, & Jain, 2017).

The results show that females’ scores on the FCI increased and that they persevered through the problems instead of giving up. The combination of contexts that appealed to female interests, student choice, and multiple chances to try a problem factors that could be implemented into future curricula designed to make a traditionally stereotypical male subject more appealing and interesting to female students.
Significance and Limitations

The call for change in physics curricula to interest more female students in STEM and specifically physics has been gaining more traction over the past decade as researchers examine the affective side of physics pedagogy. This current study has taken a new approach at designing physics assignments in a way to specifically engage the interests of female students. The assignments combined student choice, variation in context, and video analysis to create an adaptable learning experience for students. The development of the WebAssign intervention is one that could be used by other teachers to try to better engage students, particularly female students, in physics. This study shows that giving students choice in the context of the physics problem can result in positive outcomes in student achievement. All the students did very well on the homework questions, and the data demonstrates that they persisted through many tries to get the answer correct.

The use of video analysis questions is an area for future research that wasn’t fully explored in this study. Even though the students did not do as well on the video problems as they did on the word problems, the video problems were the most popular problems on the assignment and the ones that students showed the most enjoyment in, at least according to the students’ comments. Further work is needed to better determine how to best tap into that interest and use it to engage students, but also use it to help them learn physics.

However, there are several limitations of this study that should be addressed. Some students had never used WebAssign prior to the study and while an online tutorial was provided, some teachers contacted the author with problems their students were having with the technology. Similarly, two schools reported that the students could not watch the embedded
videos because their schools blocked YouTube©. This study used a convenience sample of schools, teachers, and students who were willing to take the effort to complete this study. The students were already in AP Physics classes and were most likely high achieving students anyway. Future studies should take this into account and investigate the role that context, choice, and video analysis has on students who are at lower academic levels. Socioeconomic differences were not addressed in this study and while minorities made up a sizeable portion of the sample group, very few traditionally underserved students were part of this study. Future studies should seek out a wider population of underserved minorities and students of lower socioeconomic status.

By exploring the impact of students’ choices and interests in learning physics, we can make steps in the right direction to make physics more appealing to girls so that one day, physics will not be considered just a man’s field, but everyone’s field.
REFERENCES


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http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA006655


10.1037/a0027697.supp (Supplemental)


10.1037/a0030307.supp (Supplemental)


Appendices
Appendix A.

IRB

NORTH CAROLINA STATE UNIVERSITY
INSTITUTIONAL REVIEW BOARD FOR THE USE OF HUMAN SUBJECTS IN RESEARCH
SUBMISSION FOR NEW STUDIES

Protocol Number 6552

Project Title
Using Choice to Uncover the Role of Gender Stereotypes in High School Physics Assignments: Examining students’ interests, beliefs, conceptual understanding and motivations

IRB File Number

Original Approval Date:
02/10/2016

Approval Period
02/10/2016 - 02/10/2017

Source of funding (if externally funded, enter PINS or RADAR number of funding proposal via ‘Add New Sponsored Project Record’ button below):

Dissertation Grant, Personal Funds

NCU/ Faculty point of contact for this protocol: IRB; only this person has authority to submit the protocol
Blanchard, Margaret: Science, Technology, Engineering, & Mathematics Education (STEM)

Does any investigator associated with this project have a significant financial interest in, or other conflict of interest involving, the sponsor of this project? (Answer No if this project is not sponsored)
No

Is this conflict managed with a written management plan, and is the management plan being properly followed?
No

Preliminary Review Determination

Category
Expedited 7

In lay language, provide a brief synopsis of the study (limit text to 1500 characters)
The goal of this project is to examine the role of gender stereotypes in high school physics assignments. This study will investigate how the physics curriculum can be modified to make the subject more appealing to women. The study will involve different groups of students to choose from those who are interested in science, sports, and traditional physics. This project intends to use a quasi-experimental design to see if introducing physics through contexts that female students have shown interest in will translate into positive attitudes and interests in physics.

Briefly describe in lay language the purpose of the proposed research and why it is important.
In 2012, 19% of the physics degrees and 36% of the engineering degrees earned were earned by women. Women are not choosing to pursue degrees in STEM, which in turn leads to fewer women pursuing STEM careers. Physics is the keystone course to most STEM degrees and numerous studies point to the lack of interest in women in the subject. However, the gender gap in science and engineering is always present and has been shown to widen as students move from primary to secondary grade levels. The current design of high school physics courses that makes use of traditional examples with little real world application clearly has resulted in attracting more males to physics. This study intends to use a quasi-experimental design to see if introducing physics through contexts that female students have shown interest in will translate into positive attitudes and interests in physics as a topic.

My research qualifies for Exemption. Exempt research is minimal risk and must fit into the categories b.1 - b.6 found here: http://www.hhs.gov/ohrp/humansubjects/guidance/45crf46.html

0
Is this research being conducted by a student?

Yes

Is this research for a thesis?

No

Is this research for a dissertation?

Yes

Is this independent research?

No

Is this research for a course?

No

Do you currently intend to use the data for any purpose beyond the fulfillment of the class assignment?

No

Please explain

If so, please explain

If you anticipate additional NCSU-affiliated investigators (other than those listed on the Title tab) may be involved in this research, list them here indicating their name and department.

None

Will the investigators be collaborating with researchers at any institutions or organizations outside of NC State?

No

List collaborating institutions and describe the nature of the collaboration

What is NCSU's role in this research?

Describe funding flow, if any (e.g. subcontractors)

Is this international research?

No

Identify the countries involved in this research

An IRB equivalent review for local and cultural context may be necessary for this study. Can you recommend consultants with cultural expertise who may be willing to provide this review?

Adults 18-64 in the general population?

Yes

NCSU students, faculty or staff?

No

Adults age 65 and older?

No

Minors (under age 18)—be sure to include provision for parental consent and/or child assent?

Yes

List ages or age range:

15-18

Could any of the children be “Wards of the State” (a child whose welfare is the responsibility of the state or other agency, institution, or entity)?

No

Please explain.

Prisoners (any individual involuntarily confined or detained in a penal institution—can be detained pending arraignment, trial or sentencing)?

No

Pregnant women?

No

Are pregnant women the primary population or focus for this research?
Provide rationale for why they are the focus population and describe the risks associated with their involvement as participants

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fetuses?</td>
<td></td>
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<tr>
<td>Students?</td>
<td>No</td>
<td></td>
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<tr>
<td>Does the research involve normal educational practices?</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Is the research being conducted in an accepted educational setting?</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Are participants in a class taught by the principal investigator?</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Are the research activities part of the required course requirements?</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Will course credit be offered to participants?</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Amount of credit?</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

If class credit will be given, list the amount and alternative ways to earn the same amount of credit. Note the time it takes to gain the same amount of credit by the alternate means should be commensurate with the study task(s).

How will permission to conduct research be obtained from the school or district?

A letter will be sent to the schools' administration and cooperating teacher. Permission for the research will be sought from principals, and any additional, required permissions will be pursued. If needed, a letter will also be sent to the administration at the district level, describing the study and asking for permission for the study to be conducted.

Will you utilize private academic records?

No

Explain the procedures and document permission for accessing these records.

Employees?

No

Describe where (in the workplace, out of the workplace) activities will be conducted.

From whom and how will permission to conduct research on the employees be obtained?

