Understanding Middle School Students' Perceptions of Physics Using Girl-Friendly and Integrated STEM Strategies: A Gender Study

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Abstract

According to the American Physical Society, women accounted for only 20% of bachelor's degrees in the fields of physics and engineering in 2010. This low percentage is likely related to young girls' K-12 education experiences, particularly their experiences *prior* to high school, during which time young women's perceptions of Science, Technology, Engineering, and Math (STEM) and STEM careers are formed (Catsambis, 1995; Maltese & Tai, 2011; National Research Council, 2012; Sadler, Sonnert, Hazari, & Tai, 2012; Tai, Liu, Maltese, & Fan, 2006; Scantlebury, 2014; Sikora & Pokropek, 2012). There are no significant gender differences in academic achievement in middle school, yet young women have less positive attitudes towards careers in science than their male peers (Catsambis, 1995; Scantlebury, 2014). This suggests that the low female representation in certain STEM fields is a result of not their abilities, but their perceptions; for fields like physics where negative perceptions persist (Häussler & Hoffman, 2002; Labudde, Herzog, Neuenschander, Violi, & Gerber, 2000), it is clear that middle school is a critical time to intervene.

This study examines the perceptions of 6th grade middle school students regarding physics and physics-related careers. A theoretical framework based on the literature of girl-friendly and integrated STEM strategies (Baker & Leary, 1995; Halpern et al., 2007; Häussler & Hoffman, 2000, 2002; Labudde et al., 2000; Moore et al., 2014b; Newbill & Cennamo, 2008; Rosser, 2000; Yanowitz, 2004) guided this work to understand how these instructional strategies may influence student's perceptions of physics for both girls and boys. The overarching goal of this work was to understand similarities and differences between girls' and boys' perceptions about physics and physics-related careers. This convergent parallel mixed-methods study uses a series of student surveys and focus group interviews to identify and understand these similarities and differences. Classroom observations also helped to identify what instructional strategies teachers used that influence student perceptions.

Findings from this study indicate very few differences between the perceptions of physics and physics-related careers for 6th grade girls and boys. However, the differences that exist, though subtle, may indicate how K-12 science instruction could more positively influence girls' perceptions. For instance, while girls are just as interested in science class as their male counterparts, they are more motivated when a social context is included; this has implications for how they view physics-related careers. The findings of this study shed light on not only why fewer females pursue careers in physics, but also how K-12 science reform efforts might help to increase these numbers.

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CHAPTER I

Rationale

For many years, the disparity between the numbers of men and women in the sciences has been greatly apparent. Some suggest that this disparity is shrinking, but despite any small gains, it is clear there is still a lack of balance. Recent publications indicate that science degrees awarded to women vary by specific sub-field of science (U.S. Department of Labor (DOL), Bureau of Labor Statistics, 2011; Halpern et al., 2007; Matson, 2013). The American Physical Society (APS) reported only 20% of bachelor's degrees awarded to women in physics and engineering in 2010. This is lower than the 35% observed across all Science, Technology, Engineering, and Mathematics (STEM) fields and significantly lower than the nearly 60% of degrees awarded to women in biology (APS, 2010). This pattern for women's interest in careers involving fields such as biology, medicine, and agriculture compared to physical sciences, mathematics, and engineering has been observed in 50 countries around the world, making it a global issue that is present in both post-industrial and developing countries (Sikora & Pokropek, 2012).

These skewed distributions are likely related in part to young girls' K-12 education experiences. By the time girls enter high school their interests in STEM careers are low, with only 15.7% of girls interested in pursuing STEM-related careers compared to about 40% of boys (Sadler, Sonnert, Hazari, & Tai, 2012). Additionally, these STEM-related career interests continue to drop for girls so that by the time they leave high school, only 12.7% are interested, once more compared to 40% of boys (Sadler et al., 2012). Initiating students' interest in STEM careers during high school is incredibly difficult to do (Jenkins & Nelson, 2005; Sadler et al., 2012) as student decisions to continue into a STEM career are solidified sometime during high school; therefore, *initiating* interests at this time is too late. Other research hints that these decisions are made as early as eighth grade (Maltese & Tai, 2011; Tai, Liu, Maltese, & Fan, 2006), further indicating the need to intervene prior to high school. There is clear need to increase girls' interest in STEM careers *before* high school if there is any hope of increasing female representation in STEM fields that are drastically under-represented by women, particularly physics.

Interests in STEM careers are influenced by a variety of factors (e.g., Maltese & Tai, 2011) and the beliefs and attitudes that shape these interests begin at a young age (Archer et al., 2010, 2012; Jones, Howe, & Rua, 2000; Pajares, 2006). Students as young as 10 years old have identified interests in science, but have also identified careers in STEM as "not for me" (Archer et al., 2010, 2012; Jenkins & Nelson, 2005). Research has also shown that the greatest differences in STEM attitudes decrease between the ages of 10 and 14 (Archer et al., 2010; Kotte, 1992). Evidence suggests that middle school is *the* time in which young women's perceptions, including attitudes and beliefs, of STEM are formed, which may affect future career aspirations (Brophy, Klein, Portsmore, & Rogers, 2008; Calabrese Barton, Tan, & Rivet, 2008; Catsambis, 1995; National Research Council [NRC], 2012).

Additionally, there has been much focus on examining the identities that students have related to science and how these identities may conflict with their personal identities and self-concepts (Archer et al., 2010; Makarova & Herzog, 2015). Much to the antithesis of earlier work in gender studies, there exists a lack of significant differences between girls and boys in academic achievement in middle school (Castambis, 1995; Sikora & Pokropek, 2012). While girls and boys at the middle school age tend to be interested in science, young women notoriously have lower science self-concept towards science and science careers compared to their male counterparts (Catsambis, 1995; Häussler & Hoffman, 2000, 2002; Häussler, Hoffmann, Langeheine, Rost, & Sievers, 1998; Labudde, Herzog, Neuenschwander, Violi, & Gerber, 2000; Sikora & Pokropek, 2012). Thus, the driver for low the low number of women in certain STEM fields is not their abilities, but their negative *perceptions* of these fields; for fields like physics where negative attitudes have consistently persisted (Häussler & Hoffman, 2000, 2002; Haussler et al., 1998; Labudde et al., 2000), it is clear that middle school is a critical time to intervene.

The STEM fields as a whole have historically been under-represented by woman, and physics in particular has persisted as a discipline that continually fails to attract women (APS, 2010; Häussler et al., 1998; Häussler & Hoffman, 2000, 2002; Labudde et al., 2000; Scantlebury, 2014; Tolley, 2003). Previous research has examined "girl-friendly" instructional strategies that have the effect of positively influencing young girls' perceptions of science. The majority of girl-friendly science research has specifically been focused on physics due to the lack of female representation in physics-related careers and lack of interest in secondary school physics courses (Häussler et al., 1998; Häussler & Hoffman, 2002; Labudde et al., 2000). Girl-friendly instructional strategies include making content relatable to everyday applications through the use of societal connections and connections to prior experiences (Baker & Leary, 1995; Halpern et al., 2007; Häussler & Hoffman, 2000, 2002; Labudde et al., 2000; Rosser, 2000; Yanowitz, 2004). Interactive discussions and experiences in physics classes have also shown positive impacts on *both* boys' and girls' beliefs regarding their science achievement (Labudde et al., 2000). While the term "girl-friendly" implies that instruction is catered specifically to the needs of girls, as of yet, no work suggests that these strategies inhibit the learning of boys.

Current K-12 education reform documents lean towards promoting STEM in an integrated manner (NRC, 2012, 2013). The STEM integration framework of Moore et al. (2014b) proposes that STEM integration combines one or more of the STEM disciplines wherein they are taught together harmoniously, typically using engineering as the bridge between fields. This framework is guided by six tenets: 1) a motivating and engaging context, 2) the inclusion of mathematics and/or science content, 3) student-centered pedagogies, 4) an engineering design or redesign challenge, 5) learning from failure, and 6) an emphasis on teamwork and communication (Moore et al., 2014b). This framework is compatible with girl-friendly instructional strategies that will lead to building and maintaining girls' positive perceptions of physics and physics-related careers. In order to improve perceptions, though, there is a need to first understand what perceptions currently exist. Integrated STEM efforts are relatively new and little research exists on how these methods in combination with a framework of girl-friendly strategies may affect the perceptions of students with regard to specific science disciplines or STEM careers. Additionally, by examining the perceptions of both girls and boys it is possible to identify pathways for both sexes to gain and maintain interest in STEM fields.

Statement of Purpose

This project aims to raise awareness of girl-friendly and integrated STEM practices and strategies in hopes of building and maintaining girls' positive interest in science in middle school and beyond. The claim that guides this research is that students' science-related perceptions affect their choices when it comes to future careers. Thus, by improving girls' perceptions of the field of science, more women will choose to pursue STEM careers; this is of particular interest for physics. By understanding students' current thinking about physics and physics-related careers in the context of girl-friendly and integrated STEM instruction, this work attempts to identify the needs of both girls and boys to uncover points of access. Results of this work may ignite the interest of science teachers and science education researchers to consider what is necessary in bringing girl-friendly and integrated STEM teaching strategies to the classroom in order to engage and interest a broader audience of students.

Research Questions

The STEM integration framework discussed above (Moore et al., 2014b) provides a contextual foundation for my study, which will fill the gap on research on students' perceptions, including attitudes and beliefs, with regards to integrated STEM learning through exploring the following research questions:

- *In what ways do teacher practices affect the way middle school students view their role in the physics classroom as well as their perceptions regarding a physics-related career?*
    a. *What girl-friendly and integrated STEM instructional strategies do teachers use that influence student perceptions?*
    b. *What patterns arise in girls' and boys' perceptions towards physics and physics-related careers?*
    c. *What differences exist between girls' and boys' perceptions of physics and physics-related careers?*

Significance of Study

Investigating the practices of middle school science teachers when bringing integrated STEM and girl-friendly strategies to their classrooms can be informative when thinking about what changes need to take place in classrooms that affect students' perceptions of STEM fields. This is of particular interest for girls in physics. By examining the way students learn about physics, view themselves in physics class, and view themselves in physics-related careers, we can narrow down the factors that affect these perceptions.

Studying student perceptions surrounding physics is based on the assumption that increased positive science self-concept will lead to more girls choosing to pursue careers in STEM fields. Research has indicated that the role of self-perception and identity is more important and complex for girls than it is for boys in making these decisions (Archer et al., 2010, 2012; Britner, 2008). It is clear that there is a need to examine what effects girl-friendly and integrated STEM instructional strategies will have on students' perceptions towards STEM fields as research indicates that student attitudes and beliefs appear to be the best predictor to determine students' future career choices; if we can find a way to positively impact and maintain interest in STEM, great changes could take place. If students are better able to identify with STEM careers, they may overcome the "not for me" attitude that currently exists for upper elementary and early middle school students (Archer et al., 2010, 2012; Jenkins & Nelson, 2005).

The ultimate purpose of promoting girl-friendly instructional strategies is to increase the number of young women who aspire to go into STEM fields, especially those that are less represented, such as physics and engineering. Since many researchers agree that the middle-school years are of utmost importance in retaining girls' interest in science (e.g., Archer et al., 2010, 2012; Brophy et al., 2008; Catsambis, 1995; NRC, 2012; Sadler et al., 2012), it is important that this age group be the focus for this study. By understanding what impacts of bringing girl-friendly instructional strategies to an integrated STEM classroom has on students, we can learn several things. We can learn what changes in practice need to take place for *teachers* in order for students, particularly girls, to increase and/or maintain positive beliefs about physics. We can learn what is important to *students* when it comes to physics and have some idea of what qualities make a person interested in physics and positive about their physics abilities. Results from this study will be invaluable to K-12 science education as it will inform how current reform efforts in STEM education may allow for multiple access points to interest all students in STEM careers, even the fields like physics that are grossly under-populated by women.

Overview of Following Chapters

Chapter II discusses the literature that has informed the rationale for this study, focusing on an overview of historical perspectives, student perceptions, identity, and the choice of middle school for this study. Additionally, it provides the theoretical framework that was used to guide this work, describing both girl-friendly and integrated STEM instructional strategies. Chapter III provides an explanation of methodology used in this study, first, by describing the context that enabled the study to take place. It further discusses the research design and data collection methods, which include the collection of quantitative and qualitative data sources in the convergent parallel mixed-methods design. Descriptions of the participants as well as the methods of analysis are also provided. Chapter IV explains the findings of the research, which compare and contrast the results of the data both with respect to girls and boys as well as with the different data sources. The fifth and final chapter, Chapter V, summarizes the findings through a conclusion and shares implications of this research before suggesting how to extend this work.

CHAPTER II

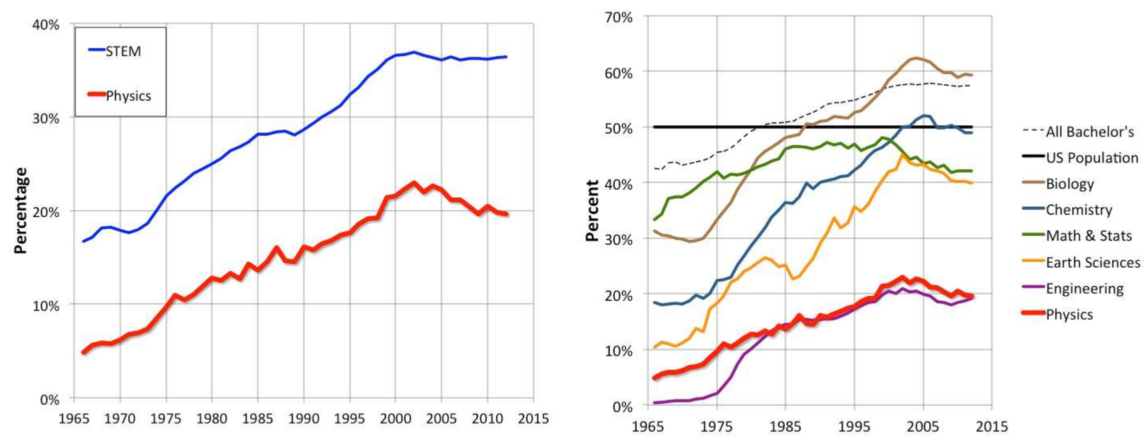
Literature Review

Introduction

This chapter reviews the literature that serves as the backbone to my study. It begins with a tour of the history of women in science, specifically focused on the underrepresentation of women in physics careers. Various factors, including social and cultural factors, affect the decision to pursue career paths and looking at the role of K-12 education in the lives of young girls may help to identify more specific factors that contribute to this underrepresentation. The crux of this work is in examining perceptions (including attitudes and beliefs), thus the next section reviews what is known about the influences of students' perceptions towards STEM fields and STEM careers. The study presented here may provide educators and educational research with information about how to encourage girls to enter science fields, specifically through instructional strategy decisions made by K-12 educators. The final section describes my theoretical framework developed around instructional strategies. The framework draws on both work in girl-friendly science and integrated STEM instructional strategies.

Girls and Women in Physics – Now and Then

The question of why there are so few women in STEM fields has pervaded time and has remained relevant even in the 21st century. It is clear that there is still a lack of balance between the sexes in STEM careers, as across all STEM fields women only account for 35% of all bachelor's degrees (APS, 2010) (see Figure 2.1). In certain fields, this disparity is not an issue. For instance, the underrepresentation of women does not exist in fields such as biology and other life sciences, where women account for 50% or more of the bachelor's degrees awarded (APS, 2010; Halpern et al., 2007; Matson, 2013). However, the American Physical Society reported in 2010 that only 20% of bachelor's degrees were awarded to women in the fields of physics and engineering, and these women account for 26% of the total science and engineering workforce (Halpern et al., 2007). In the United States, it is likely that these distributions have historical roots that have, over time, transformed into a socio-cultural problem.



(a) (b)

Credits: APS/Source: IPEDS Completion Survey

Figure. 2.1. Bachelor's degrees awarded to women in various STEM fields. (a) Comparison of the percentage of bachelor's degrees awarded to women between all STEM fields and the field of physics. (b) Comparison of the percentage of bachelor's degrees awarded in individual STEM fields.

Until the mid-1800s, women were barred from entering college in the United States. At that time, education for women was viewed as a social activity to develop a sense of discipline, which was limited to the upper class (Tolley, 2003). Even when women did break into science careers, they had to constantly battle against gender stereotypes that dictated what was "right" or "wrong" in terms of careers for women. For example, the development of science societies in the early 1800's was a positive development for the general field of science, but these societies prevented women from entering, allowing them to maintain the image of an exclusive boys' club (Watts, 2007). While an opportunity for women to study science at higher levels of education existed, the reality was that not much had changed in practice. Throughout this time period, women continued to pursue careers in teaching secondary school sciences, which was the only acceptable science-related field for women (Tolley, 2003; Watts, 2007).