How will potential participants be approached and informed about the research so as to reduce any perceived coercion to participate?

Is the employer involved in the research activities in any way?

No

Please explain:

Will the employer receive any results from the research activities (i.e., reports, recommendations, etc.)?

No

Please explain. How will employee identities be protected in reports provided to employers?

Impaired decision making capacity/Legally incompetent?

No

How will competency be assessed and from whom will you obtain consent?

Mental/emotional/developmental/psychiatric challenges?

No

Identify the challenge and explain the unique risks for this population.
Describe any special provisions necessary for consent and other study activities (e.g., legal guardian for those unable to consent).

People with physical challenges?
No

Identify the challenge and explain the unique risks for this population.

Describe any special provisions necessary for working with this population (e.g., witnesses for the visually impaired).

Economically or educationally disadvantaged?
No

Racial, ethnic, religious and/or other minorities?
Yes

Non-English speakers?
No

Describe the procedures used to overcome any language barrier.

Will a translator be used?
No

Provide information about the translator (who they are, relation to the community, why you have selected them for use, confidentiality measures being utilized).

Explain the necessity for the use of the vulnerable populations listed.

This study will target high school physics students in both public and private school environments. As a result, the student population being used for this study will be representative of the local communities.

State how, where, when, and by whom consent will be obtained from each participant group. Identify the type of consent (e.g., written, verbal, electronic, etc.). Label and submit all consent forms.

Students will be invited to participate by submitting a consent form electronically through WebAssign as instructed by their cooperating teacher before any data is collected. A letter will be sent home to the parents and students explaining the research and the student's role in the research and inviting them to participate. The letter consists of the project description and an invitation for both the students and parents. A copy has been provided in the additional documents section. The same description and invitation will be included online, in WebAssign for the students to refer back.

If any participants are minors, describe the process for obtaining parental consent and minor's assent (minor's agreement to participate).

A written parental consent form will be provided to the students via the cooperating teacher, before the study begins, so that they can take it home and get it signed by their parents.

Parents/guardians will sign the minor's agreement to participate in the study. The written form will be returned to the researcher by the cooperating teacher.

Are you applying for a waiver of the requirement for consent (no consent information of any kind provided to participants) for any participant group(s) in your study?
No

Describe the procedures and/or participant group for which you are applying for a waiver, and justify why this waiver is needed and consent is not feasible.

Are you applying for an alteration (exclusion of one or more of the specific required elements) of consent for any participant group(s) in your study?
No

Identify which required elements of consent you are altering, describe the participant group(s) for which this waiver will apply, and justify why this waiver is needed.

Are you applying for a waiver of signed consent (consent information is provided, but participant signatures are not collected)? A waiver of signed consent may be granted only if: The research involves no more than minimal risk; The research involves no procedures for which consent is normally required outside of the research context.
No

Would a signed consent document be the only document or record linking the participant to the research?
Is there any deception of the human subjects involved in this study?
No

Describe why deception is necessary and describe the debriefing procedures. Does the deception require a waiver or alteration of informed consent information? Describe debriefing and/or disclosure procedures and submit materials for review. Are participants given the option to destroy their data if they do not want to be a part the study after disclosure?

For each participant group please indicate how many individuals from that group will be involved in the research. Estimates or ranges of the numbers of participants are acceptable. Please be aware that participant numbers may affect study risk. If your participation totals differ by 10% from what was originally approved, notify the IRB.

Approximately 300 student participants are anticipated.

Of that group ~ 70% are anticipated to be male, 30% female.

I am anticipating each teacher will represent a school with a total of approximately 15 schools. Of those it is estimated that 12 will be public schools and 3 private. It is estimated that 20 students from each school will participate.

It is expected that each participating school will contribute 1 participating teacher for a total of 15 teachers.

How will potential participants be found and selected for inclusion in the study?

High school general physics and AP Physics teachers will be recruited through private ETS/AP Physics, NC DPI, NCSTA, and NC-AAPT listserves. Teachers will be sent an invitation to participate which will include a description of the project and a description of the tasks they are being asked to do, in the letter attached. The same invitation will also be posted on the listserves discussed above. An incentive of ~$75 will also be available for any teacher who agrees to participate and complete all of the tasks. A letter describing the project and what the teachers and students will be asked to do is included in the teacher letter project description/invitation.

Students will be asked to participate in the research study by their teachers.

For each participant group, how will potential participants be approached about the research and invited to participate? Please upload necessary scripts, templates, talking points, flyers, blurbs, and announcements.

Teachers will receive an invitation e-mail to participate and an informed consent letter. They will also receive informed consent letters to hand out to students in their classes. Teachers who offer to participate will be compensated with a ~$75 gift card upon completion of the project. The goal is to recruit ~10 teachers.

Student participants who complete the project will receive a ~$10 gift card. The goal is to recruit ~100-200 students.

Describe any inclusion and exclusion criteria for your participants and describe why those criteria are necessary (if your study concentrates on a particular population, you do not need to repeat your description of that population here.)

The only exclusion criteria that this project has for participants is that they have access to a computer that has internet access to the world wide web. The nature of the way the instrument is set up is that the variables being studied can only be investigated by being delivered electronically. As discussed below in the participant experience section, students will make a choice of a context of a problem they wish to do. That choice is one variable being measured and it could not be replicated in a hard copy version of the instrument. Students who do not have access to this technology, but who want the experience, will be given a hard copy of a the assignments from the 'traditional physics' context problems. However, their work will not be used in the study. Other than access to a computer, there will be no inclusion or exclusion criteria for participants other than students' enrollment in a high school physics or AP physics course.

Is there any relationship between researcher and participants - such as teacher/student, employer/employee?
No

What is the justification for using this participant group instead of an unrelated participant group? Please outline the steps taken to mitigate this relationship.

Describe any risks associated with conducting your research with a related participant group.

Describe how this relationship will be managed to reduce risk during the research.

How will risks to confidentiality be managed?

Address any concerns regarding data quality (e.g. non-candid responses) that could result from this relationship.
In the following questions describe in lay terms all study procedures that will be experienced by each group of participants in this study. For each group of participants in your study, provide a step-by-step description of what they will experience from beginning to end of the study activities.

**Chronological Order of Procedure**

1. Teachers are contacted and asked if they would be willing to participate in and recruit student participants for this study. Teachers are told they will receive a $75 gift card for their participation and help during the project. (Approximately 10 teachers will be recruited).

2. For willing teachers, the researcher will ask permission for the research to be conducted from principals, and any additional, required permissions will be pursued.

3. Teachers who accept the invitation are sent informed consent documents to distribute to student participants. Teachers recruit student participants and inform students that if they complete the project they will get a $10 gift card. Teachers will be encouraged to offer extra credit to students in order to get them to participate. Students who agree to participate are given consent forms to have their parents/guardians complete. Students return completed forms the teachers. Teachers themselves complete informed consent documents and return those along with collected student & parent consent forms to the researcher in a self-addressed stamped envelope (SASE) that the researcher sends them.

4. **Parents:** The parents of the students will be asked to sign the informed consent document to allow or not to allow their students to participate in the study.

5. Teachers will ask students to complete the project on their own time over the course of 2-3 weeks. Students who do not wish to participate will see no change in their classroom experience for the duration of this project.

6. Teachers will provide students who want the extra credit, but do not or cannot participate on the online project with hardcopy versions of the WebAssign homework given. The work of students with the hardcopy will not be used in this project.

7. Teachers will reinforce the fact that participating students must complete all parts of the project to receive their gift card.

8. Teachers are sent instructions and the link to the Qualtrics teacher survey and are asked to provide examples of problems they do in class when teaching Newton’s Laws.

9. Teachers complete the teacher version of the Physics Motivation Questionnaire (PMQ) in Qualtrics and mail (in SASE) or e-mail copies of example problems and lessons, they use in teaching the unit on Newton’s Laws, to the researcher.

10. Once the students have returned their signed informed consent letters to the cooperating teacher and have agreed to participate, they will be given log in information by their teacher to access the surveys (in Qualtrics) and online assignments (in WebAssign).

11. Teachers are sent web links and student log in information for the attitude surveys and the WebAssign instrument. Teachers will be asked to complete the surveys and WebAssign homework on their own time, but teachers may give them class time as per the teacher and students’ circumstances.

12. Students will first take a pre-treatment attitude survey (Colorado Learning Attitudes about Science Survey-CLASS) and the Physics Motivation Questionnaire (PMQ) and the pre-physics concept survey (Force Concept Inventory-FCI). Students will view a short YouTube video tutorial on how to use WebAssign to do the homework problems.

13. Once they complete these students will begin the first of 5 homework assignments. Each assignment consisting of 4 questions. Students will complete these assignments over the course of 2-3 weeks. Each assignment should take no longer than an hour to complete and at most an hour and half. The homework assignments will include written questions and questions that contain short videos to analyze. All of the questions are based on the physics concepts of Newton’s Laws and their applications. These assignments will easily fit into a unit on Newton’s Laws or serve as review material for a course exam. All student responses will be recorded online in WebAssign.

14. Each homework assignment consists of 4 problems: 3 written and 1 video format. When students begin the first problem they will be given the choice of 3 contexts (sports, biology, traditional physics) of the physics problem. They will not see the question prior to making their choice, only the 3 contexts.

15. For example, for the first problem: they would be asked to make a choice between doing a problem on net force on either an elevator, a spider, and a mountain climber.

16. The student will only do the version/context they choose and not the other versions of the question. Students will continue this for each of the questions.

17. The video versions of the questions are no different in the presentation and format of the question. Students will be presented with 3 contexts/versions (sport, biology, traditional physics) but they will only choose one version to do.
They will enter their response and or save their work so that they can come back later. Once they enter an answer, and click 'submit' their answer will be automatically graded by WebAssign. Students will have 5 chances to correctly answer the question before they are locked out of the problem. Students may request an automatic extension past the due date of any/all assignments for 48 hours after the assignment comes due - this will be programmed into WebAssign and the students may use this if they need more time to complete the assignment. Once the first assignment has been completed, the next one will be available, and so on until all assignments have been completed.

10. Once students have finished all 5 assignments, they will be given the post-CLASS and post-FCI.
11. Teachers are sent written solutions and answer keys to the homework questions.
12. Students are finished with the project.
13. Teachers are sent their $75 gift card via e-mail.
14. Students who completed the project are sent their $10 gift card and receive any teacher specific extra credit. Gift cards will be mailed to the teacher to distribute to the participating students.

Non-participants who did not want to do the project are given solutions to written problems and receive any teacher specific extra credit upon completion.

Describe how, where, when, and by whom data will be collected.

Quantitative Data:
Students:
Cooperating teachers will have the students take the pre-intervention Force Concept Inventory (FCI) online on WebAssign. The FCI will be given to the students at once all the informed consent documents have been collected and returned. Once this occurs the WebAssign accounts will be released to the students and they will be able to take the pre FCI. The post-FCI will be taken after the final homework assignment has been completed approximately 2-3 weeks after the initial pre-FCI was taken. Students will take the assessments as part of class assignments in order to use data from those who gave consent.

Numerical responses of the homework problems will be collected and recorded by WebAssign for each student during the deployment of the homework problems during the 2-3 weeks of the intervention.

Qualitative Data:
Students:
Cooperating teachers will make sure that students are given log in information to take the initial per-intervention attitudes survey (Colorado Learning Attitudes about Science Survey or CLASS) and the pre-intervention motivation survey (Physics Motivation Survey (PMQ)) online through Qualtrics before the intervention in WebAssign starts. After the intervention, the cooperating teacher will make sure that the students take the post-CLASS and post PMQ surveys also online through Qualtrics.

Student responses to WebAssign homework questions will be collected in WebAssign as students complete their assignments. This will occur as the student works in WebAssign and is automatic.

Teachers: Teachers will submit written examples of the specific physics examples they use in class during the target unit at the end of the intervention. They will be asked to mail in hard copies of these examples when they mail in the student forms. Teachers will also complete the teacher version of the PMQ on Qualtrics at the end of the intervention.

Social?
No

Psychological?
Yes

Financial/Employability?
No

Legal?
No

Physical?
No

Academic?
Yes

Employment?
No
Financial?
No

Medical?
No

Private Behavior?
No

Economic Status?
No

Sexual Issues?
No

Religious Issues/Beliefs?
No

Describe the nature and degree of risk that this study poses. Describe the steps taken to minimize these risks. You CANNOT leave this blank, say 'NA', or 'no risks'. You can say "There is minimal risk associated with this research."

Students will be asked to complete pre and post attitude surveys which could potentially make the students feel uncomfortable. However, the results of the surveys will be collected online and no one else will see the results other than the researchers. Students will also be asked to explain why they chose the context that they did, and again that could potentially make the students feel nervous or uncomfortable. But their responses will only be visible to the researchers and will be submitted online.

Any academic risk is also minimized. Students will be completing online homework assignments which will be automatically graded by WebAssign which could be potentially stressful to the student. To avoid any potential stress, students will be allowed to submit an answer to a question up to five times before the question accepts no more responses. This will give students more time to try another approach to solving the problem and feedback on their previous method. Each assignment will be assigned to the students with a definite due date and due time, but an option for an automatic 24 hour extension to the assignment will be available for each student. These measures will be taken to avoid any potential risk or stress to the academic nature of the assignment. Students will be allowed these measures to ensure that stress associated with grades can be mitigated. Even though the scores students receive while doing these homework problems won't be part of their class grade or used in any way by their teacher, some students may experience discomfort if they don't make a high enough grade.

If you are accessing private records, describe how you are gaining access to these records, what information you need from the records, and how you will receive/record data.

The researcher will not be accessing private records.

Are you asking participants to disclose information about other individuals (e.g., friends, family, co-workers, etc.)?
No

You have indicated that you will ask participants to disclose information about other individuals (see Populations tab). Describe the data you will collect and discuss how you will protect confidentiality and the privacy of these third-party individuals.

If you are collecting information that participants might consider personal or sensitive or that if revealed might cause embarrassment, harm to reputation or could reasonably place the subjects at risk of criminal or civil liability, what measures will you take to protect participants from those risks?

General demographic data will be collected in this study through the online system Qualtrics. Students will self-report the following: race/ethnicity, gender, age, grade level, intended college major, extracurricular activities. Qualtrics will be used to allow the students to submit their information online, and will be password protected which will be known to the researchers.