Historical events in the history of the United States led to on-going educational reforms throughout the 1900s. One of the most prominent features was in how views of physics changed due to worldwide events. Post World War II, physics was viewed by K-12 students as a field that "conjured up images of factories and machines, harsh rationality, and cold, inanimate nature" (Tolley, 2003, p. 121). The rise in the importance of physics in schools post World War II presented physics as a masculine endeavor and the accompanying textbooks encouraged gender stereotypes (Tolley, 2003). It was no wonder that women chose to not study a subject once thought to promote mental discipline and natural theology (Tolley, 2003). After the launching of Sputnik in 1957, there was a strong push to increase student knowledge of physics, a course reserved for highly gifted students who showed considerable talent in science and mathematics, regardless of gender (DeBoer, 1991; Tolley, 2003). There are no indications, however, that female enrollment in physics courses or college programs increased at that time (Tolley, 2003). It can be assumed that women continued to struggle for gender equality in the United States well throughout the mid-twentieth century when it came to representation in physics.

A gap exists in the research on gender and science from the early-twentieth century until the late 1980s (Baker, 2002; Tolley 2003). Issues regarding gender equity were not a prime focus until the late 1980s to early 1990s when there was “a focus on fixing school science by employing more girl-friendly instructional strategies, topics, and curriculum, as well as gender-fair assessments” (Baker, 2002, p. 660). This was concurrent with the passing of Title IX, which issued schools to treat all students the same, regardless of gender. Researchers could not ignore the gender differences in school sciences anymore, yet at the advent of the twenty-first century, we still do not understand why women are less likely than men to pursue careers in certain STEM fields. Though some may argue that science has still produced works of achievement regardless of an equal representation of women, many fields are deprived of the talent and research that minorities, including women, could produce (National Academies, 2007).

Though there are historical roots in the United States and various movements in place to increase the numbers of women and minorities to pursue STEM fields, it is hard to ignore the fact that there is a distinct gendered pattern of students’ interests in 50 countries (Sikora & Pokropek, 2012). That is, of students who are interested in science in early high school, boys are interested in the physical sciences and girls are interested in the biological sciences (Sikora & Pokropek, 2012). Though results of the 2006 Program for International Student Assessment (PISA) showed that nearly equal amounts of 15-year-olds are expecting to go into science careers (27% female, 24% male), on average boys are three times as interested in careers involving computing, engineering, and mathematics (CEM), which includes physics, compared to girls (Sikora & Pokropek, 2012). On the other side, girls heavily outnumber boys when it comes to career interests in the fields of biology, agriculture, and health (BAH). Sikora and Pokropek (2012) argue that students self-segregate by combining a gender essentialist understanding of careers with their self-expression which leads them to be interested in and inevitably choose a career that seems gender-appropriate. While not the focus on the study presented here, another question that must be asked is how this distinct division between CEM and BAH fields propagates and how not only we can encourage women to pursue fields in CEM, but moreover, how we can encourage men to pursue fields in BAH. Some educational researchers concern themselves with how reforms in K-12 education may either help or hinder these types of differences (Scantlebury, 2014; Sikora & Pokropek, 2012).

Understanding Perceptions

Attitudes and Beliefs Overview

For many years the assumption was that women did not pursue science for the simple reason that they were not as talented at mathematics and science as their male counterparts (e.g., Adamson, Foster, Roark, & Reed , 1998; Catsambis, 1995; Gillibrand, Robinson, Brawn, & Osborn, 1999; Tai et al., 2006; Tolley, 2003). Some blamed (and still blame) simple human physiological differences between men and women. However, a look at the current performance of girls in science shows that the once-thought apparent achievement gap between boys and girls in mathematics and science no longer exists (Halpern et al., 2007; Heubner, 2009, Sikora & Pokropek, 2012). For example, one study researched mandated tests in ten different states, as well as the National Assessment of Educational Progress (NAEP) data, and concluded that there were no significant differences in the achievement of male and female students (Huebner, 2009). The results of the 2006 PISA also showed no gender differences in achievement (Sikora & Pokropek, 2012). However, neither of these studies provides an explanation as to the reasons *why* women are less inclined to pursue science in spite of similar achievement levels between boys and girls.

Huebner (2009) looked at how at an early age boys' and girls' confidence levels in mathematics and science differ greatly, finding that boys rated their *perceived ability* in mathematics and science higher than girls even though there was no difference in their achievement tests. Confirming what other researchers have found, Heubner (2009) found that the higher confidence (or self-concept) a student has in a given field of study, the more likely that student is to further pursue that field; thus, when other researchers (e.g. Sikora & Pokropek, 2012) report that girls have lower science self-concept than males, we can begin to understand how women might be less likely to pursue a career in the sciences. It may be the case that girls are more critical of their abilities and thus are more likely to think they are not talented, preventing them from choosing a career that they are equipped to pursue successfully. This suggests that understanding the science self-concept of young children may be an important step to combat the lack of women in science fields. This notion that experiences at a young age inform future career paths is not new (Pajares, 2006). However, how to achieve increased self-concept for girls remains a question, though historical findings suggest a strong factor is the socio-cultural values that are associated with the sciences (Tolley, 2003).

While girls have shown high academic achievement in the sciences, their low attitudes and interest in science as a career have pervaded time (Catsambis, 1995). The overall gender gap in the science workforce appears to have shrunk in more recent years, but looking at each science discipline individually reveals interesting patterns (Figure 2.1). Multiple researchers report gains in women's interests and persistence in the biological sciences while the physical sciences consistently lag behind (Britner, 2008; Halpern et al., 2007; Heilbronner, 2012; Makarova & Herzog, 2015; Matson, 2013; Scantlebury, 2014; Sikora & Pokropek, 2012). Various researchers reports that students' interest in physical science begins to decline as early as upper elementary (Baker & Leary, 1995; Dawson, 2000; Jones, Howe, & Rua, 2000), and this decline may be more severe for girls than for boys.

Women's preference for biology is not completely surprising, given that the emphasis on biology in the 1800s was that it was a science better suited for girls, as it allowed them to be outdoors and encouraged healthy living and cheerfulness (Tolley, 2003). These differences we see between biological and physical sciences today may be residual from 19th and early 20th century gender stereotype values, which may have led to the sustained lack of women in physics. These stereotypes have the potential to critically interfere with young girls' science self-concepts, which may further prevent them from having positive perceptions about physics and physics-related careers. A recently published review on the status of gender in science posits that there is a cultured gendering of physics itself, which could be one of the reasons why few outside of the male-normative society pursue this particular field (Scantlebury, 2014). Further, studies have shown that girls and women have a skewed vision of physics, seeing it as a career that involves working alone (Hazari, Sonnert, Sadler, & Shanahan, 2010; Whitelegg, Murphy, & Hart, 2007).

Identity Conflicts

The idea that the *culture* of the STEM fields prevents many from pursuing careers in these fields is shared by various researchers (e.g., Archer et al., 2010, 2012; Hazari et al., 2010; Scantlebury, 2014). In this sense, it may be that there is a mismatch between students' personal identity and their perceived identity of any given field (Archer et al., 2010, 2012; Hazari et al., 2010). This mismatch may ultimately marginalize students who are unable to fit into the stereotypical image of science, which has unfortunately shaped students' perceptions of what a scientist is. For physics, this is a major concern as the overall numbers of students choosing to major in physics is decreasing; Scantlebury (2014) suggests that the *culture* of the field is responsible for this change in interest. This is because most people, both men and women, hold implicit biases (National Academies, 2007). Further, Hazari et al. (2010), who examined high school students' physics identities, posit that even in early years, students are able to see the gendering of certain sciences, such that physics is male appropriate.

Several researchers have looked at the role of identity to explain why K-12 students claim to enjoy science, but see it as "not for me" (e.g., Archer et al., 2010, 2012; Jenkins & Nelson, 2005). The findings of Archer et al. (2010) report on the way that 10-

year-old students differentiate between "doing science" and "being a scientist" and how this differentiation is important to understand the mismatch between identities. While students enjoy the act of performing science, they often fail to see alignment between their personal identity and the science identity that they have created in their minds; this identity is assumed to have been shaped by socio-cultural influences, including stereotypes (Archer et al., 2010; 2012; Hazari et al., 2010). Though students at the age of 10 have limited understandings of what a future science career involves, they strongly associate it with masculinity (Archer et al., 2010). In general, career aspirations are guided by seeing how the career identity fits (Gottfredson, 2002), thus if a scientists' identity is not desirable, students will not choose to pursue science as a career (Archer et al., 2010). This is especially problematic for those who do not fit the stereotype that children associate with being a scientist. The Draw A Scientist Test (DAST) used by Scherz and Oren (2006) found that, "the common image was that of a scientist as a bespectacled male with unkempt hair in a white lab-coat" (p. 977). This stereotypical image is one that marginalizes students who do not physically look the same. For girls in particular, at the very least they must find ways to balance the identities of femininity and science, a field that is strongly associated with masculinity (Archer et al., 2010; 2012).

Student and Teacher Gender Associations

Word associations have been helpful in exploring students' and teachers' perceptions of various STEM fields. Makarova and Herzog (2015) explored perceptions of STEM fields by examining how secondary students and teachers associated chemistry, physics, and mathematics with words that were "feminine" and words that were "masculine." What they found was that mathematics was negatively associated with women by both male and female students (Makarova & Herzog, 2015). Chemistry was seen as positively related to men by male students, but female students showed no association (Makarova & Herzog, 2015). The results of looking at physics indicated that female students saw the field as negatively associated with women, and male students viewed it as positively associated with men (Makarova & Herzog, 2015). These findings are disconcerting and hint that gender stereotypes still remain when considering certain STEM disciplines.

These results imply that young women are not able to identify with either mathematics or physics, which could be one reason why few women pursue careers in the mathematics-heavy field of physics. It is possible, though, to overcome this mismatch in identity. Calabrese Barton et al. (2008) explored middle school girls' abilities to create a hybrid space that represents students' personal and science identities in order to find their place in science class. It is possible that as students age, creating the hybrid space discussed in Calabrese Barton et al. (2008) is important when it comes to seeing a career in science as "for me." Further, Makarova and Herzog (2015) suggest the importance of the role of the teacher, a thought akin to Hazari et al. (2010), who suggest a need to examine current teaching strategies and how they may influence students' perceptions, identities, and career aspirations. Specifically, they point to the positive influences that "gender-inclusive" education can have on girls' interest and achievement in science disciplines (Makarova & Herzog, 2015); this idea of "girl-friendly" instructional strategies will be explored in more detail later in the chapter.

Focus on Middle School

Several researchers have identified the middle-school years as vitally important when it comes to attitudes towards STEM fields for girls and minorities (e.g., Brophy et al., 2008; Catsambis, 1995; Sadler et al., 2012). Further, the National Research Council (2012) has an interest in encouraging a diverse population (including women) to pursue an interest in science careers and has acknowledged that, "Girls' interest in science dramatically declines compares to boys' as students transition into middle-school (p.281)." Though middle-school aged girls have lower positive attitudes towards careers in science than their male counterparts, there remains a *lack* of significant differences in academic achievement between girls and boys (Catsambis, 1995; Sikora & Pokropek, 2012). In fact, the middle-school years may be *the* formative years for which young women's opinions of STEM are formed, potentially influencing their future career paths. Tai et al. (2006) noted that by 8th grade, most career aspirations are established, and they specifically note that early science experience should not be overlooked, especially when it comes to physical science and engineering. This could mean that mere exposure to these fields is one way to positively affect girls' perceptions of these fields.

Sadler et al. (2012) report that high school freshmen's interest in STEM careers was the best predictor for determining interest when students reach higher education. Additionally, this study found that males maintained around a 40% interest in STEM fields throughout high school, whereas females' interests significantly dropped from 15.7% to 12.7% (Sadler et al., 2012). This implies that by the time students reach high school, low attitudes towards STEM careers exist for females and decline even further over time, implying future low rates of women entering STEM careers. Though Sikora and Pokropek (2012) had shown nearly equal interests in STEM careers across 50 countries between girls and boys at around the same age, the results of Sadler et al. (2012) emphasize the importance of these interests in the United States specifically. Archer et al. (2010) confirm this by stating, “Research has demonstrated that the majority of young children have positive attitudes to science at age 10 but that this interest then declines sharply and by age 14, their attitude and interest in the study of science has been largely formed (p. 617).” The idea that career paths are structured at an early age is not a new idea, and it is believed that the beliefs and attitudes of young children ultimately affect their career choices (Pajares, 2006). If the trend is for the loss of interest of girls in high school, then we need to find a way to increase interest in STEM *before* high school, sometime in the middle-grades, as research indicates it is a critical time for development.

Even as young as first grade, girls are drawn towards the social and natural sciences compared to boys who are drawn towards the physical sciences, suggesting a divergence at an early age (Adamson et al.,1998). While science competence from grades 1–6 appear fairly equal between the sexes, choices of science fair project *topics* suggests that social factors play a role in what attracts girls and boys to specific sciences (Adamson et al., 1998). Self-selected, single-sex groups imply that the topic decision may be based more on *aligning* to gender stereotypes and other social constructs as physical science is continually perceived as masculine, which children seem to grasp at a young age (Adamson et al., 1998). When asking male and female former Science Talent Search awardees to consider why they did or did not pursue STEM degrees and occupations, Heilbronner (2012) found a similar pattern to Adamson et al. (1998) in which women chose biology-related careers over engineering and physics careers, if they chose STEM careers at all; unsurprisingly, men were more likely to choose the latter fields. These awardees also reflected upon their self-efficacy during college STEM courses with results revealing that women experienced lower feelings of self-concept compared to their male counterparts (Heilbronner, 2012).

Others (e.g., Baker & Leary, 1995; Dawson, 2000; Jones et al., 2000) have noted the decrease in interest in physical sciences for *all* students at an early age. Jones et al. (2000) report on the gender differences in science experiences, attitudes, and perceptions of science courses and careers of 6^{th} grade students. Though this work is slightly dated, the same problems show up such that girls are not interested in physical sciences and boys are not interested in biological sciences. Similar to the ideas presented above from Sikora and Pokropek, (2012), Jones et al. (2000) offer that simultaneous to girls having little exposure to physical sciences at an early age, they argue that boys are also deficient in biological experiences. This is reflected in the above example of students' chosen science experiments (Adamson et al., 1998). In short, Jones et al. (2000) offer, "Teachers cannot escape the responsibility to present science as equally appropriate for girls and boys, to expect girls to use the tools of science with facility, and to expect both boys and girls to engage thoughtfully in science activities (p. 190)."

Theoretical Framework

In light of recent reforms in K-12 education, the National Research Council (2012) has concerns about the decline in students' interest in STEM careers. This fear is not unfounded especially considering minority groups, which includes women. In general, the greatest changes in students' attitudes toward science occur at each transitional stage in education, and this change is unfortunately negative (National Academies, 2007). My research presented here focuses on the middle school level for this very reason. It is the hope of the National Research Council (2012) and researchers (e.g., Archer et al., 2010, 2012; Brophy et al., 2008; Calabrese Barton et al., 2008; Halpern et al., 2007; Scantlebury, 2014) to engage a more diverse population of students in STEM fields. Students' experiences in K-12 science influence this trajectory, thus it is important to examine instructional strategies that play a role in developing students' perceptions. The theoretical lens adopted in my research merges girl-friendly instructional strategies and an integrated STEM framework. Below, I present each of these frameworks in turn and briefly discuss the importance of examining a blended framework.

Girl-friendly Instructional Strategies

In addition to the concerns described above that posit various reasons as to why there are few women in STEM careers, particularly physics, researchers have begun to question the influence of instructional strategies on students' perceptions (e.g., Hazari et al., 2010; Makarova & Herzog, 2015). Further, it is worth exploring how students' science self-efficacy and self-concept might be shaped through their schooling. Bandura (1977) described how self-efficacy is one of the strongest predictors of achievement, but it is thought that the relationship for female students may be more complex (Britner, 2008). For high school aged boys, this general relationship appears to hold, but is much more complex for girls (Britner, 2008). For high-school aged girls, mastery experiences, social persuasions, vicarious experiences, and physiological states play an important role depending on the specific science field (Britner, 2008). Mastery and vicarious experiences refer to students' ability to master capabilities and engage with materials to perform a task, respectively (Britner, 2008). Social persuasions are verbal and non-verbal judgments from others that may affect one's self-efficacy (Britner, 2008). Physiological states, such as anxiety, stress, and other moods, may additionally affect self-efficacy.

One strategy that has been used to increase science self-efficacy has been the use of single-sex science classrooms (Gillibrand et al., 1999; Häussler & Hoffman, 2002). While this approach has been successful, it gives an unrealistic sense of the world. The world is not conveniently separated into women and men and at some point young women will have to eventually learn and work alongside men in future higher education and careers, especially if choosing a career in science. The idea to isolate the sexes in learning, though it seems to be productive, is not a realistic choice that should be made. Additionally, it does not seem fitting as other researchers have shown that adopting girl-friendly practices, discussed below, is beneficial to both sexes.

Since physics continually remains at the bottom of attracting women to the field, we must examine what makes it unappealing to girls at young ages. One idea is to examine science identity and science self-concept, the development of which is related to self-efficacy and is important for maintaining interest in science as it relates to attitudes and beliefs (Brickhouse, Lowery, & Schultz, 2000). One of the most difficult parts of making physics seem appealing to girls and increase their physics self-concept is in being able to make physics useful for everyday application, as well as giving examples of societal and personal applications (e.g., Baker & Leary, 1995; Häussler & Hoffman, 2000; Labudde et al., 2000; Rosser, 2000; Stadler, Duit, & Benke, 2000; Yanowitz, 2004). Making these connections to real-world applications in a physics class positively and significantly impacts not only girls' but boys' expectations for success in future physics courses (Häussler et al., 1998; Häussler & Hoffman, 2000, 2002; Labudde et al., 2000). We can somewhat conclude that what works for girls will not negatively affect the way boys view and interact with physics (Labudde et al., 2000).