Additionally, WebAssign will also be password protected and the researchers will assign a password to each student so that they are the only ones able to access their accounts. Students will use WebAssign to submit their answers to the questions in the intervention and only the researchers will have access their answers. The cooperating teachers will be given the class content test data upon request. The nature of this research project requires that the participants have access to the internet, so only students with access will be invited to participate.

If any of the study procedures could be considered risky in and of themselves (e.g. study procedures involving upsetting questions, stressful situations, physical risks, etc.) what measures will you take to protect participants from those risks?
The questions in the demographics survey, the attitudes survey (CLASS), the conceptual inventory (FCI), the Physics Motivational Questionnaire (PMQ) and the online homework questions in WebAssign, are not considered risky. None of these questions involve emotionally stressful situations, physical risks, or are upsetting.

Describe the anticipated direct benefits to be gained by each group of participants in this study (compensation is not a direct benefit).

The potential benefits of participating in this study are that students will have more practice solving basic physics problems and they may find themselves more interested in physics as a subject because of their ability to choose problems that interest them in the intervention. They will be exposed to applications of physics in situations that they may not have thought of before. End of course test scores may be higher as a result of the additional exposure to the material.

If no direct benefit is expected for participants describe any indirect benefits that may be expected, such as to the scientific community or to society.

Society and the scientific community may benefit from this study because of the knowledge gained about the role of choice in student interests in physics as well as knowledge gained about the role that gender bias and stereotype play in student interest in high school physics courses.

Will you be receiving already existing data without identifiers for this study?

No

Will you be receiving already existing data which includes identifiers for this study?

No

Describe how the benefits balance out the risks of this study.

Will data be collected anonymously (meaning that you do not ever collect data in a way that would allow you to link any identifying information to a participant)?

No

Will any identifying information be recorded with the data (ex: name, phone number, IDs, e-mails, etc.)?

Yes

Will you use a master list, crosswalk, or other means of linking a participant's identity to the data?

Yes

Will it be possible to identify a participant indirectly from the data collected (i.e. indirect identification from demographic information)?

No

Audio recordings?

No

Video recordings?

No

Images?

No

Digital/electronic files?

Yes

Paper documents (including notes and journals)?

Yes

Physiological Responses?

No

Online survey?

Yes

Restricted Computer?

Yes

Password Protected files?

Yes

Firewall System?

Yes

Locked Private Office?

Yes

Locked Filing Cabinets?

Yes

Encrypted Files?
Describe all participant identifiers that will be collected (whether they will be retained or not) and explain why they are necessary.

The first and last names of participants, and their demographic information, will be collected at the beginning of the project in order to allow students to create accounts on WebAssign so that they can access the research instrument. It is also necessary to collect identifying information so that the pre and post intervention data can be linked. As data is collected from a variety of schools, their identifying information will also be used to match the participant with the school.

A master list will be generated with the participant’s identifying information and a corresponding identifying number. This identifying number will be unique to each participant and will be used to match up their information and results from the study.

Once the students set up their accounts in WebAssign, the researcher will go into their accounts and permanently replace their names with the unique identification number. Students will still be able to log in and access their account, but their scores and results will not correspond to a name in the WebAssign gradebook or roster. Anyone viewing the results on WebAssign will only see scores associated with a number, not a name. Students will still be able to contact the researcher directly in WebAssign, but only identified to the researcher by the identification number.

The master file will be kept on the NCSU provided Google Drive with a 2 step login verification process. If any links between data and participants are to be retained, how will you protect the confidentiality of the data?

The master file will be kept on the NCSU provided Google Drive with a 2 step login verification process.

If you are collecting data electronically, what (if any) identifiable information will be collected by the host site (such as email and/or IP address) and will this information be reported to you?

No e-mail or IP address data will be collected from Qualtrics, but participant’s names will be collected in order to match up pre and post intervention survey data. Similarly, WebAssign will collect participant names in order to match up the data with the participant. WebAssign does collect IP address data for the instructor’s use only. Only the researcher and certain WebAssign staff have access to this information. The researcher will use an NCSU WebAssign account which is password protected for this study. IP address information will not be used for this study. This information is only available to the researcher, as part of WebAssign’s security features, and this information will be deleted with the roster of students in WebAssign at the end of the project. When signing up for a WebAssign account, the platform does ask for student e-mail addresses as an option for resetting locked student accounts or for accessing accounts because of forgotten passwords, but students will be instructed by their cooperating teacher not to enter in their e-mail addresses.

Describe any ways that participants themselves or third parties discussed by participants could be identified indirectly from the data collected, and describe measures taken to protect identities.

The research participants will have numbers assigned as their code name, which will be used as a pseudonym for data analysis. The numbers will not correspond to any identifying information about that student such as school gender, or other demographic data. Written responses from participants will also be assigned to this code in order to mask any identifying information.

For all recordings of any type: Describe the type of recording(s) to be made Describe the safe storage of recordings. Who will have access to the recordings? Will recordings be used in publications or data reporting? Will images be altered to de-identify? Will recordings be transcribed and by whom?

No recordings will be made in this study.

Describe how data will be reported (aggregate, individual responses, use of direct quotes) and describe how identities will be protected in study reports.

Quantitative data will be collected in an aggregate manner, along with results from some of the qualitative surveys. Individual written responses to specific questions in the intervention will be collected and pseudonyms will be used throughout the analyses, results, and findings sections of this research project and no statements that could identify a location, teacher, student, any individual or school will be used in the reports of this project.

Will anyone besides the PI or the research team have access to the data (including completed surveys) from the moment they are collected until they are destroyed?

No

Describe any compensation that participants will be eligible to receive, including what the compensation is, any eligibility requirements, and how it will be delivered.

Cooperating teachers will be recruited to participate in this research project. Teachers who agree to deliver the surveys and the interventions, and to return the informed consent documents to the researcher will receive a $75 Amazon Gift card upon completion of the project. To be eligible, teachers will need to be able to volunteer one class (1 gift card per
class) of either an AP Physics or Honors Physics. Teacher participants whose classes only complete the pre and post surveys will not receive any additional compensation. The teacher gift card will be delivered electronically to the teacher through e-mail.

Student participants who complete all parts of the project will receive a $10 gift card which will be sent to the teacher to distribute to the participating students. (Since no student e-mail addresses were collected, snail mail will be the used.) The teachers at each school will be free to offer extra credit to their students as they see fit. No school will be aware of what any other school's teacher offered in the way of extra credit. The researcher will have no involvement in the process of offering or not offering extra credit other than the suggestion of using it.

Explain compensation provisions if the participant withdraws prior to completion of the study.

There are no compensation provisions if the participant withdraws before completion of the study. To receive compensation, teachers must see the study through to the end.
Appendix B.
CLASS
(http://www.colorado.edu/sei/class/CLASS8-18-04.pdf)

Teachers: Please fill out the following information.

Please enter your name:

Please enter your email address:

Please enter your school name:

Please enter the name of the course you intend to use this survey in:

We would appreciate it if you could also take the survey for us. This would be immensely helpful to us in that it would enrich our expert response data base. After taking the survey you may return here to retrieve the survey in a PDF format.

Introduction

Here are a number of statements that may or may not describe your beliefs about learning physics. You are asked to rate each statement by selecting a number between 1 and 5 where the numbers mean the following:

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Choose one of the above five choices that best expresses your feeling about the statement. If you don't understand a statement, leave it blank. If you have no strong opinion, choose 3.

Survey

1. A significant problem in learning physics is being able to memorize all the information I need to know.

   Strongly Disagree 1 2 3 4 5 Strongly Agree
   not answered

2. When I am solving a physics problem, I try to decide what would be a reasonable value for the answer.

   Strongly Disagree 1 2 3 4 5 Strongly Agree
3. I think about the physics I experience in everyday life.

Strongly Disagree 1 2 3 4 5 Strongly Agree
not answered

4. It is useful for me to do lots and lots of problems when learning physics.

Strongly Disagree 1 2 3 4 5 Strongly Agree
not answered

5. After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.

Strongly Disagree 1 2 3 4 5 Strongly Agree
not answered

6. Knowledge in physics consists of many disconnected topics.

Strongly Disagree 1 2 3 4 5 Strongly Agree
not answered

7. As physicists learn more, most physics ideas we use today are likely to be proven wrong.

Strongly Disagree 1 2 3 4 5 Strongly Agree
not answered

8. When I solve a physics problem, I locate an equation that uses the variables given in the problem and plug in the values.

Strongly Disagree 1 2 3 4 5 Strongly Agree
not answered

9. I find that reading the text in detail is a good way for me to learn physics.
10. There is usually only one correct approach to solving a physics problem.

Strongly Disagree 1 2 3 4 5 Strongly Agree

11. I am not satisfied until I understand why something works the way it does.

Strongly Disagree 1 2 3 4 5 Strongly Agree

12. I cannot learn physics if the teacher does not explain things well in class.

Strongly Disagree 1 2 3 4 5 Strongly Agree

13. I do not expect physics equations to help my understanding of the ideas; they are just for doing calculations.

Strongly Disagree 1 2 3 4 5 Strongly Agree

14. I study physics to learn knowledge that will be useful in my life outside of school.

Strongly Disagree 1 2 3 4 5 Strongly Agree

15. If I get stuck on a physics problem on my first try, I usually try to figure out a different way that works.

Strongly Disagree 1 2 3 4 5 Strongly Agree
16. Nearly everyone is capable of understanding physics if they work at it.

   Strongly Disagree  1  2  3  4  5  Strongly Agree
   ○ ○ ○ ○ ○
   not answered

17. Understanding physics basically means being able to recall something you've read or been shown.

   Strongly Disagree  1  2  3  4  5  Strongly Agree
   ○ ○ ○ ○ ○
   not answered

18. There could be two different correct values for the answer to a physics problem if I use two different approaches.

   Strongly Disagree  1  2  3  4  5  Strongly Agree
   ○ ○ ○ ○ ○
   not answered

19. To understand physics I discuss it with friends and other students.

   Strongly Disagree  1  2  3  4  5  Strongly Agree
   ○ ○ ○ ○ ○
   not answered

20. I do not spend more than five minutes stuck on a physics problem before giving up or seeking help from someone else.

   Strongly Disagree  1  2  3  4  5  Strongly Agree
   ○ ○ ○ ○ ○
   not answered

21. If I don't remember a particular equation needed to solve a problem on an exam, there's nothing much I can do (legally!) to come up with it.

   Strongly Disagree  1  2  3  4  5  Strongly Agree
   ○ ○ ○ ○ ○
   not answered

22. If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.
23. In doing a physics problem, if my calculation gives a result very different from what I'd expect, I'd trust the calculation rather than going back through the problem.

24. In physics, it is important for me to make sense out of formulas before I can use them correctly.

25. I enjoy solving physics problems.

26. In physics, mathematical formulas express meaningful relationships among measurable quantities.

27. It is important for the government to approve new scientific ideas before they can be widely accepted.

28. Learning physics changes my ideas about how the world works.
29. To learn physics, I only need to memorize solutions to sample problems.

   Strongly Disagree 1 2 3 4 5  Strongly Agree

   not answered

30. Reasoning skills used to understand physics can be helpful to me in my everyday life.

   Strongly Disagree 1 2 3 4 5  Strongly Agree

   not answered

31. We use this statement to discard the survey of people who are not reading the questions. Please select agree-option 4 (not strongly agree) for this question to preserve your answers.

   Strongly Disagree 1 2 3 4 5  Strongly Agree

   not answered

32. Spending a lot of time understanding where formulas come from is a waste of time.

   Strongly Disagree 1 2 3 4 5  Strongly Agree

   not answered

33. I find carefully analyzing only a few problems in detail is a good way for me to learn physics.

   Strongly Disagree 1 2 3 4 5  Strongly Agree

   not answered

34. I can usually figure out a way to solve physics problems.

   Strongly Disagree 1 2 3 4 5  Strongly Agree

   not answered

35. The subject of physics has little relation to what I experience in the real world.
36. There are times I solve a physics problem more than one way to help my understanding.

37. To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed.

38. It is possible to explain physics ideas without mathematical formulas.

39. When I solve a physics problem, I explicitly think about which physics ideas apply to the problem.

40. If I get stuck on a physics problem, there is no chance I'll figure it out on my own.

41. It is possible for physicists to carefully perform the same experiment and get two very different results that are both correct.
42. When studying physics, I relate the important information to what I already know rather than just memorizing it the way it is presented.
Appendix C

Force Concept Inventory (FCI)

1. Two metal balls are the same size, but one weighs twice as much as the other. The balls are dropped from the top of a two-story building at the same instant of time. The time it takes the balls to reach the ground below will be:
   (A) about half as long for the heavier ball.
   (B) about half as long for the lighter ball.
   (C) the same time for both balls.
   (D) considerably less for the heavier ball, but not necessarily half as long.
   (E) considerably less for the lighter ball, but not necessarily half as long.

2. Imagine a head-on collision between a large truck and a small compact car. During the collision,
   (A) the truck exerts a greater amount of force on the car than the car exerts on the truck.
   (B) the car exerts a greater amount of force on the truck than the truck exerts on the car.
   (C) neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
   (D) the truck exerts a force on the car but the car doesn’t exert a force on the truck.
   (E) the truck exerts the same amount of force on the car as the car exerts on the truck.

3. Two steel balls, one of which weighs twice as much as the other, rest on a horizontal table with the same speeds. In this situation,
   (A) both balls impact the floor at approximately the same horizontal distance from the base of the table.
   (B) the heavier ball impacts the floor at about half the horizontal distance from the base of the table than does the lighter.
   (C) the lighter ball impacts the floor at about half the horizontal distance from the base of the table than does the heavier.
   (D) the heavier ball is considerably closer to the base of the table than the lighter, but not necessarily half the horizontal distance.
   (E) the lighter ball is considerably closer to the base of the table than the heavier, but not necessarily half the horizontal distance.

4. A heavy ball is attached to a string and swings in a circular path in a horizontal plane as illustrated in the diagram at the right. At the point indicated on the edge of the string, the string suddenly breaks at the ball. If these events were observed from directly above, indicate the path of the ball after the string breaks.

b. A boy throws a steel ball straight up, disregarding any effects of air resistance, the force(s) acting on the ball until it returns to the ground is (are):
   (A) its weight vertically downward along with a steadily decreasing upward force.
   (B) a steadily decreasing upward force from the moment it leaves the hand until it reaches its highest point beyond which there is a steadily increasing downward force of gravity as the object gets closer to the earth.
   (C) a constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point, after which there is only the constant downward force of gravity.
   (D) a constant downward force of gravity only.
   (E) none of the above. The ball falls back down to the earth simply because that is its natural action.