Häussler & Hoffman (2000) systematically developed a physics curriculum through assessing student interest with regards to content, contexts, and activities that aligned with the cognitive and emotional needs of students. Their conclusion was that both girls and boys "are interested in physics in the context of its practical applications, its potential to explain natural phenomena, or in the context of chances and risks which lie in physics-based technologies" (Häussler & Hoffman, 2000, p. 704). By making sure physics relates to practical applications and is seen as doing something positive for the human race, we can interest both boys and girls; this will be discussed further when considering an integrated STEM education framework.

Many researchers have noted girl-friendly teaching practices in physics. Häussler et al. (1998) identified seven guidelines for a girl-friendly curriculum, found to be beneficial for both boys and girls when it comes to improving physics self-concept. The specific guidelines are: 1) providing opportunities to be amazed, 2) linking content to prior experiences, 3) providing first-hand experiences, 4) encouraging discussion and reflections of the social importance of science, 5) letting physics appear in application-oriented contexts, 6) showing physics in relation to the human body, and 7) letting students experience the benefit and use of treating physics quantitatively. A broader set of guidelines, published in the Institute of Education Sciences (IES) Practice Guide *Encouraging Girls in Science*, suggests additional girl-friendly approaches to science (Halpern et al., 2007). These rely on knowing that academic abilities are not static, providing students with feedback, including female role models, creating classroom environments that foster long-term interests in STEM, and providing spatial training (Halpern et al., 2007). Newbill and Cennamo (2008) drew on the value of emotion, role models, and the need to address attitude functions to create fifteen instructional guidelines similar to those listed above. Included in their framework is cooperative or collaborative learning, as well as incorporating examples of career options that solve social problems (Newbill and Cennamo, 2008). Additionally, choices in student grouping during group work may also affect a girls' self-concept in physics and other sciences, and it may be the responsibility of the teacher to aid students when selecting group members (Kowalski, 2007; Rosser, 1998). While more guidelines and suggestions are available, in each of these cases it is evident that the teacher plays a large role in creating an environment to foster the development and growth of positive science self-concepts in girls, as well as boys.

Promisingly, Makarova and Herzog (2015) showed that science teachers perceived physics as being positive for both male and female associated words. Knowing that teachers are perhaps the most important factor that influences students' attitudes towards science (Barker, 2000) it is possible that this "non-gendering" of their own scientist stereotype could benefit students. Further, as will be explored below, by engaging teachers in girl-friendly practices it is possible that the pivotal role of the teacher may positively influence students (particularly girls) in terms of their perceptions of science and science careers.

STEM Integration

Recent national documents (NRC, 2012), suggest STEM instruction as a way in which science and engineering can come to life for girls in K-12 education. The *Next Generation Science Standards* (NRC, 2013) focus on this with the strong emphasis on scientific and engineering practices rather than a simple memorization of scientific facts. Though STEM appears in many differences places and policies, it has not been well-defined (Bybee, 2014). In many policy documents, STEM simply refers to mathematics or science, but in some cases, STEM may refer to a science course that incorporates other disciplines (Bybee, 2014). STEM can also refer to a combination of one or more disciplines or a transdisciplinary course or program (Bybee, 2014). These last two ideas are what some may further categorize as *integrated* STEM, which refers to the integration of one or more of the STEM disciplines, wherein engineering is typically used as the "glue" or "bridge" between the disciplines through the use of an engineering design challenge (Moore et al, 2014b).

The inclusion of engineering in K-12 education has previously been identified as advantageous to student learning through the use of: 1) providing a real-world context, 2) developing problem-solving skills in that context, and 3) developing communication skills and teamwork (Brophy et al., 2008; Hirsch, Carpinelli, Kimmel, Rockland, &

Bloom, 2007; Koszalka, Wu, & Davidson, 2007). At a glance, these aspects reflect some of the features of girl-friendly science (Häussler et al.,1998; Newbill & Cennamo, 2008), thus it is important to understand the intersection, or integration, of science and engineering as a way to improve student perceptions of physics. It is possible that by combining these fields in a way such that girl-friendly strategies are used, positive perceptions of physics can be formed and maintained with the appropriate instructional strategies.

Integrating engineering into science may be a way to gain and maintain self-concept and interest in young girls. The integrated STEM framework discussed in Moore et al. (2014b) includes: 1) a motivating and engaging context, 2) the inclusion of mathematics and/or science content, 3) student-centered pedagogies, 4) an engineering design or redesign challenge, 5) learning from failure, and 6) an emphasis on teamwork and communication. The purpose of the motivating and engaging context provides students with real problems that require them to draw from multiple disciplines in order to solve a given problem or design challenge (Moore et al., 2014b). The inclusion of teamwork and communication enables students to develop skills such as listening skills and learning to compromise (Moore, Glancy, Tank, Kersten, & Smith, 2014a). These STEM integration approaches allow girls and boys to work with their hands, talk about science in groups, and relate science to human problems, much like the suggestions of girl-friendly instructional strategies promote; thus, these aspects fit many of the recommendations for an effective girl-friendly curriculum. Perhaps the most promising feature that appears in Moore et al.'s (2014b) integrated STEM framework is the prominence of the real-world applications of science and mathematics content, which directly aligns to the findings of Häussler & Hoffman (2000) in which they found that girls and boys are particularly interested in practical applications of physics.

Though the integrated STEM instructional framework above provides little specificity as to how one should integrate the STEM fields. Two possible models offered by Moore (2008) for integrating engineering are *context* and *content* integration. With *context* integration, there is one content focus that can be placed in contexts from other disciplines; the primary objective is to develop understanding in only one content area that can be used in other contexts. Conversely, *content* integration involves an overarching motivating and engaging context that relies on using and developing understanding of content from multiple disciplines. This type of integration allows teachers to teach mathematics and science content in relation to solving an engineering design challenge, one of the key features of integrated STEM instruction (Roehrig Wang, Moore, & Park, 2012).

A Combined Instructional Framework to Support Gender Equality

There is a clear alignment between the goals of girl-friendly instructional strategies and STEM integration. In both cases, the goal is to not only increase the level of student achievement, but also to increase students' interest in STEM careers. Table 2.1 shows how not only the overall goals of the frameworks are aligned, but how the independent *tenets* of these frameworks are aligned. A comparison between several girl-friendly instructional strategies (Häussler et al., 1998; Newbill & Cennamo, 2008) and the integrated STEM framework of Moore et al. (2014b) is shown to emphasize the importance of the work presented here. Alignment between these two frameworks is vital in understanding how a combined instructional framework may be beneficial to increase girls' science self-concept and STEM career aspirations. For instance, the motivating and engaging context discussed by Moore et al. (2014b) is similar to tenets 1, 2, 3, and 5 of the girl-friendly instructional strategies (Häussler et al., 1998). An engineering design challenge or redesign would allow students to see how physics appears in application-oriented contexts.

Table 2.1

Comparison Between Girl-Friendly and Integrated STEM Strategies

Girl-Friendly Strategies (Häussler et al., 1998; Newbill & Cennamo, 2008)	Integrated STEM Framework (Moore et al., 2014)
1. Provide opportunities to be amazed.	1. Motivating and engaging context.
2. Link content to prior experiences.	2. Inclusion of mathematics and/or science content.
3. Provide first-hand experiences.	3. Student-centered pedagogies.
4. Encourage discussion and reflections of the social importance of science.	4. Engineering design challenge or redesign.
5. Physics appears in application-oriented contexts.	5. Learning from failure.
6. Relate physics to the human body.	6. Emphasis on teamwork and communication.
7. Experience physics quantitatively.	
8. Engage in collaborative learning.	

While there are numerous studies that exemplify the merits of girl-friendly instructional strategies, there are few that examine how integrated STEM strategies may influence students' perceptions of STEM fields and STEM careers. Additionally, there is no known work that examines how the combination of these two frameworks may affect student perceptions (both for girls and boys) of STEM fields and STEM careers, especially those disciplines where girls are highly underrepresented. It is important to understand how this new trend in science education may affect girls' beliefs towards science, and by adopting a mixture of the integrated STEM framework suggested by Moore et al. (2014b) in combination with girl-friendly practices suggested by others (Häussler et al., 1998; Newbill & Cennamo; 2008) this can happen.

CHAPTER III

Methodology

Purpose and Research Questions

The purpose of this study is to understand the role of girl-friendly and integrated STEM instructional strategies in the way middle school students view their place in physics, both in the classroom and as a potential future career. Ultimately, this study will identify how these strategies influence students' perceptions of physics and physics-related careers and propose suggestions as to how to positively increase and maintain these perceptions for both girls and boys. Many agree that the middle-school years are of utmost importance in retaining girls' interest in science (e.g., Archer et al., 2010, 2012; Brophy et al., 2008; Catsambis, 1995; NRC, 2012; Sadler et al., 2012); thus, there is a focus on middle school students for this study. The overarching goal of this work is to improve girls' perceptions of STEM fields and STEM careers, with a particular emphasis on physics. Another goal is to understand what teacher practices may influence the development of these perceptions. Further, there is a broad goal to bring awareness to science teachers in efforts to not just encourage girls in STEM fields, but to avoid encouraging stereotypes in their classroom, even when done subconsciously. In order to address these goals, this study focuses on the following research questions:

- *In what ways do teacher practices affect the way middle school students view their role in the physics classroom as well as their perceptions regarding a physics-related career?*

a. *What girl-friendly and integrated STEM instructional strategies do teachers use that influence student perceptions?*
b. *What patterns arise in girls' and boys' perceptions towards physics and physics-related careers?*
c. *What differences exist between girls' and boys' perceptions of physics and physics-related careers?*

Methods

Context Overview

This study was conducted under the umbrella of the five-year NSF-funded Mathematics and Science Partnership grant, Engineering to Transform the Education of Analysis, Measurement, and Science (EngrTEAMS) (EHR #1238140). EngrTEAMS provides 4^{th}–8^{th} grade science teachers with intensive professional development to learn how to bring integrated STEM education to their science classrooms through using the integrated STEM framework as described by Moore et al. (2014b). The first cohort of the EngrTEAMS project started in summer of 2013; these teachers came from three partner school districts in the greater Minneapolis-St. Paul regions. The study presented here focuses on the second cohort during the 2014–2015 academic year, represented by the same school districts. During this second year a total of forty-two teacher participants (hereafter, Fellows) came together to work in teams to develop integrated STEM curricula to meet state science standards in a chosen science content area: earth, life, or physical science.

During each year of EngrTEAMS, Fellows participate in three weeks of intensive professional development over the summer. Table 3.1 outlines the timeline of the 2014 summer activities and an overview of the follow-up through classroom coaching during the 2014-2015 academic year. This professional development engages Fellows in learning about STEM integration instructional techniques, using the framework of Moore et al. (2014b) to guide Fellow's learning. Fellows spend time learning and engaging in various activities as part of the EngrTEAMS's staff-developed STEM integration activities and curricula. Through the professional development, Fellows learn in-depth information about bringing engineering practices and methods of data analysis to their science classrooms, as most of the Fellows are new to STEM integration. While Minnesota has not adopted the *Next Generation Science Standards* (NRC, 2013), our state standards require teachers to teach engineering as part of the Nature of Science and Engineering standards (MN DOE, 2009). Fellows also learn more about STEM integration within a particular science content area. In the 2014 summer professional development, Fellows had the choice of the water cycle, evolution, and force and motion to focus on earth, life, and physical science, respectively.

In addition to learning about integrated STEM instructional techniques, Fellows worked in groups of 2-4 to develop and write integrated STEM curricula, which they were required to teach in their own classrooms during the 2014–2015 academic year. This was done alongside an assigned classroom coach. These coaches were all PhD-track graduate students in Science, Mathematics, or STEM Education. They all participated in a graduate-level course to learn how to coach teachers through reflective and

Table 3.1

Schedule of EngrTEAMS 2014 Summer Professional Development and Academic Year Follow-Up

Topic	Timeline	Description
Engineering and Data Analysis	June/July 2014 (6 days)	All forty-two teachers learned about Engineering and Data Analysis together through integrated STEM activities.
Content Specific STEM Integration Learning	June 2014 (4 days)	Teachers split into their selected content area to learn more specific ways to teach life, earth, and physical science in an integrated STEM curriculum as defined by Moore et al. (2014).
Curriculum Writing and Development	June/July 2014 (6 days)	Teachers worked in small teams to develop a curriculum unit that they will write and implement in their classrooms.
Summer Piloting	July/August 2014 (2 days per team)	Summer STEM camp students participated in the teams' piloting of their written curriculum.
Curriculum Revisions	Fall 2014	Teams worked together to revise their curriculum based on summer piloting.
Classroom Implementation	Fall 2014-Spring 2015	Individual teachers implemented the curriculum in their classrooms.
Curriculum Revisions	Fall 2014-Spring 2015	Teams worked together to revise their curriculum based on classroom implementation.
Reflective Coaching Conversations	Fall 2014-Spring 2015	Teams worked with their assigned graduate student coach to reflect on classroom practices.

transformative practices. Additionally, each coach acted as a team member in his or her respective group to help develop his or her teams' integrated STEM curriculum. This included assisting in the piloting of their team's curriculum with a group of STEM summer camp students. Coaches helped their teams reflect on the summer piloting as an opportunity to reflect forward on how this curriculum would be shaped for classroom implementation. Throughout the 2014–2015 academic year, classroom coaches worked with their teams to continue to develop curricula as well as provide support through classroom observations and reflective coaching conversations. This was done through monthly individual coaching meetings and occasional team meetings, during which time was dedicated to *team* reflection and curriculum writing.

My Role and Focus in EngrTEAMS

My role throughout the 2014-2015 EngrTEAMS project included co-facilitating the professional development days with the seventeen physical science Fellows and participating as a classroom coach to one teacher team. This team was comprised of two middle school teachers, who graciously provided me with additional access to their students in order to carry out this study; this is discussed in detail below. The content covered during the four days of content-specific professional development focused on force and motion. During these four days of professional development, physical science Fellows were immersed in a variety of lessons and activities to prepare them for creating similarly styled lessons for use in their own classrooms. Table 3.2 provides a brief description of the daily activities and discussions in which Fellow participated. In addition to these content specific activities, Fellows engaged in activities that would help them become curriculum writers. Specifically, exercises that focused on "unwrapping" state science standards and *Understanding By Design* (*UBD*) (Wiggins & McTighe, 2012) were used to guide this curriculum writing, as many of the Fellows had not had experience with writing their own curriculum.

One of the key discussions that I was asked to lead during this time was one on girl-friendly instructional strategies. Fellows took part in discussions about gender equity in science classrooms, specifically engaging in learning about girl-friendly instructional strategies that have been documented in research on improving girls' perceptions of physics (e.g. Baker & Leary, 1995; Häussler et al., 1998; Häussler & Hoffman, 2000; Labudde et al., 2000; Rosser, 2000; Yanowitz, 2004). This included sharing this research

Table 3.2

Daily Schedule of Physical Science Professional Development

Activity	Brief Description
Day 1	
Unwrapping the standards	This activity allowed Fellows to understand Minnesota state science standards at a deeper level by identifying the key concepts and skills students need to learn.
Gear Up!	Fellows participated in lessons and activities that used bicycles to discuss simple machines, gears, and gear ratios.
Introduction to *UBD*	Professional development leaders guided Fellows through *UBD*, using the Gear Up! unit as a model.
Reflection	Fellows reflected individually on their day.
Day 2	
Assign Groups	Curriculum writing teams were paired with their classroom coach based on interests and interactions on Day 1.
Recap Gears	Fellows reflected on the previous days' Gear Up! lessons and activities to further their understanding of multiple graphical and visual representations.
Balancing Act	Fellows learned about how to improve activities by including multiple STEM concepts, using a PhET simulation..
Teamwork in the Classroom	A conversation that connected to big group PD day discussed group structure and strategies in the classroom. This conversation also covered how boys and girls may or may not be paired in groups.
Crash Course	Fellows used Vernier LabQuest2 handheld computers and motion detectors to graph their motion and predict what various graphs would look like given a certain motion. Fellows used this knowledge to attempt to solve a "sledding crash" scenario.
Reflection	Fellows reflected individually on their day.
Day 3	
Girl-Friendly Science Instruction	By presenting some research on girl-friendly science instructional strategies, Fellows engaged in conversation about the boys and girls in their classrooms and how they encourage girls to actively participate.
PhET Forces in 1D	Unwrapping the standards practice through a Make it Better activity.
Tabletop Hovercraft	Fellows used a hovercraft to experience Newton's 1st Law and were introduced to video analysis. Fellows participated an engineering design challenge to create a tabletop hovercraft that moved either the greatest distance or in the straightest line. Video analysis was shown as a tool to show evidence for their claims.
Brainstorm	Using the *UBD* model, Fellows worked in their teams to start brainstorming ideas for their integrated STEM curriculum.
Team Debrief	Fellows and coaches debriefed.
Day 4	
Revisit Prior Work	Fellows were allowed to work on either the PhET simulation activity or dig into their own curriculum to work on the UBD guide to curriculum writing.
Present Egg Drop	The Egg Drop is a typical engineering activity used in classrooms, but often does not successfully teach science content or address a motivating and engaging context. Fellows critique this activity and provide some ways to modify it.
Push it to the Limit	Fellows practiced writing a lesson/unit with an engineering design challenge, including choosing standards, working through *UBD*, building and testing a model, presenting their model, and getting feedback.
Breakout	Fellows worked in their curriculum writing teams or asked questions about tools used in the previous 4 days.
Team Debrief	Fellows and coaches debriefed.

as well as allowing Fellows to talk in small groups about their experiences with girls' and boys' engagement, participation, and achievement in their own classrooms. This discussion allowed Fellows to reflect on those experiences and realize where they could include more girl-friendly instruction not only into their integrated STEM curricula, but more broadly into their instructional strategies. The purpose of including these discussions in the professional development was to help frame the context required for the study presented here. The side-by-side comparison of girl-friendly and integrated STEM instructional strategies shown in Table 2.1 was shared with these teachers in order to help them see how integrated STEM could easily be aligned with girl-friendly strategies.