* Use the statement and diagram below to answer the next four questions:

The diagram depicts a hockey puck sliding, with a constant velocity, from point “a” to point “b” along a frictionless, horizontal surface. When the puck reaches point “b”, it receives an instantaneously horizontal “kick” in the direction of the heavy print arrow.

C. Along which of the paths below will the hockey puck move after receiving the “kick”?

/ The speed of the puck will after it receives the “kick”?

(A) Equal to the speed “v1” it had before it received the “kick”.
(B) Equal to the speed “v” it possessed before the “kick”, and independent of the speed “v1”.
(C) Equal to the arithmetic sum of speeds “v1” and “v”.
(D) Greater than either of speeds “v1” or “v”, but smaller than the arithmetic sum of these two speeds.
8. Along the trackless path you choose, how does the speed of the puck vary after receiving the "kick"?
(A) No change.
(B) Continuously increasing.
(C) Continuously decreasing.
(D) Increase for a while, and decreasing thereafter.
(E) Constant for a while, and decreasing thereafter.

9. The main forces acting after the "kick," on the puck along the path you choose are:
(A) the downward force due to gravity and the effect of air pressure.
(B) the downward force of gravity and the horizontal force of momentum in the direction of motion.
(C) the downward force of gravity and the upward force exerted by the table, and a horizontal force acting on the puck in the direction of motion.
(D) the downward force of gravity and the upward force exerted by the table, and no horizontal force acting on the puck.
(E) None of these, since the puck is at rest there are no forces acting on it.

10. The accompanying diagram depicts a semicircular channel that has been entirely attached to a table top. A ball is thrown into the channel at "1" and exits at "2," which of the path representations would most nearly correspond to the path of the ball as it exits the channel at "2" and rolls across the table top.

11. In the situation,
(A) neither student exerts a force on the other.
(B) student "a" exerts a force on "b," but "b" doesn't exert any force on "a".
(C) student "b" exerts a force on "a," and "a" exerts a larger force.
(D) student "a" exerts a force on "b," but "b" exerts the larger force.
(E) each student exerts the same amount of force on the other.

12. A book is at rest on a table top. Which of the following force(s) is(are) acting on the book?
1. A downward force due to gravity.
2. The upward force by the table.
3. A net downward force due to air pressure.
4. A net upward force due to air pressure.

(A) 1 only
(B) 1 and 2
(C) 2, 3, and 4
(D) 1, 2, and 4
(E) None of these, since the book is at rest there are no forces acting on it.

Refer to the following statement and diagram while answering the next two questions.

A large truck backs down on the road and receives a push back into town by a small compact car.

13. While the car, still pushing the truck, is speeding up to get up to cruising speed:
(A) the amount of force of the car pushing against the truck is equal to that of the truck pushing back against the car.
(B) the amount of force of the car pushing against the truck is less than that of the truck pushing back against the car.
(C) the amount of force of the car pushing against the truck is greater than that of the truck pushing against the car.
(D) the truck's engine is running so it applies a force as it pushes against the truck but the truck's engine is not running so it can't push back against the car, the truck is pushed forward simply because it is in the way of the car.
(E) neither the car nor the truck apply any force on the other, the truck is pushed forward simply because it is in the way of the car.

14. After the person in the car, while pushing the truck, reaches the cruising speed at which he/she wishes to continue to travel at a constant speed:
(A) the amount of force of the car pushing against the truck is equal to that of the truck pushing back against the car.
(B) the amount of force of the car pushing against the truck is less than that of the truck pushing back against the car.
(C) the amount of force of the car pushing against the truck is greater than that of the truck pushing against the truck.
(D) the car's engine is running so it applies a force as it pushes against the truck but the truck's engine is not running so it can't push back against the car, the truck is pushed forward simply because it is in the way of the car.
(E) neither the car nor the truck apply any force on the other, the truck is pushed forward simply because it is in the way of the car.
15. When a rubber ball dropped from rest bounces off the floor, its direction of motion is reversed because:

(A) energy of the ball is conserved.
(B) momentum of the ball is conserved.
(C) the floor exerts a force on the ball that stops it and then drives it upward.
(D) the floor is in the way and the ball has to keep moving.
(E) none of the above.

16. Which of the paths in the diagram to the right best represents the path of the cannon ball?

17. A stone falling from the roof of a tall castle building to the surface of the earth:

(A) reaches its maximum speed quite soon after release and then falls at a constant speed thereafter.
(B) speeds up as it falls, primarily because the closer the stone gets to the earth, the stronger the gravitational attraction.
(C) speeds up because of the constant gravitational force acting on it.
(D) falls because of the intrinsic tendency of all objects to fall towards the earth.
(E) falls because of a combination of the force of gravity and the air pressure pushing it downward.

18. When responding to the following question, assume that any frictional forces due to air resistance are so small that they can be ignored.

19. Two people, a large man and a boy, are pulling as hard as they can on ropes attached to an object as illustrated in the diagram to the right. Which of the indicated paths (A-G) would most likely correspond to the path of the crate as they pull it along?

* The positions of two blocks at successive 0.20 second time intervals are represented by the numbered squares in the diagram below. The blocks are moving toward the right.

(continued on the next page)
20. Do the blocks ever have the same speed?
(A) No.
(B) Yes, at instant 2.
(C) Yes, at instant 5.
(D) Yes, at instant 2 and 5.
(E) Yes, at some time during interval 3 to 4.
* The positions of two blocks at successive equal time intervals are represented by numbered squares in the diagram below. The blocks are moving toward the right.

21. The acceleration of the blocks are related as follows:
(A) acceleration of "a" > acceleration of "b"
(B) acceleration of "a" = acceleration "b" > 0
(C) acceleration of "b" > acceleration of "a"
(D) acceleration of "a" = acceleration of "b" = 0
(E) not enough information to answer

22. A golf ball driven down a runway is observed to travel through the air with a trajectory (light path) similar to that in the depiction below.

Which following force (s) (one) acting on the golf ball during its entire flight?
1. the force of gravity
2. the force of the "tail"
3. the force of air resistance

(A) 1 only
(B) 1 and 2
(C) 1, 2, and 3
(D) 1 and 3
(E) 2 and 3

23. A bowling ballaccidently falls out of the cargo bay of an airliner as it flies along in a horizontal direction. As seen from the ground, which path would the bowling ball most closely follow after leaving the airplane?

* When answering the next four questions, refer to the following statement and diagram.

A rocket, drifting outwards in outer space from position "a" to position "b", is subjected to no outside forces. At "b", the rocket's engine starts to provide a constant thrust at right angles to line "ab". The engine turns off again as the rocket reaches some point "c".

24. Which path below best represents the path of the rocket between "a" and "c"?

(A) 
(B) 
(C) 
(D) 
(E) 

25. As the rocket moves from "a" to "c", its speed is

(A) constant.
(B) continuously increasing.
(C) continuously decreasing.
(D) increasing for a while and then constant thereafter.
(E) constant for a while and decreasing thereafter.
26. At "c" the rocket's engine is turned off. Which of the paths below will the rocket follow beyond "c"?

27. Beyond "c", the speed of the rocket is:

(A) constant.
(B) continuously increasing.
(C) continuously decreasing.
(D) increasing for a while and constant thereafter.
(E) constant for a while and decreasing thereafter.

28. A large box is being pushed across the floor at a constant speed of 4.0 m/s. What can you conclude about the forces acting on the box?

(A) If the force applied to the box is doubled, the constant speed of the box will increase to 8.0 m/s.
(B) The amount of force applied to move the box at a constant speed must be more than its weight.
(C) The amount of force applied to move the box at a constant speed must be equal to the amount of the frictional forces that resist its motion.
(D) The amount of force applied to move the box at a constant speed must be more than the amount of the frictional forces that resist its motion.
(E) There is a force being applied to the box to make it move but the external forces such as friction are not "real" forces they just resist motion.

29. If the force being applied to the box in the preceding problem is suddenly discontinued, the box will:

(A) stop immediately.
(B) continue at a constant speed for a very short period of time and then slow to a stop.
(C) immediately start slowing to a stop.
(D) continue at a constant velocity.
(E) increase its speed for a very short period of time, then start slowing to a stop.
Appendix D

Problem Set Instrument

1. A happy otter slides down a wet log into a pond. The log is 3.5 m long and inclined at 23° with respect to the horizontal. If the coefficient of kinetic friction between the otter and the log is 0.3, how long does it take the otter to slide down the log starting from rest? BC

2. A baseball player decides to slide the last 2.0 m into home plate. If the coefficient of friction between the player and the ground is 0.45, and the player has an initial speed of 2.3 m/s, how long will it take for the player to slide into home plate? SC

3. A block is sliding down a ramp inclined at 30° with respect to the horizontal. If the ramp is 18.0 m long and the block has an initial speed of 1.5 m/s, how long will it take the block to come to rest? The coefficient of kinetic friction between the ramp and block is 0.4. TR

2. A 0.500 kg softball is accelerated from rest to 33.5 m/s over the distance of a stretched arm (about 0.9 m). What is the average force on the ball by the hand during the pitch? SC

3. Orange jewelweed seed pods can project an 11 mg seed with an initial velocity of 4.0 m/s straight up in the air. If the time of the explosive release is 4 ms, what force is generated on the seed to give it this velocity? BC

4. In a cathode ray tube, electrons are accelerated by an electric field. If an electron is accelerated from 1e3 m/s to 1e5 m/s in such a field in a millisecond. What average force did the electron experience? TR

5. If a Wolf spider with mass of 7.0 e-5 kg is climbing up on its thread toward a tasty fly. The thread exerts a force of 1.2 e-3 N upward force on the spider. What is the acceleration of the spider? BC

6. A mountain climber with a mass of 200 kg slips and falls off the side of a mountain only to be stopped by the safety rope anchored on the rock. In stopping the climber’s fall, the rope applies a force of 5880 N on the climber. What is the climber’s acceleration while coming to a stop? SC

7. An 800 kg elevator car is carrying two 100 kg students down from an upper floor when it comes to a stop. In stopping the elevator car and passengers, the cable applies a force of 10780 N
upward on the car. What is the acceleration on the elevator car and students as the car comes to a stop? TR

4.  
- Trained pilots can generally handle 9 g’s of acceleration before they pass out. If a skilled pilot is traveling in a high performance jet at a speed of 960 km/hr, what is the smallest radius of a horizontal turn that can be made without the pilot passing out? BC

- A high performance race car is traveling down a straight, level race track when it enters into a flat turn of radius 610 m. If the coefficient of static friction between the tires and the road is 0.6, how fast can the driver be going without skidding off of the curve? SC

- A 0.5 kg ball on the end of a 1 meter long string is swung horizontally above the head of a physics student at a constant rate. If the string can experience a maximum tension of 10.0 N before snapping, what is the fastest the ball can be swung? TR

5.  
- A bald eagle is flying with a speed of 36 km/hr in a circle above a lake looking for its next meal. The eagle is banked to make the turn and its wings are tilted at an angle of 30° from the horizontal. If the lift force is perpendicular to the eagle’s wings, and is responsible for keeping the eagle in the air, what is the radius of the circle in which the eagle is flying? BC

- An airplane is flying in a horizontal circle with a speed of 500 km/hr. The plane is banked for the turn and its wings are tilted at an angle of 40° from the horizontal. If the lift force is perpendicular to the plane’s wings, and is what keeps the plane in the air, what is the radius of the circle in which the plane is flying? TR

- A NASCAR racecar is making its way into the first turn at 75.0 km/hr. The turns on the racetrack are engineered so that the cars can make the turn without any help from frictional forces. Assuming that the turn is banked at an angle of 27° with respect to the horizontal, what is the radius of the turn the car is making? SC

6.  
- In 2013, 12 year old power lifter Naomi Kutin set the world record in her division by squatting 231 lbs (105 kg) three times. If Naomi has a mass of 44 kg (equivalent to a weight of 97 lbs), how much force does one of her legs produce on the upward portion of her squat? Assume that she completes the squat with a constant velocity. BC

- In 2014, Dalton LaCoe set the High School National Championship record for the men’s 114 lbs (52 kg) division by squatting 424.25 lbs (192.50 kg) once. Assuming that Dalton has a mass of 52 kg, how much force does one of his legs produce on the upward portion of his squat? Assume that he completes the squat with a constant velocity. SC
A 5.0 kg bucket is filled with 10.0 kg of water and is being pulled up from the bottom of a well. If the rope will break when the net tension on it exceeds 200 N, what is the maximum force that can be applied to the rope so that the bucket can still be pulled up, without breaking the rope? TR

7.
One species of mantis shrimp, *Gonodactylaceus falcatus*, has been observed hitting blue crabs so hard that the crab’s claws are knocked off, others have been observed cracking the glass on aquarium tanks. The raptorial appendages of the shrimp are accelerated from rest in 140 micro-seconds to a speed of 330 m/s right before they make contact with the crab. If the appendage mechanism of a *G. falcatus* mantis shrimp can be modeled using a simple spring-mass system with a spring constant of 65,000 N/m, how much force will the shrimp’s appendage create right before it hits the crab? BC

8.
Bruce Lee was known to be able to deliver a knock-out punch over the distance of one inch. He attributed this ability to the years of study spent on the masterly of kung fu. While the processes are more complicated than can be investigated fully here, we can estimate the procedure. Lee’s punch has been clocked at 190 km/h. If Lee’s body acted like a spring with a spring constant of 870,000 N/m with his 400 g fist as the accelerated mass, how much force could he deliver at the end of the one-inch punch? SC

Two large bighorn sheep, the first with mass 200 kg and the other with a mass of 250 kg, charge each other straight on. If the first sheep is traveling with a speed of 11.0 m/s and the second is traveling at 9.0 m/s, which sheep experiences the greater force of impact? BC

Two linebackers on opposing teams in a football game are running at each other with speeds of 3.0 m/s and 2.7 m/s respectively. If the first linebacker has a mass of 100 kg and the second has a mass of 110 kg, which linebacker experiences the greater force of impact? SC

A Mack truck, weighing 8 metric tons and a Volkswagen beetle weighing 0.5 metric tons are driving straight at each other with speeds of 50 mph and 60 mph respectively when the collide head on. Which vehicle, the beetle or the truck experiences the greater force of impact? TR
9. A baby sparrow is pushed out of its nest and falls from a limb in a tree high above the ground and lands in the grass below. The ground cushions the bird’s fall by bending two inches. Assuming that the bird has a mass of 20.0g and hits the grass with a speed of 2.0 m/s, what is the magnitude of the force of the grass on the bird? BC