The biggest factor for aligning the integrated STEM curricula and girl-friendly strategies came from the motivating and engaging context that allows all students access to a given problem or situation. When talking about force and motion, it is easy to default to selecting contexts that include trains and automobiles, which rarely ignite interest in young girls. For example, the large-scale engineering design challenge presented during the professional development asked Fellows to consider the context of protecting cargo on a train, as part of a redesign of typical egg drop engineering challenges. The context chosen to share with the Fellows was about a train derailment that occurred in Lac-Megantic, Canada on July 6, 2013. The presentation of this context focused not only on the mechanics of trains and train crashes, but on how these events may impact the surrounding community, especially because this real event left 42 injured and 5 presumed dead. The ability to design and engage students in a multi-dimensional context was stressed to the Fellows as a way to open up these types of challenges to girls.

In addition to my role as a facilitator of the summer professional development, I was the classroom coach for two middle school physical science teachers who taught at the same suburban school - Ralph, a veteran science teacher of over twenty-five years, and Shana, who had been teaching for eight years. Both Ralph and Shana had been teaching 6th grade at the same school for the past six years, and during the 2014–2015 academic year, they taught all of the 6th grade students in their school, which totaled approximately 300 students. As part of the EngrTEAMS project, I had worked with Ralph during the 2013–2014 academic year as his coach and through this, was able to develop a strong, trusting relationship with him. I had met Shana on several occasions prior to the summer 2014 professional development. After our three weeks working together in the summer plus the piloting with summer camp students, Ralph and Shana agreed to allow me access to their classrooms and students above and beyond the scope of the EngrTEAMS project. My strong relationship with these teachers set the stage for me to be able to gain more access to their classrooms than required by the EngrTEAMS project, which led to a positive relationship between myself and their students.

Participants

The 6th grade student participants in this study came from the suburban middle school in which Ralph and Shana taught. Ralph, who additionally taught 7th grade life science, taught approximately 100 6th grade students in three different sections. Shana, who exclusively taught 6th grade, had approximately 200 students total in her six sections.

The demographics of this school were as follows: 67% Caucasian, 13% African American, 12.7% Asian American, 6% Latino American, and 0.3% Native American. Roughly 18% of students at this school were eligible for the free or reduced lunch program.

Research Design

This work uses a mixed-methods approach to examine the impacts of girl-friendly and integrated STEM instructional strategies on student perceptions of physics and physics-related careers. To address the research questions, this study employed mixed-methods to create a full picture of what occurs in these classrooms, using both quantitative and qualitative data and data analysis (Creswell & Plano Clark, 2011). These data are comprised of the primary sources of Likert-scale surveys and transcripts of focus group interviews. The secondary data source is classroom observations, which help to provide rich descriptions of the typical structure of these two classrooms in order to decipher the instructional strategies and contextualize students' responses in the interviews.

The convergent parallel mixed-methods design (Figure 3.1) was chosen in order to allow the quantitative surveys and qualitative focus group interviews to be collected and analyzed separately before comparing the findings to address the research questions (Creswell & Plano Clark, 2011). While the overall design is mixed-methods, the specific design for understanding the qualitative data is an interpretive multi-case study design, wherein the two cases being examined are girls and boys (Yin, 2014). This combination of using a case study design within a larger mixed methods research design has been noted as meriting consideration (Yin, 2014). The use of a case design was selected based on the nature of the research questions and the ability of each case to provide rich descriptions of students' perceptions of physics and physics-related careers. This is described in more detail in Figure 3.2.

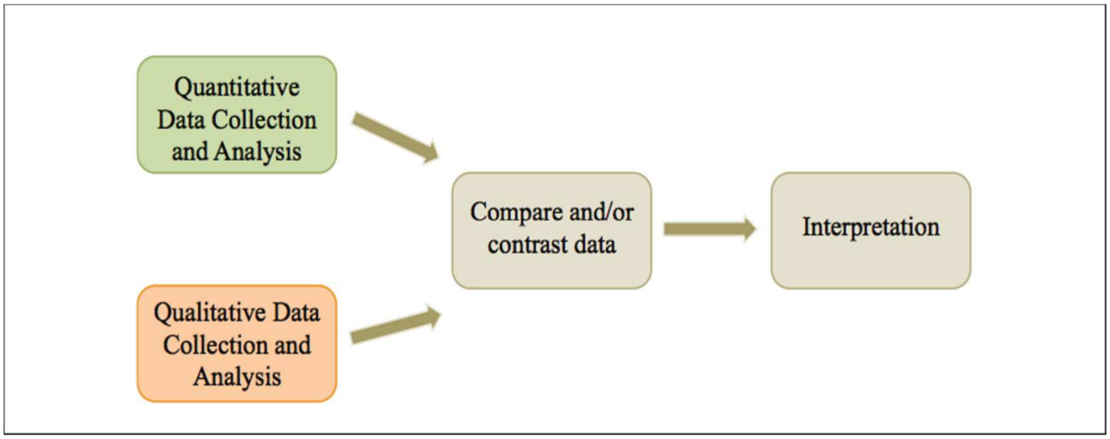


Figure 3.1. Visual representation of general research design, modeled after a convergent parallel mixed-methods study in which both quantitative and qualitative data are present (Creswell & Plano Clark, 2011).

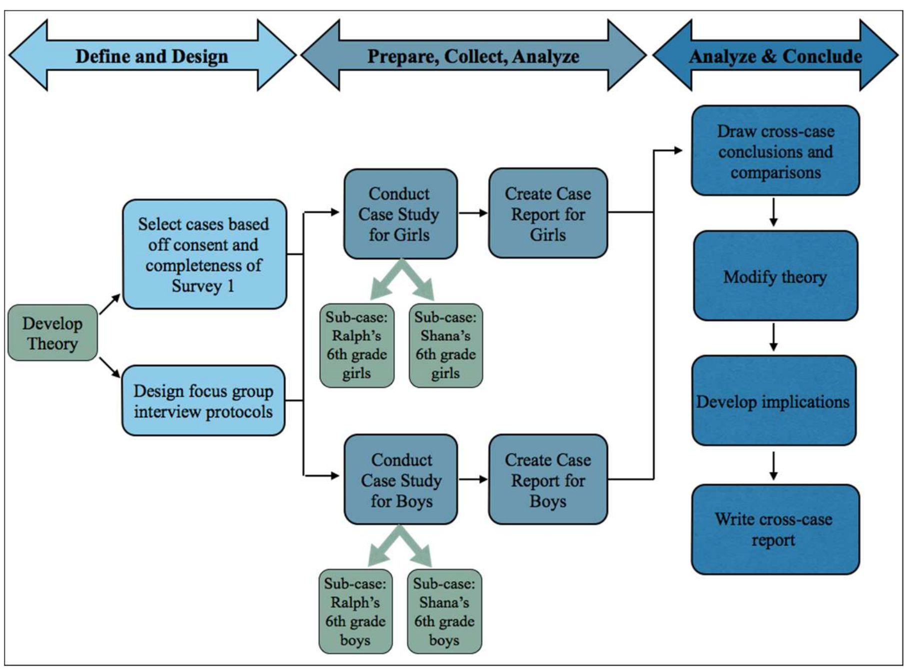


Figure 3.2. Interpretive Multi-case design with analysis, adapted from Yin (2014).

Data Collection. Data for this study were collected between September and January of the 2014–2015 academic year. Figure 3.3 outlines the timeline of this data collection. A description of each data source and how it was collected is discussed below.

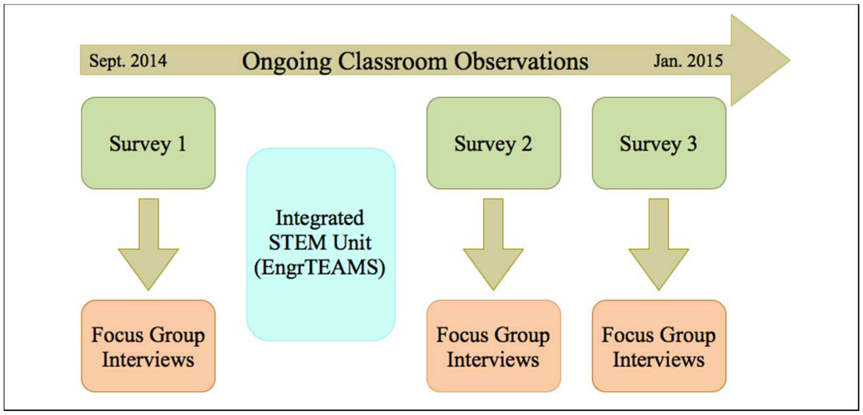


Figure 3.3. Timeline of data collection throughout the 2014–2015 academic year.

Student surveys. A 15-item 5-point Likert-scale survey (Appendix A) was created in order to access information regarding students' perceptions of physics and physics-related careers, as well as their science instructional preferences; these three areas of interest guided the creation of the survey. The purpose of this quantitative survey was to provide a general overview of 6^{th} grade students' perceptions of physics and physics related careers. This 5-point Likert survey asked students to rate items from 0 to 4, corresponding to *Strongly Disagree* to *Strongly Agree*. Tables 3.3, 3.4, and 3.5 outline the purpose of each of the 15 items on the survey. Table 3.5, which focuses on the instructional preferences, shows the alignment to several girl-friendly practices as informed by Häussler et al. (1998) and Newbill and Cennamo (2008). Before the survey was finalized and administered to students, I asked Ralph and Shana to provide feedback on the wording for their 6^{th} grade students. Additionally, they suggested that the survey include a brief description of physics, as they felt their students may have a limited understanding of the field. Surveys also asked students to identify which gender they most associated with.

Table 3.3

Survey Items Related to Student Perceptions of Physics

Survey Item	Purpose of Item
1. I like learning about how things work.	To understand students' interest in physics at a broad level.
2. I am interested in the topics we will be learning in science this year (e.g. particles, light, sound, motion, forces, energy).	To understand students' interest in physics topics.
3. I like to learn about physics topics outside of school.	To understand students' interest in physics at a broad level.
5. Science is one of my favorite classes in school this year.	To understand students' interest in science class, which covers physics topics.
6. I easily understand physics topics.	To access students' physics self-concept.
7. Learning physics can be helpful in my everyday life.	To access students' beliefs about the applications of physics.
9. You have to be good at math to understand physics.	To access students' beliefs about the intersection of mathematics and physics.

Table 3.4

Survey Items Related to Student Perceptions of Physics-Related Careers

Survey Item	Purpose of Item
4. I would like to have a career where physics plays a role.	To access students' interest in careers involving physics.
8. Anyone can be good at physics.	To access students' beliefs about who uses physics.
10. Physics is just a subject to learn in school.	To access students' belief of physics and its importance in the real-world.

Table 3.5

Survey Items Related to Science Instructional Practices

Survey	Girl-Friendly Strategy
11. I prefer to work in groups in science class.	Collaborative learning (Newbill & Cennamo, 2008)
12. I like using math to solve science problems.	Experience physics quantitatively (Häussler et al., 1998)
13. I prefer hands-on activities when learning science.	Provide first-hand experiences (Häussler et al., 1998)
14. I like participating in class discussions about science.	Encourage discussion and reflections of the social importance of science (Häussler et al., 1998)
15. I like when I can relate to the topics we learn in science class.	Link content to prior experiences (Häussler et al., 1998)

Students completed these surveys three times during the school year, as depicted in Figure 3.3. The first survey was administered in mid-September 2014, a few weeks after the start of the school year in order for students to acclimate to their new middle school environment. This took place after I spoke with each of Ralph and Shana's 6th grade science classes, a total of approximately 300 students. During this time, I explained the broader EngrTEAMS project in addition to my explaining that I would be collecting my own data, specifically letting them know that I was interested in interviewing some of them. The nature of the study presented here was limited to telling students that I was interested in what they thought about science. Student assent and parent consent forms were distributed and collected before students were asked to complete the first round of surveys.

All three of Ralph's classes participated in the surveys, though not all students completed all of the surveys. Due to time constraints in Shana's classroom, she was only able to administer this survey to three of her six 6th grade classes, thus only three of her classes were considered for any analysis, which further limited which of her students were selected for focus group interviews. While limiting the sample size, this ended up balancing the distribution of student participants coming from these two teachers' classes. The second survey was administered shortly after the conclusion of the implementation of the EngrTEAMS integrated STEM curriculum unit; this was in late November 2014. The final survey was administered a few weeks after the school's winter break ended towards the end of January 2015. Due to student absences, the number of students taking the surveys each time in these six sections varied slightly, as indicated in Table 3.6. In the end a total of 189 individual students from six total sections completed the surveys, though, as discussed below, not all of these students were considered for analysis.

Table 3.6.

Total Survey Completion Numbers

	Ralph	Shana
Survey 1 (N = 164)	N = 89	N = 75
Girls	41	35
Boys	48	40
Survey 2 (N = 167)	N = 80	N = 87
Girls	37	38
Boys	43	49
Survey 3 (N = 172)	N = 86	N = 86
Girls	40	40
Boys	46	46

Student focus group interviews. Focus group interviews were conducted with a total of twenty-seven students from Ralph and Shana's classes. These interviews provided a smaller set of students the opportunity to elaborate on their physics-related perceptions in a social environment, and were conducted shortly after the administration of each survey (see Figure 3.3). One girl and one boy group were selected from each of Ralph and Shana's classes for a total of four focus groups. Inclusion in the groups was based off of completeness of the first survey and, more importantly, whether parental consent was given to be interviewed outside of class. These two conditions left thirty-six students eligible for focus group interviews. In order to better balance the number of girls and boys from both Ralph and Shana's classes in the focus interviews, nine students were not invited to focus group interviews; responses on the survey were not used make this decision, but rather, a careful selection was made to create a balance. As more girls were eligible, the limiting factor was the number of boys from each teacher's classes. One girl from Ralph's class who was invited to the first meeting did not show up, and thus was not invited to the following meetings. The decision to create gendered groups by teachers aligned with the goals of this study, but additionally assured that the participants in each of the two cases were considered homogeneous in some way (Krueger & Casey, 2000). Table 3.7 shows the distribution of the four groups with respect to sex and teacher.

Table 3.7

Student Focus Group Interviews with Group Name

	Ralph	Shana
	N = 11	N = 16
Girls	6 (Blue)	9 (Orange)
Boys	5 (Red)	7 (Green)

Twenty-seven students participated in the focus group interviews in four different groups as indicated in Table 3.7. Students who participated in focus groups represented a more diverse population than the school district as a whole. Further, the students in the focus group were more diverse than the demographics of this particular school, whose student population is made up of 67% Caucasian, 13% African American, 12.7% Asian American, 6% Latino American, and 0.3% Native American. The two female groups (Case 1) were composed of 8/15 Caucasian, 5/15 African American, and 2/15 Asian American girls in total. The two male groups (Case 2) were composed of 8/12 Caucasian, 2/12 African American, 1/12 Asian American, and 1/12 Latino American boys in total. Table 3.8 displays this information. All names are pseudonyms.

Focus groups were chosen for this particular study to suit the nature of the interpretive multiple case study design within the mixed-methods study. Because there are two cases, the unit of analysis is each case rather than individual students. This is why

Table 3.8

Demographics of Students Who Participated in Focus Group Interviews

		Ralph	Shana
Girls			
	Caucasian	Samantha, Lindsey	Zara, Ashlyn, Cass, Jessica, Evelyn, Lisa
	African American	Alisa, Monet	Roberta, Raylen, Brianna
	Asian American	Rachel, Megan	
Boys			
	Caucasian	George, Thomas, Robbie	John, Joe, Nate, Frank, Lloyd
	African American		Donovan, Jimmy
	Asian American		Felix
	Latino American	Jose, Preston	

the groups were organized with the "sub-case" structure as depicted in Figure 3.2. These sub-cases also assured that what students said from one focus group in a given case was consistent with the other in the same case, which is why more than one focus group is used in this type of design (Krueger & Casey, 2000). Additionally, focus groups were employed in this study to identify patterns and trends across groups, in line with the research questions and analysis guiding this study (Krueger & Casey, 2000).

The social setting of the focus groups allowed for students to disperse ideas to discuss with their peers in a friendly environment. These focus groups were conducted during students' lunch period and were enticed to join by the variety of candy I brought to each meetings. The relaxed setting helped to further create an environment where students were not pushed towards agreement or consensus. Further, as the moderator and interviewer, I made it apparent to these students that I was simply looking for their opinion and there was no right or wrong answer, allowing them to feel comfortable if they disagreed with their peers. I also encouraged quiet students to respond by calling on them by name and was careful to maintain an unbiased stance throughout the interviews.

Krueger and Casey's (2000) tips on focus groups interviews with young people were taken into consideration before any focus group was conducted.

In order to gain a deeper understanding of how teacher implementation of girl-friendly and integrated STEM instructional strategies may affect student perceptions of physics and physics related careers, a semi-structured guide was created for each of the three focus group meetings; these protocols are provided in Appendices B-D. The three main topics addressed in the surveys guided the questions in the three protocols, such that the focus was really around perceptions of physics, perceptions of physics-related careers, and science instructional strategies.

The fist protocol was developed to understand students' initial perceptions of physics and physics-related careers, thus was an exploratory instrument that allowed students to organically talk about their experiences. For instance, by asking students to identify what types of activities they liked and did not like in science class, I was able to identify what girl-friendly and integrated STEM practices used by the teacher had an impact on student perceptions. The second protocol specifically asked students to talk more about their experiences with the integrated STEM curriculum unit that exposed them to an engineering design challenge. Additionally, this second interview protocol tapped deeper into students' interest levels in physics-related careers. The third protocol asked students to talk about a recent assignment in their science class in order to learn more about students' perceptions of science and physics, but the primary focus was on reflecting on their experiences in the classroom since the beginning of the year and thinking more about careers.

The protocol used was kept the same for all groups during each round of interviews, within reason; for example, there were occasions in which students took a conversation in a different direction before the interviewer could refocus the group's conversation. These guided questions asked students to consider their teachers' instructional strategies as well as their own experiences and perceptions of physics and physics-related careers. The gender-separated focus groups provide indication of the level of different needs of middle school girls and boys in physics classrooms.

Classroom observations. As part of the overall EngrTEAMS design, classroom observations were conducted during the implementation of the integrated STEM curriculum in Ralph and Shana's classrooms. These observations only make up part of the total observations. While the curriculum lasted fifteen days, only 14 and 12 days were observed in Ralph and Shana's classrooms, respectively. Additional observations were conducted both before and after the EngrTEAMS curriculum was implemented for a total of 11 and 10 non-EngrTEAMS-related observations in Ralph and Shana's classrooms. One target class from each of their classrooms was identified after initial observations in September 2014. These target classes were selected based on recommendations from Ralph and Shana, as well as classes that fit the researcher's schedule the best. My role as the observer in these classrooms was usually limited to sitting in the back of the room, taking field notes. When students were working in groups on laboratory activities or the engineering design challenge, I walked around and interacted with students, asking them to explain what they were doing. As some of these students were also participants in the focus group interviews, I consciously did not focus my attention on these groups, but treated them equally amongst all groups in the classroom.

The purpose of these observations was two-fold. One purpose was to understand the culture of these two classrooms so as to understand the culture of this school's 6^{th} grade science experience. More specifically, the observations revealed what girl-friendly practices were employed throughout the length of the study. Extensive field notes were collected during these observations in order to gain an understanding of the extent to which girl-friendly practices were used on a regular basis. The second purpose of these observations was to create a presence in these classrooms as a participant observer and to familiarize myself with the students. This was important for the purpose of the focus group interviews, in which I could reference activities or lessons students had participated in during their classes and it allowed me to understand the typical teaching style of both Ralph and Shana.

Data Analysis

Overview. Due to the nature of the research design, the data analysis was completed in three main phases: 1) analysis of quantitative data, 2) analysis of qualitative data, and 3) comparative analysis of both sets of data. This overall analysis procedure is depicted in Figure 3.4. A description of each of these phases can be found below.

Quantitative Analysis. In order to be able to compare between all three sets of the surveys, only complete sets of surveys were considered for analysis, thus the sample size was reduced to a total of 139 students from the total 189 that had completed at least one

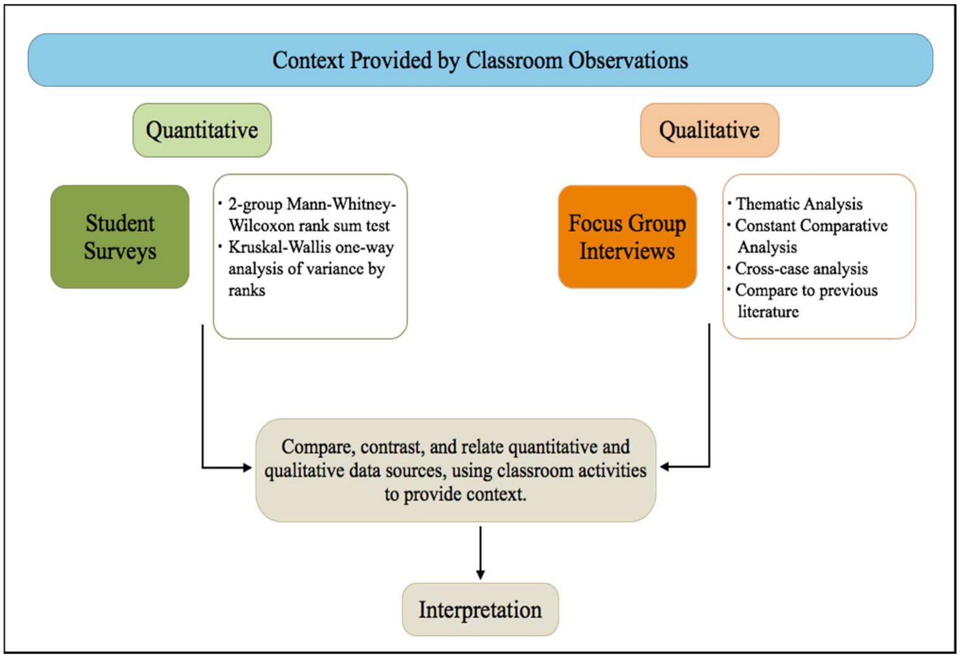


Figure 3.4. Summary of analysis procedures for both quantitative and qualitative data.

survey. Fortunately, the balance between girls and boys remained, leaving 64 girls' and 75 boys' completed surveys for analysis. This limited the individual analysis of the surveys to be able to compare consistently and increase the confidence in the survey responses. The Cronbach's alpha for each administration of the survey showed good internal consistency with α_1 = .74, α_2 =.78, and α_3 =.79 for surveys 1, 2, and 3, respectively.

The remaining surveys from 139 students were analyzed using a non-parametric 2-group Mann-Whitney-Wilcoxon rank sum test to examine the differences in perceptions between girls and boys. This test was chosen due to the ordinal nature of the survey and the independent sampling of the two groups (girls and boys). Selection of this test was due to making fewer assumptions about the distribution of responses as well as the relatively small sample size to understand if the independent samples represented two different populations (Hollingsworth, Collins, Easton Smith, & Nelson, 2011; Roberson, Shema, Mundfrom, & Holmes, 1995; Sheskin, 2000). Each of the 15 items on the survey was analyzed using this method in order to develop an understanding of these differences. Cohen's-*d* was calculated in order to measure effect size of statistically significant items. Each round of survey was analyzed in this fashion.

A second analysis was completed to identify any differences over time through a repeated measures test. Due to the ordinal nature of Likert items, a non-parametric Friedman rank-sum test was used to identify changes in each item for both girls and boys; this test is the non-parametric equivalent to a repeated-measured one-way analysis of variance (ANOVA) test that does not assume normality or homoscedasticity. As with the Mann-Whitney-Wilcoxon rank sum test, the Friedman rank-sum test was selected so as to not make assumptions about the distributions (Sheskin, 2000). This test is also powerful when the sample sizes are different. Since there were 64 girls and 75 boys, this was important for running this test. The purpose of this test was to examine how girls' and boys' perceptions change over time due to exposure to physics and the instructional strategies their teachers used in class. The Z value of the Wilcoxon signed-rank test was used to calculate an effect size of statistically significant items as there is no direct way to measure the effect size of the Friedman rank-sum test. This was done after using the post-hoc Bonferroni adjustment to identify where the significance occurred between groups (i.e. the different administrations of the survey). Effect size was then calculated using $r = \frac{Z}{\sqrt{N}}$.

Qualitative Analysis. Within two days of each of the focus group meetings, the interviews were transcribed. For each round of interviews, codes were identified first within each individual focus group interview and further between group interviews through a constant-comparative method (Corbin & Strauss, 2008). This was necessary in order to consider the sub-groups of the cases (i.e. the girls from Ralph's classes and the girls from Shana's classes made up one case, but initial coding was done separately). This coding was done using the program DeDoose. For each of the transcripts, student responses to the interview questions, developed through the research questions guiding this study, were coded, leading to each question being coded. According to Yin (2014), this approach to coding relied on theoretical propositions in order to know how to code. A constant comparative method was employed for each case (girls and boys) to generate an understanding of the with-in case groups (Corbin & Strauss, 2008; Miles & Huberman, 1994). Table 3.9 shows the final codes and themes identified in the interview data.

Each round of focus group interviews were analyzed in this manner and once all analyses were completed, themes from each respective interview were compared and contrasted with one another per case. A cross-case comparison was used to synthesize the findings between the separate cases to better understand similarities and differences between them (Corbin & Strauss, 2008). The single-sex focus groups provide some indication of the level of different needs of middle school girls and boys in physics classrooms. These final themes were then compared to previous literature related to gender equity in science (as a whole) and girl-friendly instructional strategies.

One of the key things to note is that, as anticipated from talking with Ralph and Shana, students did not have an understanding of what a physics-related or science-

Table 3.9

Themes and Codes Identified in Focus Group Interviews

Themes	Codes
Instructional Strategies	Group work
	Choosing your own topic
	First-hand experiences
	Writing notes
	Practical implications
Science Perceptions	About science in school
	Changing attitudes about science
	Influences from Others
Engineering Design Challenge	Assigned roles
	Competition
	Distractions from others
	Balance
	Budget/materials
	"Passengers"
	Math/calculations
	Time to build
Perceptions of Science Careers	How to improve change of science career
	Stereotype of scientists
	What do scientists do?
	Knowledge of physics
Career goals (general)	Doing something you love
	Family
	Freedom
	Money
	Being challenged
	Options open
	Helping others/society
	Seeing the world
	Stability
	Treated Nicely

related career was. Students often interpreted questions surrounding this topic as me asking about their interest in being a scientist, especially early on in the interviews. This understanding that there are physics-related and science-related careers, however, developed over time, as addressed in Chapter IV.

Additionally, field notes from classroom observations were used as a secondary source. These field notes provide rich descriptions of the classroom culture and contextualize students' responses in the surveys and focus group interviews. The theoretical framework of this study guided the deductive coding of these notes to indicate where girl-friendly and integrated STEM instructional strategies took place (Miles & Huberman, 1994). Table 3.10 provides the shorthand codes used to identify where these strategies were used. Each observation was coded using this framework in order to understand if and when Ralph and Shana were exhibiting girl-friendly and integrated STEM strategies in their respective classrooms.

Table 3.10

Codes Used to Analyze Classroom Observations

Girl-Friendly Strategies (Häussler et al., 1998; Newbill & Cennamo, 2008)		Integrated STEM Framework (Moore et al., 2014)	
Tenets	Codes	Tenets	Codes
1. Provide opportunities to be amazed.	AMAZE	1. Motivating and engaging context.	CONTEXT
2. Link content to prior experiences.	LINK	2. Inclusion of mathematics and/or science content.	CONTENT
3. Provide first-hand experiences.	FHE	3. Student-centered pedagogies.	SCPed
4. Encourage discussion and reflections of the social importance of science.	DISS	4. Engineering design challenge or redesign.	EDC
5. Physics appears in application-oriented contexts.	APPL	5. Learning from failure.	FAIL
6. Relating physics to the human body.	HUMAN	6. Emphasis on teamwork and communication.	TWComm
7. Experience physics quantitatively.	QUANT		
8. Include cooperative and collaborative learning to illustrate the social nature of science.	COLL		

Comparative Phase. In order to better answer the research questions, the findings of the student surveys and focus group interviews were compared to one another to create the "big picture" of what happens throughout the first half of a 6th grade students' school year in terms of perceptions. This included not only the comparison between girls' and boys' responses from the focus group interviews, but further examined the relationships that could be made between the results of the quantitative surveys and focus group interviews. By considering the classroom context, this information provides a full understanding of how different instructional strategies may influence middle school students' perceptions of physics and physics-related careers.

The chapter that follows presents the findings of this work, considering the quantitative and qualitative results in light of the classroom context. The theoretical framework discussed in Chapter II provides grounding for the approach to how the classroom activities were examined. This context provides a window in how the findings of survey and focus group interviews might have been affected by the instruction in Ralph and Shana's classrooms.

CHAPTER IV

FINDINGS

This chapter presents the findings of the study. In order to paint a picture of these 6th grade classrooms, the first section provides a narrative of classroom activities, including descriptions of girl-friendly and integrated STEM instructional strategies used. The second section presents the quantitative data found through student surveys. Following these quantitative findings, the next section focuses on the student focus group interview data. This section is broken up by interview round and by gender before discussing the interview findings as a whole. The fourth and final section of this chapter compares, contrasts, and relates the quantitative and qualitative findings given the context of classroom instructional strategies.

The Classroom Context

Both Ralph and Shana's classrooms exhibited elements of both girl-friendly and integrated STEM instructional strategies over the course of the study period. As described in Chapter III, twenty-five observations were conducted in Ralph's classroom and twenty-two in Shana's. Field notes from these observations were coded for instances of girl-friendly and integrated STEM instructional strategies, using the theoretical framework codes presented in Table 3.10. Summaries of the observed lessons are provided below.

First Month of School

For the first six weeks of the school year, both Ralph and Shana spent time guiding their students through scientific inquiry. For Ralph, this included working with real data and laboratory observations, thus students worked on various activities; for example, students designed their own laboratories to compare the absorbency of two brands of paper towels. The paper towel activity also provided students practice using tools such as graduated cylinders to measure volume. This activity asked students to design their own methods and collect the data that would answer the question they wanted to ask. Students had learned about volume using regular solids in their mathematics class the previous year, thus, Ralph expanded upon this knowledge. For instance, he allowed students to use centimeter cube manipulatives to understand that $1cm^3 = 1mL$. This allowed students to calculate the volume of an object using both cm^3 and mL such that students were able to align their prior knowledge to this new knowledge. Further, Ralph related the connection between cm^3 and mL to mass as a way to prepare students to learn about density. Laboratory activities were completed in small groups where students engaged in first-hand experiences to quantitatively interact with physics. Students were encouraged to make mathematical predictions and were often amazed when they were correct, evidence of girl-friendly instructional strategies (Häussler et al., 1998).

In Shana's classroom, there was also an emphasis on learning about the process of scientific inquiry. This included practice taking notes and defining vocabulary associated with these types of experiments (e.g., independent, dependent, and control variables). For example, students tested different ways to make a small paper helicopter. Students, similar to those who participated in Ralph's paper towel activity, were to come up with their own question to test. Shana used a large amount of small group and whole class discussions in order for students to show their understanding and learn from one another. Students were reminded of the importance of documentation with respect to procedures and data, as well as finding ways to clearly present data so as to practice communicating their knowledge with their peers.

Even in the first month of the academic year, Ralph and Shana incorporated girl-friendly instructional strategies in their lessons. Specifically, they focused on providing first-hand experiences and allowed students to interact quantitatively with physics material (Häussler et al., 1998). Additionally, they focused on group work and discussion to encourage students to learn from one another (Newbill & Cennamo, 2008).

Candy Bag Unit

As an introduction to engineering, Ralph and Shana both tasked their students to design and build a candy bag that would hold the most weight; this occurred around Halloween, providing students with context and relevance. Students in both classes worked on an initial prototype after designing and labeling their design. The intention of the initial prototype was for students to get a feel for how these bags could be constructed and to make observations about the weak points of the bag (i.e. where the bag failed/broke). The final prototypes were constructed with the added constraint of a budget to limit their materials. In Shana's class, students selected roles for the assignment (e.g., treasurer, materials manager, and design director) and there was an emphasis on creating goals as part of a class of collaborative learners. These goals were created by individual students to help them reflect on the ways they were going to contribute to their groups.

Though there were roles, Shana emphasized that all students in a given group were to contribute to constructing the candy bag.

In both classrooms, the candy bag activity included time for students to reflect on their designs, focusing on the importance of data and observations. This led to a formal introduction of the engineering design process, engaging students in discussions about the similarities and differences between the processes used by scientists and engineers to solve problems. As with earlier inquiry activities, Shana spent more time explicitly encouraging students to work in groups and practice working with different students in an effort to develop communication and teamwork skills, an influence from the EngrTEAMS summer professional development (Smith, 2014). The strategies used in this unit showed elements of both girl-friendly and integrated STEM instruction, including: first-hand experiences, letting physics appear in application-oriented contexts, collaborative learning, student-centered pedagogies, an engineering design challenge, and development of teamwork and communication (Häussler et al., 1998, Moore et al., 2014b; Newbill & Cennamo, 2008).

Integrated STEM Unit - Flood Rescue Mission

The integrated STEM unit developed by Ralph and Shana as part of the EngrTEAMS project included all of the aspects of the integrated STEM framework used within the summer PD (Moore et al., 2014b). The engineering design challenge for the STEM unit asked students to create a watercraft that could save people during a flood event. In this, students needed to understand maximum capacity in order to “market” their design to the National Guard. The concept of maximum capacity requires an understanding of buoyant forces as well as volume. Thus, students were required to apply that knowledge in order to meet their "client's" needs. The dominant instructional strategy used during this three-week long unit were first-hand experiences, where students worked in groups to understand forces and relate buoyant forces to volume in order to solve an engineering design challenge that required students to understand maximum capacity. Though the curriculum unit was developed collaboratively, Ralph and Shana's implementation was somewhat different, but mostly in terms of the order that ideas and concepts were introduced. For example, while Shana began with the engineering design challenge in order for students to hear from a client (a retired teacher who was in the National Guard), Ralph focused on frontloading the science concepts. A day-by-day breakdown for each Fellow's implementation is presented in Appendix E.

In addition to the slight variations in the order of curricular components, there were some broad-level differences in the approaches of Ralph and Shana. One of the major differences related to the structure of the group work. One important thing to note was that all groups in both classes were single sex; however, groups were created differently. Ralph, who assigned seats at tables by sex, had students work in their table groups. Shana, who normally had her students arranged so there was a balance between boys and girls at tables, asked students to make a list of others they would like to work with as part of their engineering design team. She then rearranged their seating assignments to reflect students' suggestions, which led to single-sex table groups that students worked in throughout the length of the curriculum unit.

Another important difference was the process for initial "materials testing." In Ralph's class, each student in a group chose their role from Boat Designer, Straw Sealer, Keep it Together Crew, and Math Master. Students then worked with others in these same roles to gather information about their task and share ideas with these "content experts" before bringing those ideas to their design group. While these roles also existed in Shana's class, groups remained together to individually collect information about their given role.

Next is a discussion about how the specific integrated STEM strategies (Moore et al., 2014b) used by Ralph and Shana aligned with girl-friendly instructional strategies as described by Häussler et al. (1998), providing examples of alignment between the two frameworks. Table 4.1 provides the overview of this alignment using the girl-friendly tenet numbers of Table 2.1, while descriptions are written in paragraph form below. Appendix E provides a day-by-day summary of the Ralph and Shana's implementations, including the codes presented in Table 3.10.

Motivating and engaging context. The motivating and engaging context that Ralph and Shana used was a flood rescue mission. In the spring of 2014, prior to the summer professional development, various regions in Minnesota had experienced major flooding. This context was real and recent enough for students to relate to. Additionally, Ralph and Shana knew a retired teacher who worked for the National Guard. He acted as the "client" of the design challenge (discussed below in more detail), and appeared in a video message for the students to view in their classroom.

Table 4.1

Overview of STEM Integration Unit and Girl-Friendly Instructional Strategies

STEM Integration Tenet	Brief Description	Why is it Girl-Friendly? (Häussler et al., 1998; Newbill & Cennamo, 2008)
Motiving and Engaging Context	Help the National Guard prepare for floods	1. Provide opportunities to be amazed 2. Link content to prior experiences 4. Encourage discussion and reflections of the social importance of science 5. Allow physics to appear in application-oriented contexts 6. Relate physics to the human body
Mathematics and/or Science Content	Volume, forces, buoyancy, maximum capacity	5. Allow physics to appear in application-oriented contexts 7. Experience physics quantitatively
Student-Centered Pedagogies	Hands-on laboratory experiences, class discussion	1. Provide opportunities to be amazed 2. Link content to prior experiences 3. Provide first-hand experiences 4. Encourage discussion and reflection of the social importance of science 8. Include cooperative and collaborative learning experiences
Engineering Design Challenge	Design a watercraft prototype to use in a flood	4. Encourage discussion and reflection of the social importance of science 5. Allow physics to appear in application-oriented contexts 8. Include cooperative and collaborative learning experiences
Learning from Failure	Initial testing with materials	No clear alignment
Teamwork and Communication	Working in groups, work as a class towards a common goal	4. Encourage discussion and reflection of the social importance of science 8. Include cooperative and collaborative learning experiences

Why is this girl friendly? While the idea of *boats* is frequently viewed as masculine, the context of saving people is something that appeals to all students. The fact that this context touched on five of the key elements in the Häussler et al. (1998) framework indicates that this context is extremely important for not only student learning, but for students to see a relationship between physics, engineering, and society. The five key elements that aligned to girl-friendly instructional strategies (Häussler et al.,

1998) were: 1) providing opportunities to be amazed, 2) linking content to prior experiences, 3) encouraging discussion and reflections of the social importance of science, 4) relating physics to the human body, and 5) allowing physics to appear in application-oriented contexts.

Inclusion of mathematics and/or science content. Since these classrooms were 6th grade science classes, the inclusion of science content was the focus. Because of the specific science content selected, it was also natural to introduce mathematics concepts. In this curricular unit, students learned about volume and forces and how these two ideas can be used together to understand buoyancy and maximum capacity. Many of the laboratory activities had students collect data and, in some cases, make graphs to understand these relationships.

Why is this girl-friendly? The inclusion of both mathematics and science content in this curriculum allowed for physics to appear in application-oriented contexts as well as exposing students to experience physics quantitatively (Häussler et al., 1998). This tight relationship between physics and mathematics with the particular content provided students with meaningful conceptual relationships.

Student-centered pedagogies. The bulk of the learning in this unit occurred through hands-on laboratories and activities in small groups as well as through small group and whole-class discussions. Because of the way that Ralph and Shana set up the engineering design challenge such that each class was competing with another class (i.e. students were not competing within their classes in order to promote a collaborative effort to solving the challenge), discussions were an important part of students' learning where the sharing of *their* ideas were what helped others to learn.

Why is this girl-friendly? The student-centered pedagogies used during the unit included: 1) linking content to prior experiences, 2) providing first-hand experiences, 3) providing opportunities to amaze students, and 4) encouraging discussion and reflection of the social importance of science, and 5) including collaborative experiences (Häussler et al., 1998; Newbill & Cennamo, 2008).

Engineering design or redesign challenge. As part of the motivating and engaging context, students were asked to design and build a watercraft prototype that could be used in a flood. In this, students were allowed to use aluminum foil, regular straws, bubble tea straws, craft sticks, film canisters, hot glue, and duct tape to build these watercrafts. Students were given a budget in order to 1) minimize the amount of waste in the classroom and 2) guide students to critically plan out their design. The goal was for students to be able to build a boat that could hold the maximum capacity as predicted by calculations. This was assigned as a class effort, thus groups within one class period were competing against the other classes; this design was to encourage all students in one class to help one another in an effort to build collaboration, teamwork, and communication. This had the unexpected result of some groups sharing their leftover budget money with their classmates in order to assure a successful watercraft.

At the end of the unit, Ralph and Shana tested each groups' watercraft in a tank of water, filling the watercraft to the predicted maximum capacity using a combination of small weights and figurines. Those that did not sink were counted as successful, while those that sank were counted as failures. Though there was not enough time for students to redesign their watercrafts, students in both classes were tasked with writing a mini-report to send to their client. This report asked students to include data and reasoning as to why their watercraft design should be chosen, adding in any advice that they would consider to improve upon their design.

Why is this girl-friendly? This engineering design challenge provided students with first-hand experiences in an application-oriented context (Häussler et al., 1998). Students were also encouraged to connect their findings to the societal impacts a watercraft design like theirs would have (Häussler et al., 1998). This was emphasized by the use of figurines in the shape of people and animals, that the students could imagine their watercraft rescuing. The collaborative effort that resulted from a cross-class competition allowed students to learn from others in their class, as opposed to putting external pressure on them to be “the best” (Newbill & Cennamo, 2008).

Learning from failure. Students in both classes, though encouraged to succeed in making sure their group’s watercraft did not sink, were told by both Ralph and Shana that failure was a natural and purposeful part of engineering. Thus, students were given the opportunity to work with their given tasks (e.g., Straw Sealer) and talk with their peers about the successes and failures before moving forward with a final design.

Why is this girl-friendly? By allowing students to learn from failure, students were encouraged to discuss their experiences. While this feature is not currently present in the literature on girl-friendly instructional strategies it is present in the STEM integration framework (Moore et al., 2014b).

Emphasis on teamwork and communication. Through the EngrTEAMS professional development, Ralph and Shana learned about the importance of building teamwork in their classrooms as way to ensure successful engineering design challenges (Smith, 2014). In this vein, Ralph and Shana's students worked in small groups throughout the length of the integrated STEM curriculum unit. This teamwork and collaboration was strengthened by the fact that the division of labor honored each group member's responsibility and importance to the group due to the individual roles that Ralph and Shana had created.

Why is this girl friendly? The cooperative and collaborative learning environments that Ralph and Shana created in their classrooms in these groups helped to illustrate the social nature of science (Newbill & Cennamo, 2008). Students were encouraged to rely on their group members, which encouraged discussion and reflection of the social importance of science (Häussler et al., 1998).

My Own Science

Though not observed, it is important to note that before the last round of focus group interviews were conducted, Ralph and Shana both assigned the *My Own Science* project to their students. For the purpose of focus group interviews, this assignment was used as a way to gain insight on students' choices in science class. This assignment started with in-class brainstorming followed by a take-home project. In this assignment, students were asked to pick a project in which they were interested, both with regards to science content and type of project. The science content did not have to be related to anything they were currently learning, but could be any science topic of interest. Students were allowed to choose an activity from the following list: scientific method experiment, engineering design challenge, read a science magazine article, visit a science center/program/seminar, interview a scientist or engineer, or watch an approved science television program. For each activity, students were given a template to complete the assignment. In all, students had two weeks to complete the project after picking out an idea and getting approval from their respective science teacher. Students were allowed to work with other 6th grade students, including students from other classes. Various tools were shared with the students to come up with an idea, such as the website *Science Buddies*.

Quantitative Results

As discussed in Chapter III, the total number of student surveys considered for analysis was 139 students, 64 girls (34 from Ralph's class and 30 from Shana's) and 75 boys (41 from Ralph's class and 34 from Shana's). While the total number of students who completed the survey at least one time was 189 students, the analysis used required that comparisons be made between the same sets of students, thus the only data considered for analysis was data in which there was a complete set for a total of 139 individual students (i.e., all three surveys were completed).

Survey Results by Sex

In order to address the research questions, each survey item was analyzed using a 2-group Mann-Whitney-Wilcoxon rank-sum test (or Mann-Whitney U test) to check for statistical differences between girls' and boys' responses. Tables 4.2, 4.3, and 4.4 display the results of these tests correlating to the first, second, and third administration of the survey, respectively. Due to the relatively small sample size, few items were found to be statistically significantly different between girls and boys below a p-value of .05, thus items found to be significant at the $p<.1$ level were considered for discussion. Since the same students responded to each item, no adjustments to the significance level had to be made. Cohen's-*d* was calculated for statistically significant items in order to measure effect size. Additionally, Cliff's-δ, a more conservative test that does not assume normality, was calculated as a second measure of effect size, due to the ordinal nature of the data.

Table 4.2

Survey 1 Results by Sex

Item	M_{Girls}	M_{Boys}	*U*	*p-value*
1. I like learning about how things work.	2.78	2.93	2083	0.246
2. I am interested in the topics we will be learning in science this year (e.g. particles, light, sound, motion, forces, energy).	2.43	2.60	1981	0.240
3. I like to learn about physics topics outside of school.	1.83	1.90	2261	0.741
4. I would like to have a career where physics plays a role.	1.52	1.74	2037	0.235
5. Science is one of my favorite classes in school this year.	2.24	2.55	1911	0.057~
6. I easily understand physics topics.	2.14	2.18	2341	0.829
7. Learning physics can be helpful in my everyday life.	2.35	2.59	1952	0.083~
8. Anyone can be good at physics.	2.60	2.50	2391	0.661
9. You have to be good at math to understand physics.	2.16	1.92	2565	0.218
10. Physics is just a subject to learn in school.	1.39	1.50	2109	0.400
11. I prefer to work in groups in science class.	3.07	3.11	2268	0.928
12. I like using math to solve science problems.	2.11	2.14	2314	0.923
13. I prefer hands-on activities when learning science.	3.51	3.35	2571	0.319
14. I like participating in class discussions about science.	2.55	2.48	2580	0.420
15. I like when I can relate to the topics we learn in science class.	2.61	2.68	2370	0.896

~ p<.1, *p<.05, **p<.01, ***p<.001

At the beginning of the school year, the results of the survey show that, overall, girls and boys had similar perceptions about physics, physics-related careers, and instructional preferences. The exceptions were the following two items: 5) *Science is one of my favorite classes in school this year* (d = 0.31, δ = 0.25) and 7) *Learning physics can be helpful in my everyday life* (d = 0.28, δ = 0.22). In both cases, girls agreed with these statements significantly less than the boys. While the effect sizes for these two items were found to be small, they indicate that the differences in student responses to these two items have real-world significance (Cohen, 1988). In short, at the beginning of the year, boys preferred science class over girls and were able to see how physics related to their lives.

Table 4.3

Survey 2 Results by Sex

Item	M_{Girls}	M_{Boys}	U	p
1. I like learning about how things work.	2.87	3.03	2139	0.242
2. I am interested in the topics we will be learning in science this year (e.g. particles, light, sound, motion, forces, energy).	2.56	2.71	2200	0.378
3. I like to learn about physics topics outside of school.	1.78	2.04	2001	0.132
4. I would like to have a career where physics plays a role.	1.72	2.03	1998	0.066~
5. Science is one of my favorite classes in school this year.	2.34	2.48	2194	0.367
6. I easily understand physics topics.	2.25	2.45	2043	0.183
7. Learning physics can be helpful in my everyday life.	2.64	2.82	2056	0.154
8. Anyone can be good at physics.	2.56	2.82	2104	0.366
9. You have to be good at math to understand physics.	2.23	2.36	2221	0.430
10. Physics is just a subject to learn in school.	1.73	1.63	2409	0.621
11. I prefer to work in groups in science class.	3.24	3.12	2542	0.312
12. I like using math to solve science problems.	2.19	2.39	2168	0.368
13. I prefer hands-on activities when learning science.	3.52	3.37	2516	0.451
14. I like participating in class discussions about science.	2.67	2.60	2561	0.467
15. I like when I can relate to the topics we learn in science class.	2.73	2.72	2389	0.926

~ p<.1, *p<.05, **p<.01, ***p<.001

After the implementation of the integrated STEM unit, neither of the two items of significance from the first round of surveys remained significant, but another item became statistically significant: 4) *I would like to have a career where physics plays a role* (d = 0.32, δ = 0.23). Again, this item was more agreeable to the boys in these classes. This could be explained by the fact that at that point in the year, students were more familiar with physics or that by introducing engineering as a related field – students, especially boys, could see the relevance in learning physics.

Table 4.4

Survey 3 Results by Sex

Item	M_{Girls}	M_{Boys}	U	p
1. I like learning about how things work.	2.67	2.95	1979	0.057~
2. I am interested in the topics we will be learning in science this year (e.g. particles, light, sound, motion, forces, energy).	2.39	2.60	2123	0.222
3. I like to learn about physics topics outside of school.	1.84	2.07	2138	0.233
4. I would like to have a career where physics plays a role.	1.92	1.99	2231	0.636
5. Science is one of my favorite classes in school this year.	2.10	2.57	1728	0.010**
6. I easily understand physics topics.	2.19	2.41	2078	0.144
7. Learning physics can be helpful in my everyday life.	2.65	2.67	2251	0.822
8. Anyone can be good at physics.	2.63	2.77	2099	0.454
9. You have to be good at math to understand physics.	2.12	2.35	2042	0.109
10. Physics is just a subject to learn in school.	1.56	1.36	2623	0.243
11. I prefer to work in groups in science class.	3.16	3.27	2216	0.481
12. I like using math to solve science problems.	2.21	2.53	1889	0.060~
13. I prefer hands-on activities when learning science.	3.41	3.31	2384	0.638
14. I like participating in class discussions about science.	2.36	2.54	2122	0.267
15. I like when I can relate to the topics we learn in science class.	2.72	2.89	2137	0.242

~ $p<.1$, *$p<.05$, **$p<.01$, ***$p<.001$

Nearly two months after the end of the integrated STEM unit, survey results showed interesting differences with three of the items: 1) *I like learning about how things work* (d = 0.34, δ = 0.24), 5) *Science is one of my favorite classes in school this year* (d = 0.43, δ = 0.35), and 12) *I like using math to solve science problems* (d = 0.33, δ = 0.24). Again, boys were more agreeable to these statements than the girls. In general, the average responses for all three of these items was only slightly more positive than *Neutral*. The results of this third round indicate that at the time of the survey boys still preferred science class over the girls and were interested in learning how things work. The fact that boys started to see a connection between physics and mathematics, and were interested in it, may indicate the level of exposure to mathematics used in their science classrooms.

Survey Results Over Time

Another way to view this data was to view changes over time for both girls and boys in order to address differences and similarities between their two collective perceptions. This required using a Friedman rank-sum test, the non-parametric equivalent to a repeated-measures ANOVA. The effect size (*r*) was also calculated. The results (Table 4.5) for girls' survey responses showed two items that, overtime, girls became more agreeable to. These related to: 4) *I would like to have a career where physics plays a role* and 7) *Learning physics can be helpful in my everyday life*. A post-hoc test using Wilcoxon signed-rank tests with Bonferroni correction showed the significant differences between Survey 1 and 3 ($p<.01$, $r = .28$) for Item 4 and between Survey 1 and 2 ($p<.01$, $r = .25$) and Survey 1 and 3 ($p<.01$, $r = .24$) for Item 7. A third item was also found to be significant in the Friedman test, but post-hoc analysis indicated no differences between survey instances, thus an effect size could not be calculated: 14) *I like participating in class discussions about science*. Again, the effect sizes are small, but indicate real-world significance for these two items. Over time, it seems that exposure to physics in 6th grade allowed girls to see where physics might fit into a career, as well as how physics is relatable to "real-world" things. It is possible that exposure to engineering is somewhat responsible for these changes. However, one must note that even after half of a year in 6th grade physical science, girls were still neutral about wanting to pursue a career involving physics.

Table 4.5

Changes Over Time for Girls Using Friedman Rank-Sum Test

Item	M_{Girls1}	M_{Girls2}	M_{Girls3}	χ^2	*p*
1	2.78	2.87	2.67	1.53	0.464
2	2.43	2.56	2.39	1.44	0.487
3	1.83	1.78	1.84	0.619	0.734
4	1.52	1.72	1.92	11.76	0.003**
5	2.24	2.34	2.10	2.21	0.331
6	2.14	2.25	2.19	1.76	0.415
7	2.35	2.64	2.65	11.70	0.003**
8	2.60	2.56	2.63	2.72	0.257
9	2.16	2.23	2.12	1.04	0.595
10	1.39	1.73	1.56	3.67	0.159
11	3.07	3.24	3.16	1.72	0.424
12	2.11	2.19	2.21	0.695	0.706
13	3.51	3.52	3.41	0.787	0.675
14	2.55	2.67	2.36	7.62	0.022*
15	2.61	2.73	2.72	0.397	0.820

~ p<.1, *p<.05, **p<.01, ***p<.001

Using the Friedman rank-sum test, seven of the survey items were found to significantly change over time for the boys as indicated in Table 4.6. However, after performing the Bonferroni correction, only two of these items were found to be significant such that an effect size could be calculated. These two items showed something rather interesting and unexpected - boys become more interested in the quantitative aspect of physics. That is to say, over time they became more agreeable to the following statements: 9) *You have to be good at math to understand physics*, and 12) *I like using math to solve science problems*. A post-hoc test using Wilcoxon signed-rank tests with Bonferroni correction showed the significant differences between Survey 1 and

3 ($p<.05$, $r = .20$) and Survey 1 and 3 ($p<.01$, $r = .23$) for Item 9 and between Survey 1 and 3 ($p<.01$, $r = .32$) for Item 12. Once more, the effect sizes indicate a level of real-world significance.

Table 4.6

Changes Over Time for Boys Using Friedman Rank-Sum Test

Item	M_{Boys1}	M_{Boys2}	M_{Boys3}	χ^2	*p*
1	2.93	3.03	2.95	1.17	0.558
2	2.60	2.71	2.60	1.67	0.434
3	1.90	2.04	2.07	4.47	0.107
4	1.74	2.03	1.99	6.96	0.031*
5	2.55	2.48	2.57	2.40	0.302
6	2.18	2.45	2.41	6.19	0.045*
7	2.59	2.82	2.67	6.83	0.033*
8	2.50	2.82	2.77	4.60	0.100~
9	1.92	2.36	2.35	9.15	0.010***
10	1.50	1.63	1.36	2.08	0.353
11	3.11	3.12	3.27	2.20	0.332
12	2.14	2.39	2.53	7.60	0.022*
13	3.35	3.37	3.31	0.452	0.798
14	2.48	2.60	2.54	2.41	0.300
15	2.68	2.72	2.89	4.64	0.098~

~ p<.1, *p<.05, **p<.01, ***p<.001

This connection to mathematics was not seen for girls and hints at something concerning that could potentially cause harm as these students complete their K-12 schooling. Even though girl-friendly instructional strategies encourage the use of quantitative methods to relate to physics (Häussler et al., 1998), it appears that boys, more so than girls, see it as *the* way to work with physics. This could cause problems in the future in the sense that girls may adopt this belief, and succumb to the stereotype threat that surrounds mathematics (Spencer, Steele, & Aronson, 1999), thus leading to a loss in confidence in their physics abilities. However, it is somewhat comforting to know that these 6th grade girls do *not* change with respect to their attitude towards the connection between physics and mathematics, remaining more or less neutral about this relationship. Though, overall, these changes are small, the effects sizes indicate that they are not to be ignored. It is possible that over time these differences become greater. In order to understand *why* some of these differences exist, it is important to consider the qualitative findings from the student focus group interviews.

Qualitative Results

The following sections present the findings from each of the two student cases (i.e., girls and boys) in this study; Blue and Orange groups represent the girls from Ralph and Shana's classes, respectively, while the Red and Green groups represent the boys in these two classrooms. Table 4.7 provides an overview of each round of the focus group interviews. Transcripts of each interview were coded to report on the influence of instructional strategies as well as finding the similarities and differences of students' perceptions by sex.

Girls

Round 1. The final themes identified in the first round of interviews centered around three main topics broken down by gender: 1) familiarity with physics, 2) science/physics in school, and 3) science/physics as a career. These students were generally unfamiliar with physics as a separate science discipline and career, thus conversations tended to focus more on science as a whole. Additionally, students were were somewhat unfamiliar with a physics-related or science-related career, which will be addressed in the findings below.

Familiarity with physics. When girls were asked to identify what they thought of when they heard the word physics, eight of the fifteen girls identified physics as

Table 4.7

Overview of Focus Group Interviews

	Purpose	Topics Addressed
Round 1	The purpose of the first round of focus group interviews was to understand students' initial perceptions of physics and physical science as they begin middle school.	1. Familiarity with physics 2. Science and physics in school 3. Science as a career.
Round 2	This second round of interviews was used to understand at a more focused level the "intervention" of the integrated STEM unit and how this might impact students' perceptions of physics and physics-related careers.	1. Integrated STEM unit 2. Revisiting careers in physics and science 3. Working with the boys/girls
Round 3	The final round of interviews was a chance to further understand how student ideas surrounding physics and physics-related careers may have changed over time due to exposure in their classroom.	1. *My Own Science* 2. What about physics now? 3. What about a career in physics? 4. Jobs in general 5. Favorites in science class

something that required experiments or hands-on activities. Samantha explicitly stated, "I think of hands-on experiments. Like, you can do it and you're involved and you're in control of the experiment." Four of the girls in the Orange group agreed with Evelyn and Cass when they shared, "I think of experiments" (Evelyn) and, "Hands-on" (Cass). Somewhat related to this, Zara put forth the idea that physics made her, "…think of scientists, like, the crazy scientists with the big goggles and the hair. And an explosion," much to the likeness of photos of Albert Einstein to which these girls had previously been exposed. Others in the Orange group agreed with this statement, though this stereotypical image was not explicitly discussed in the Blue group. Two students in the Blue group (Lindsey and Alisa) commented that the word physics made them think of gym class in relation the word "physical."

In addition to the broad understanding that physics was something you *do*, Rachel and Megan directly related the word physics to "how the world" works; for example, Megan stated, "I just think of it as, like, everything around me. If I, like, step on the floor

– what happens?” Only Monet thought of numbers, stating, “I think like, you have to add stuff up and you have to subtract it and you have to do all sorts of stuff to get an answer for one problem.” These three girls were the only girls to have expressed a major interest in careers involving science and additionally had family connections to science. Monet mentioned that her uncle studied physics, and Megan shared that her mother had majored in physics in college. Rachel noted on several occasions throughout the three interviews that her father helped her with her science work. The fact that this academic understanding of physics was only apparent in responses from girls who had family connections to the field indicates the influence of the family, but this connection was not explored in the study presented here.

Above and beyond an understanding of physics at large, the Blue group talked at length about their experiences related to astronomy. These included an interactive astronomy experience they had had the previous year and a toy constellation projector that was well-known to the group. This theme of space and astronomy was exciting to the girls, but they did not mention any explicit connection to this field of science and physics during the first round of focus group interviews. Both Megan (who had one of these projectors) and Samantha had even decorated their room with a space theme, though Samantha had since replaced it, stating, “But you know when you have a favorite color, you just kind of get tired of it after a while. It’s kind of like that, but I’m still interested in it. Just not as much as I was.”

Science and physics in school. All fifteen girls were positive about science in school, using words such as fun, exciting, cool, and interesting to describe how they felt.

They identified participating in hands-on activities and experiments as the primary reason why they enjoyed science in school. On the flipside, they identified taking notes and listening to lectures as something they were not keen on. For example:

Evelyn: *Um. So I really, I like science. I always like it more when we do interactive things, like where we get to do experiments and, like, mix things and test things.*

(Orange Group, 1)

Ashlyn: *Some stuff that I don't like…when we just have to sit there cause when I think about science, I always think of fun experiments, like, learning a bunch of stuff about how to do experiments and stuff like that.*

(Orange Group, 1)

Rachel: *So, cause, um, it's really fun if you participate. You…it sticks in your brain if you actually do it. Like, like last year we read from a textbook and took notes. It wasn't really that much fun.*

(Blue Group, 1)

These exemplars of how the girls' generally felt about science in school reflect the fact that their 5th grade science experience was rather limited, as they explained that they watched many demonstrations, but rarely engaged in experiments or other hands-on activities. Because of this, they voiced an interest in "doing science" rather than "learning science" in a traditional manner (i.e., via lecture). Further, the girls discussed in particular that active participation was necessary for hands-on activities to be successful. Despite the fact that their 5th grade science class did not use many experiments, Monet reflected on her experience by talking about one activity they did as a group, "And what was nice about that [activity] was that everyone actually took part in it and no one was left out and no one was doing all of the work."

The need for members of a group to work together, described by Monet was a factor that was discussed at length by both the Blue and Orange groups. While, overall, girls saw the benefits of working with a group (discussed below in more detail), they were frustrated when other students copied off of their notes or otherwise did not participate. Samantha stated, "I'm doing all of the work and they're just, like, sitting there." Lisa had a similar sentiment that many in the Orange group agreed with, "When you have a partner and either they do all of the work and they don't even ask for your opinion and they just write everything down. Or when they're just sitting there and are not helping you at all." This type of commentary only emphasized the importance that these girls placed on collaborative effort when working in a group.

The Blue group commiserated on this topic and explicitly discussed being taken advantage of in the classroom.

Alisa: *So, like, um, I don't like when people, like, um, like when people, like, have to copy off of your notes, and, like, especially when they don't ask you – and then they'll like, just be like, "Ok," just writing down, writing down your notes, cause then you…they get credit for what you do…*

Rachel: *For what you did.*

I: *Mhm.*

Alisa: *Even though you get credit still, but you just want it to be yours.*

I: *Megan?*

Megan: *Yeah, and like sometimes people just come up to us and think that we're brainiacs or something. And they're like, "Oh, you know this, so I'm just gonna, like, do this." Some people don't even do the experiment and they start judging you. "Oh, you put too many drops into the container," and it's like, "We're trying our best…"* (Blue Group, 1)

This excerpt shows how these students want to take ownership of their work, but at the same time, want to make sure it's fair and just. There appears to be a dichotomous response in terms of frustrations when working in a group. These students want a balance in a group where all are participating rather than 1) one student doing all of the work or 2) having someone in the group not participate at all. These girls are interested in facilitating a group that functions well. This aligns very strongly to the integrated STEM framework that emphasizes teamwork and communication (Moore et al., 2014b), as well as the ideas proposed by Newbill and Cennamo (2008). Further, the idea of *learning how to fail* (Moore et al., 2014b) could be applied to the need to learning how to fail within a group.

This idea that a group is beneficial was further endorsed when several girls identified a strength in numbers aspect to learning in science. They saw group work as an opportunity to work with new people and hear different opinions. Further, they saw the value of sharing knowledge in a group, as Brianna stated, "I think it's, like, easier to learn because, like, if you don't know an answer to a question or something, you have someone to help you." Lisa agreed with this, saying, "You get a second opinion and if you do something wrong, that's how you know if you have, like, a question and you're not sure, they can help you."

Cass, Roberta and Ashlyn, though they enjoyed science class, discussed how they could be more interested in science in school, "When science class mixes with things that you like" (Cass). Cass mentioned how, "I hate social studies and so I tried to take books, which I really like, and mix it with social studies to make me like it more. And so, it'd be cool if it would match science." Roberta's sentiment was similar, stating, "If art was mixed in with science, like more drawings and stuff like that, I'd probably be even more interested in it." Ashlyn brought up the idea that if the science experiments done in school were something that she liked, "…maybe I'd want to do it at home and get more into it and do, like, more research on it." These statements allude to the fact that science is not necessarily interesting to all people, but by contextualizing it or combining it with other content, science can be transformed into something more appealing.

Science and physics as a career. Though these initial focus group interviews revealed that these girls were interested in science in school, especially when it comes to *doing science* through hands-on activities and experiments, however, they told a different story when asked what they thought about a career involving science. Initially, the Blue group seemed positive about the idea of a career or job related to science, and the following exchange took place.

Samantha: *Well, I think it would be very interesting.*

I: *You'd think it'd be interesting?*

Samantha: *And I think it'd be fun.*

I: *It would be interesting and fun. Rachel?*

Rachel: *I think it would be cool and it would be fun.*

I: *Cool and fun.*

Monet: *The things that I want to do are, like, mostly science.*

I: *The things you want to do involve mostly science. Okay, we're actually going to talk about that in a little bit if you want to hang onto that thought. Megan?*

Megan: *Like Monet – lots of things connect with science.*

(Blue Group, 1)

It was further revealed that Rachel, Megan, and Monet were somewhat interested in careers related to science. Immediately following this exchange, Alisa shared her dissenting opinion.

Alisa:	*Um, it's not my first choice, but I would do it if I could.*
I:	*Ok, so tell me a little more about that So, it's not your first choice, but you would do it if you could.*
Alisa:	*Like, like, if I had to do it, then I would.*
I:	*Ok.*
Alisa:	*I wouldn't like hate it and dread it.*
I:	*Ok.*
Alisa:	*But I think it's cool.*

(Blue Group, 1)

Alisa's response to the idea of a career related to science, were also reflected in the Orange group. Most common in these responses was of the format: "I think it's <u>[some positive adjective]</u>, but <u>[a reason why I wouldn't pursue it]</u>." Two different types of responses presented in this conversation were: 1) somewhat interested and 2) "I would rather." Table 4.8 shows examples of these variations from the Orange group. When looking across both the Blue and Orange groups, it is apparent that mixed attitudes regarding careers related to science existed for the girls, possibly because they did not know that science-related careers were not limited to being a scientist.

When asked to consider a job or career that specifically included physics, the responses from both groups were not much different from those presented in Table 4.8. Alisa reiterated what she had stated before, admitting, "It wouldn't be my first choice, but

Table 4.8

Interest and Non-Interest in Science-Related Careers for the Orange Group

Stance	Excerpt
Somewhat Interested	Zara: Um, I'm kind of interested in it.
	Brianna: I think it would be fun and I would maybe try it out.
"I would rather…"	Roberta: It'd be more like a hobby, not, like, a job.
	Evelyn: I think it's cool, but it's not really something I would do, like, as a job.
	Cass: Um, I also think it's cool, but I obviously wouldn't do it as a job.
	Raylen: I think it's good, but I would rather be a math…math job.
	Ashlyn: I was kind of going to say the same thing as Evelyn and Cass. I think it's fun and interesting to, you know, learn all of this stuff, but I don't think I would have it as a career.
	Jessica: I think it would be fun, but I would rather be something else.
	Lisa: I think it might be kind of fun, but I don't know. I might do something else.

like, but actually a science career would be my second choice. Yeah." Rachel, who was somewhat interested in a science-related career, also discussed the difference that physics placed on her career aspirations, stating, "I wouldn't go for physics…I would do scientist…I would go for something like, a kind of science area that I like." She had previously identified marine biology as a favorite science field, something that was shared with several of the other girls from both groups, in addition to learning about space and astronomy.

Responses in the Orange group were similar. Cass stated, "Ok, um, I think it would be a good career choice for me, but I've already decided what I want to be." Jessica also mentioned liking the idea of a career related to science, but had something else in mind and said, "I think I would want to be something else." All of the other responses reflected this idea as well, with these girls having specific jobs in mind, such as a doctor, a teacher, a lacrosse player, and a home interior designer. Raylen was the only one in the Orange group who voiced a career that was related to science. She stated, "I think it would be good to do science, but I would rather be a math teacher." Interestingly, was that with the exception of Zara, those who were entertaining the idea of a career in a STEM field were from racial minorities (Brianna, Raylen, Monet, Rachel, and Megan).

Round 2. These conversations took place shortly after Ralph and Shana implemented their EngrTEAMS integrated STEM unit, described earlier in the chapter. Two students were not present for the round 2 focus groups, Alisa from the Blue group and Lisa from the Orange group. These conversations heavily focused on the integrated STEM unit that students had recently participated in, as well as digging deeper into the perceptions these students held about careers related to physics and the sciences in general.

Integrated STEM Unit. After another two months in Ralph and Shana's science classrooms after the Round 1 focus group interviews, these girls continued to talk about their preference and interest in hands-on activities, especially in comparison to traditional learning environments.

Monet: *Um, I like how we did hands-on stuff, cause I don't really like just sitting there for a while. It kind of gets boring.*

Samantha: *Like, you don't pay attention. Cause you kind of space out.*

I: *Ok.*

Megan: *I –*

Lindsey: *It's kind of fun to be, like doing something. Cause if you're just, like, staring at a screen the whole time, you get bored and don't want to do anything.*

(Blue Group, 1)

This exchange in the Blue group was also reflected in the responses of the Orange group. Ashlyn pointed out that the STEM integration unit was different in that students had the opportunity to, "Like actually build stuff. It wasn't just testing. We got to be in groups and, like, interact with other people instead of, like, sitting there taking notes." Megan pointed out, "And like, he [Ralph] like, made stuff that made it like stick in our heads, like that little pink slip, where we, like, cut it and drew a picture and wrote the definition." Even talking a bit outside of hands-on activities, the Blue group discussed how videos in class were only useful, "When they show you stuff. Like, experiments" (Samantha). For example, Ralph used Bill Nye videos to introduce his students to forces and buoyancy, but additionally used a video that he had made to show the relationship between volume and force.

Students in the Blue group talked about the redundancy of writing notes, "Especially when it's the same thing, just in different spots" (Monet). Ralph used a "fill-in-the-blank" type of note-taking style to minimize the writing load students often did. Samantha pointed out, "When I do it – I don't really get the point of it." The Orange group reiterated this, but more specifically pointed out that taking notes, "makes your hand hurt" (Unknown). Ashlyn also talked about the redundancy of notes, pointing out, "I get that we have to so we can look back at it, but I think some of it was just, like, a little too much cause we had to record like, every little thing we did and do, like, a detailed drawing." It is clear that students did not fully understand the purpose of taking notes as part of the engineering design challenge. They did not see these notes as different from traditional class notes, even though the design challenge required that they document their process.

When asked about the engineering design challenge that was part of the integrated STEM unit, students were able to identify what they liked about it and what they struggled with. One of the major benefits identified by the girls was the way in which groups were structured. Monet summed up the Blue group's general statement by stating

> *Monet:* *Um, it was kind of nice that we had people assigned for each [job], like Rachel said. Um, I liked how we all worked together on the project and even if someone said, "Well, I want to glue it here," then everyone said, "Well, why not in the middle here? It'll be stable."*
>
> (Blue Group, 2)

Monet voiced this idea about collaborative learning and engaging in argumentation within a group without it being a competition.

Additionally, both Shana and Ralph's students competed between hours, which was seen as a positive. Rachel stated, "I liked that we were competing with *hours* so we could hear different people's…like, the whole hour's ideas to improve our ideas." The division of jobs was also seen as beneficial.

> *Lindsey:* *Yeah. Um, well, I like how you, like, um, you get to talk with your group with ideas and then you get to actually test it instead of just, like, thinking about it and deciding which one to do and then you just do it. I like how you get to test out different ideas before you choose one so that if you picked a bad one, then you get a chance to, um, like, do a different one.*
>
> (Blue Group, 2)

Samantha followed this up by stating, "And um, it was really helpful, too, so then you know what to do 'cause you only have one chance. And that's kind of like your first chance in seeing how you can improve and make a good boat." Sharing ideas was helpful to these students as, "[Group members] can help if you're struggling with something" (Brianna).

The engineering design challenge was viewed as one in which partners were needed to complete the tasks. Ashlyn pointed out

> *Ashlyn:* *I thought if, like, if I was by myself doing this project, I would have been really lost, like, cause I was gone and, like, my group – they had to fill me in. It was kind of like, a little bit easier to have somebody else there.*
>
> (Orange Group, 2)

Again, this group structure was something that the girls saw as beneficial to their learning, as it provided a venue for them to discuss and reflect upon their findings, building their skills in teamwork and communication.

However, the girls were sensitive to the struggles that were part of this grouping. Because each group member was responsible for being the "expert" for one piece of the watercraft, problems arose when students were absent. Evelyn also brought up

> *Evelyn:* *Sometimes it's just hard to like [Unknown: Cooperate]...because everyone has their own ideas and sometimes it's hard to, like, put them together, when, like, one person wants to do one job another person wants to do the same job. Like, it's kind of hard to figure that kind of stuff out.*
>
> (Orange Group, 2)

The Orange group also discussed how they felt that working is groups is easier when you get to pick them because, as Zara pointed out, "Usually, like, if you pick them, you probably are good working with them." Brianna, for example, was shy, and did not like the idea of being put in a group with new people, so she would be more comfortable working with students with whom she was already familiar. Jessica also addressed working with students who do not want to participate and how this is a hindrance on her learning, "It's kind of hard to work with them and sometimes you kind of try to, like, have them included and, like, they don't want to do it or they don't try as hard." This was something that many of the girls saw as problematic with group work.

Related to problems within group work were issues regarding distractions from other students in the class. Megan discussed

> *Megan:* *And sometimes the group – the other groups – they weren't really focusing. Like, we are actually like in the middle of two, like, guy groups, so like the guys are like laughing and talking about something, like totally off-topic. And these guys are laughing and talking and trying to like, focus…one, like, guy who's trying to focus all of them. And it did work, eventually, but these guys are like being really loud. And we already have a person that's gone, so it's getting distracting and really stressful.*
>
> (Blue Group, 2)

Students identified another area of struggle with the engineering design challenge. Not only were they required to properly calculate the maximum capacity of their watercraft, they also had to create a watercraft that was balanced so that it did not flip over. This was problematic.

> *Megan:* *Um, a lot of the groups had a struggle – even ours – on like keeping it balanced. {I: Mhm. Samantha: Yeah} So, um, like, we didn't really know how to do…like…test it. And he wouldn't let us test it until that day, so it kind of, like, it didn't really give us a good idea of how it was going to work. And like, in the bag challenge – the Mystery Bag Challenge – we got…*
>
> *Rachel:* *Mystery Bag?*
>
> *Megan:* *Yeah. Sorry – Halloween.*
>
> *Unknown:* *Halloween*
>
> *Megan:* *I'm thinking of Language Arts {giggles}. The Halloween bag – we got like do it like once and then test it {I: Mhm} and then it was the real deal. {I: Ok}. So it kind of like got us like a little bit*

scared because if it didn't work, then that would be the only chance we got.

I:	*Right.*
Samantha:	*That's the hard part of the {Megan: Yeah} boat.*
I:	*Of the boat test? Yeah – was not knowing how it was going to work. {Samantha: Mhm}*
Lindsey:	*You only had one chance to um get it right.*
Rachel:	*And our budget.*
Megan:	*Yeah.*

(Blue Group, 2)

Students in Ralph's class did not get to test the balance of their boat outside of the individual task days, and this prevented students from gaining the first-hand experiences they needed in order to learn more about the boat. The budget was also seen as a constraint that forced students to think carefully through their design decisions, but students did not necessarily see the value in this. Students also identified that calculating the maximum capacity of their boat was challenging. Zara, who had previously voiced her affinity for mathematics, stated, "I really like measuring the mass of things, or, like, the volume of things. I didn't really like the math." Other girls in the Orange group agreed that the mathematics was challenging, even though they had had plenty of opportunities to engage with measurements.

Revisiting careers in physics and science. As this conversation occurred after students had been in school for around three months, it was appropriate to revisit what students thought about careers involving physics or science. This theme of careers included two sub-categories. This required gaining an understanding of what students thought people in a science career do on a daily basis and what they thought about the possibility of pursuing a career related physics after having learned more about this field of science in the previous few months.

What do you think people in a science career do? Students were asked about what they thought people in science careers do on a regular basis. Megan, who was very concerned about helping others when it came to science, talked about astronomers and how, "They can't, really, like…they want to help mankind. That's something that I think every one of us wants to do." Lindsey brought in her knowledge of school, saying that if she was a scientist, "I would probably have to, like, study and remind myself of what I already knew." The Blue group was clear in stating that they did not think about scientists in a completely stereotypical way, as evidence by the following exchange between Megan and Samantha.

> *Megan:* *And it's not just like a scientist who wears a lab coat and goes in, wears a pair of goggles and starts mixing all these chemicals….*
>
> *Samantha:* *That's what I used to think of as a scientist. [noises of agreement from others]*
>
> *Megan:* *Yeah yeah – that's what I used to think, but then like, when you do actually some research and stuff, you can like realize that people are actually risking their lives so that you know more stuff.* (Blue Group, 2)

Megan also spoke directly about "risking lives" in terms of scientists who learn about alligators, alluding to the importance of scientists. Though never discussed in the Blue group, the girls in the Orange group identified science careers as being a difficult and demanding career.

> *Roberta:* *Well, that there's a lot of thinking.*

Evelyn: *It's hard. Just because, like, say, you're an engineer. There's so much things that you have to calculate, look at, and you can't just, like, do something – you have to, like, work up to it. Like, you can't just start right away. You have to, like, kind of almost study.*

Zara: *And you have to get it right because people are kind of counting on you to get it right.*

Raylen: *It's like a test. Just like it.*

(Orange Group, 2)

This excerpt shows how there remains a perception that science is difficult. Moreover, these girls imply that scientists are under a strong demand from some external source (perhaps the general public or society as a whole) and these are pressures that may not be appealing to them. While there had been plenty emphasis on the fact that science in school required the use of first-hand experiences, this idea did not necessarily translate into what one in a science career does on a regular basis. However, there was a general understanding that engineers are the ones who get to do the fun part of building and testing, as simply summarized by Rachel, who stated, "I also like engineering a lot. It's fun." The introduction to engineering through the integrated STEM unit may have had some influence on perceptions about science-related careers in general.

What science careers need. Students in the Blue group focused on being able to see a realistic, real-world application of science content. Monet related this to things that Ralph did in the classroom that helped her understand why they did certain activities.

Monet: *Um, I like it more when we do our topics, like, if he actually talks about what we would do with it. Not just tell us, "We're going to build a boat now." Like, tell us, like, "You could be an engineer and build boats and houses," and like, actually explains what we could do with it.*

(Blue Group, 2)

Samantha acknowledged that in class they were exposed to context, but further explained, "Um, something that is, like, more realistic, more…like, you know. And maybe more experiments and maybe try to come up with something else and maybe make that something. Well, kind of like we usually do, though, except make it more realistic." Megan pushed this further and commented

> *Megan:* *So it's like, if we could like make a difference. Like, maybe like, people that like make medicine for people that are ill instead of just making Halloween bags and like, like pretend boats trying to float around. Maybe something that's actually real. So we can get somewhere?*
>
> (Blue Group, 2)

Megan's comment is related to her earlier comment about how, in general, people want to help mankind. She sees some alignment between scientists and helping society, but the connection is not fully supported by what she sees in her science classes.

Similar to the discussion about group work, Zara pointed out that she would be interested in a science career if, "…maybe one of my friends would be doing it or someone that I knew that, like…would…that I could work with." Raylen reflected what was discussed in Round 1, pointing out, "I would probably like it if I liked it more than other things." Evelyn and Ashlyn both addressed that they would not like to take notes, but would like to build things, and Roberta mirrored this opinion by stating, "Like, less writing than working." Cass opened up this statement more by explicitly stating that she thought scientists took notes as a main part of their job because, "It's what we do here, so I figure, 'Well, it has to transfer cause we're transferring into 7th and 8th grade and if you're going to take engineering science – you'll have to take notes eventually.'" Here, Cass referred to traditional class notes as something that she did not find appealing.

The lack of understanding that scientists help people and society at large and that their job is not simply to take notes shows that stereotypes of scientists influence girls' perceptions of the field. The idea of having a purpose or motivating context, or as Megan pointed out it, "If we could, like, made a difference," suggests that including engineering is a potential way to overcome this barrier. Unfortunately, at the time of the Round 2 interviews, it was not entirely clear whether or not the watercraft challenge was an engaging enough context. Samantha and Megan's comments indicate that they wanted more from the provided context. It is possible that by including more direct links to the social importance of science/physics, these girls might change their attitudes.

Working with the other gender. When asked about how they feel about working with the boys in their science class, the general consensus was that it was not seen as positive as, "They can sometimes not be on track" (Samantha) and, "I think they have a short attention span" (Roberta). However, the girls acknowledged that, "It kinds depends on, like, on who you're working with" (Zara). In fact, it seemed that these girls had a very deep understanding of the social inner-workings as exemplified by Monet's comments.

> *Monet:* *I don't really mind, like, working with boys, but like, when they're with their friends, that's a different story. [others agree]*
>
> *I:* *Ah.*
>
> *Monet:* *Yeah, like, I'm not denying that I wouldn't be like that [others agree] but I don't have like my bestest, bestest friends that I always talk to.*
>
> (Blue Group, 2)

This awareness reflects how students in the Blue and Orange groups talked about the group work in the integrated STEM curricular unit.

Round 3. The third and final round of focus group interviews occurred two weeks after students' winter break. These interviews were to ask once more about students' thoughts about physics and physics-related careers.

My Own Science. As described above, students in both Ralph and Shana's classes were given the *My Own Science* assignment as a way to allow students to explore a science topic they were interested in and do it in a way aligned to their learning preferences. Appendix F provides short descriptions of each student's chosen project as well as the particular science content. Overall, students in the Blue and Orange group were positive about the assignment and everyone did a hands-on project of some sort. In several instances, students chose "science-like" activities; many of these aligned to stereotypical female roles. For instance, Megan was interested in cooking, and from the website Ralph had offered as an aid in choosing an idea, decided to do a project which included measuring how much sugar different types of fruit had. In another instance, Evelyn and Ashlyn, who worked together on the assignment, made a paper mache volanco, simply because it was something they had seen on television and were curious about how it worked. Many of the activities, though they included a scientific method in the sense that variables were changed, did not necessarily promote scientific learning since students did not learn or apply a specific science concept.

In several cases, students described engineering projects but spoke about them as if they were scientific investigations. Raylen and Samantha both did egg drop experiments, identifying them as a scientific method experiment, but this was really engineering. Brianna talked about sewing mittens into a jacket as an engineering design challenge, but this seemed devoid of any science or engineering content. As engineering design processes were new to students as of this school year, it is possible that they were merely unfamiliar with what to call engineering.

What about physics now? When asked to once more consider the word physics and what this conjured up in students' minds, the responses were somewhat more sophisticated than what was originally stated in the first round of focus interviews. Students in the Blue group suggested that physics made them think of science, but specifically, "Beakers and, like, chemicals and stuff" (Monet). This distinction between *science* and *physics* is explored further below. Rachel's response was of a similar vein, "When I hear the word physics, um, I think of stuff…like blowing stuff up for some reason. I don't know why. I just think of blowing stuff up." Megan and Lindsey both relied on their experience in class to note that physics needed to be precise and included testing.

The Orange group reiterated their initial ideas that physics is hands-on, but in the sense that beyond, "doing a bunch of tests and, like, hands-on stuff" (Ashlyn) and, "Um, maybe like math and experiments" (Jessica), physics is related to the stereotype image. Evelyn and Zara explicitly shared:

Evelyn:	*Um…I don't…I don't really think when I hear it, I don't think of experiments. I think of experiments, but not as much as engineering. Like, sciencey…like chemicals…that kind of stuff.*
I:	*Zara?*
Zara:	*I think of like energy and speed and [Cass: [whispers] velocity] yeah, and velocity. Kind of like, sometimes experiments, but like it's kind of like a stereotype, kind of.*

(Orange Group, 3)

Brianna also mentioned that physics is, “Um, like, mixing chemicals together.” While in general, these girls did not seem to indicate that physics (or any science for that matter) is limited by gender, they still maintained the notion that *science* is that stereotypical image, that is, that science is represented by a lab you would typically associate with a chemistry lab. Specifically, physics was related to chemistry in their minds, but not so much directly related to engineering. What is most fascinating was that throughout the time of all of the three interviews, neither Ralph nor Shana had done anything that hinted at “mixing chemicals together” as one might expect in a chemistry course.

What about a career involving physics? This idea that chemistry is highly related to physics was further examined when students once more were asked to consider careers involving physics. Students in the Blue group identified a few careers that would involve physics, such as chemistry, astronomy, and medicine. In particular, Lindsey noted, “Well, I just like…I hear about chemistry a lot and I’m just thinking, ‘One of these days, we’re going to learn about it.’ And it’s just like glued into my mind.” Rachel, expanding on the idea from Round 2 that a career in science needed to help people, was explicit and said, “I think of people who like, create new stuff that, like, helps us, like, I don’t know why they need to like, know how to, like, calculate right, so I just think of inventors.” Alisa and Monet were still unsure about what they thought of a career involving physics as they were still learning about the topic. Samantha agreed with this, but also offered that people who have careers in physics must have some connection to experiments.

Cass, who had previously mentioned that a career involving physics might be a good fit for her reiterated her feelings, “I’m more interested in it than I was before, but

I'm still stuck on the same topic that I was before. I want to be a massage therapist." Zara, who often talked about her love of math, confessed that physics may not be the correct venue for her to pursue.

> *Zara:* *I mean, I don't really know. I feel like I want to have a job that includes, like, math because I actually really enjoy math. And I mean, some science can have math in it. And, er, at least most science can. But I don't really know if science is like the…I don't know the