A 60.0 kg basketball player makes the winning point with a slam dunk. The player lands straight legged on the floor with only the soles of the shoes to cushion the impact over a total distance of one inch. Right before the player’s feet touch the floor the player is moving at 4.0 m/s, what is the magnitude of the force of the floor on the player? SC

An avalanche causes a 10.0 kg rock to fall off of a cliff into the canyon below. Right before the rock hits the ground its speed is 10.0 m/s. The hard ground below applies a stopping force on the rock bringing it to a stop over a distance of half a centimeter. What is the magnitude of the force of the ground on the rock? TR

10. The Montezuma Oropendola is a bird native to Central America that builds nests that are able to swing in the trees when the wind blows. Treat the nest as a 4.5kg point mass at the end of a 1.0 long vine. If the wind starts the nest swinging back and forth with a speed of 1.0 m/s at the bottom of the swing, what is the magnitude of the tension in the vine holding the nest to the tree? BC

One extreme sport involves a rope swing on the Corona Arch in Moab, Utah. The person runs and jumps off of the cliff while attached to the end of a rope that is 130 ft (39.6m) long. If the person has a mass of 100 kg and is traveling with a speed of 28.3 m/s at the bottom of the swing, what is the maximum tension on the rope? SC

A lead ball of mass 5.0 kg is attached to the end of a 1.0 m long cord which is fixed at the other end to the top of a tall ring stand. The ball is pulled up to the side of the ring stand while keeping the cord taut and released allowing the ball to swing down. If the ball has a speed of 4.4 m/s at the bottom of the swing, what is the maximum tension on the cord? TR

11. The near-record acceleration measured for a person doing a standing high jump is 1.53 g (1.53 times earth’s gravitational acceleration). What was the normal force applied to the jumper by the floor if the jumper has a mass of 70.0 kg? SC
• The rat flea can generate an acceleration of 204 g (204 times earth’s gravitational acceleration) when jumping straight up. What is the normal force applied to the flea by the floor? Assume an average flea of mass $2 \times 10^{-7}$ kg is used. BC

• A model rocket can generate an acceleration of 20.1 g (20.1 times earth’s gravitational acceleration). If the rocket has a mass of 15.0 grams, what is the normal force being applied to the rocket at lift off? TR

12.

• If a $2 \times 10^{-7}$ kg rat flea jumps straight up off of the back of a dog getting by applying a force of $5 \times 10^{-6}$ N to the floor. The flea jumps by extending its legs by 0.50 mm, how high will the flea jump? (assume no air resistance) BC

• A person jumps straight up by fully extending their legs in the process. If a 70.0 kg basketball player does this with a leg extension of 0.5 m, how high will the player go by putting a force of 1300.0 N on the ground? (assume no air resistance) SC

• A small spring loaded toy (20.0 g) is placed flat on the ground with the spring fully compressed a distance of 5.0 cm. When released, the toy applies a force of 20 N to the ground. How high will the toy go? (assume no air resistance) TR

13.

• A hyper hamster is in its cage running furiously on a circular treadmill (aka hamster wheel), of radius 20.0 cm, when the wheel suddenly becomes jammed by a flying piece of corn. The hamster continues to run around the stopped treadmill, all the way around without falling, but it begins to tire and slow down. How fast does the hamster need to be running in order to just make it around the treadmill without falling down at the top? BC

• In 1905 Allo “Dare Devil” Diavolo sped down a ramp, on a bicycle, along a track that turned into a vertical circular loop of radius 11.0 m. Even if Diavolo uses a ramp to get up to the speed needed to complete the loop, what is the minimum speed needed to be moving with in order to just make it around the loop without falling off at the top? SC

• A student wants to set a world record by twirling a ball at the end of a rope for 24 hours. A ball is attached to the end of a 70.0 cm long string and swung in a vertical circle. After half an hour the student begins to tire and the ball begins to slow down when the student realizes that the task is more challenging than was originally thought. What minimum speed does the ball need to make the loop without falling at the top? TR

14.
• Two puppies are playing tug of war with a short, lightweight, rope. The puppy on the right has a mass of 12.0 kg, while the puppy on the left has a mass of 10.0 kg. If the net acceleration is 0.8 m/s² to the right, what is the tension of the rope between the puppies? **BC**

• Two monster trucks are connected to each other by a very strong, but very light, chain. The truck on the right has a mass of 2500.0 kg, while the truck on the left has a mass of 2300.0 kg. If the net acceleration is 1.5 m/s² to the right, what is the tension of the chain between the trucks? **SC**

• Two blocks rest on a table top and are connected to each other by a small, nearly massless cord. The block on the right has a mass of 15.0 kg, while the block on the left has a mass of 10.0 kg. A person is pulling on another cord attached to the heavier block, applying a net acceleration of 2.0 m/s² to the right. What is the tension of the cord between the blocks? **TR**

15.

• A happy penguin, of mass 30.0 kg, is making its way to the edge of an icy cliff where it will dive into the water to hunt for a meal. The penguin starts sliding down an icy path 10.0 m long and inclined 20° below the horizontal, and begins its slide with an initial velocity of 1.3 m/s. However, the penguin only travels 7.0 m before coming to a stop. What is the coefficient of kinetic friction between the penguin and the icy path? **BC**

• A downhill skier, of mass 70.0 kg, wants to know how the type of ski she wears will affect her performance. She starts by testing out her idea on a gently sloping hill. The hill is inclined at 30° below the horizontal. She begins her run at 4.5 m/s and finds that she comes to a stop, without trying, after coming to a stop after traveling 30.0 m. What is the coefficient of kinetic friction between her skis and the snow? **SC**

• A block of wood having a mass of 10.0 kg is given an initial velocity of 0.5 m/s down a ramp. The ramp is inclined at 25° below the horizontal. The block slides down the ramp, but comes to a stop after traveling 1.5 m. What is the coefficient of friction between the block of wood and the ramp? **TR**

This document is set up with 3 questions per page, for a total of 45 questions on 15 pages. Each question on the page is intended to be related to the other 2 questions by difficulty, concept being addressed, and length. However, each question presents the concept from one of three
slightly different contexts: a biology/life science context (BC); a sports related context (SC); a traditional ‘physics problem’ context (TR).

Please review each set of three questions for the following assuming that the student doing the problems would have had the corresponding content delivered in class.

**Difficulty:** Is the question of a proper level of difficulty that a student in a high school honors physics course or an AP course could do the problem within a reasonable amount of time and effort? Please indicate the level of difficulty on the scale below with 1 being the easiest, 2 moderate level of difficulty, and 3 being the most difficult.

1 (easy) 2(moderate) 3(difficult)

Please feel free to comment on your choice:

**Concept:** How similar is the physics concept being addressed in each question? Does each question address the same or similar physics concept? Please indicate the level of similarity of the three questions on the scale below with Please indicate the level of difficulty on the scale below with 1 being the not aligned, 2 somewhat aligned, and 3 being completely aligned.

1 (not aligned) 2(somewhat aligned) 3(completely aligned)

Please feel free to comment on your choice: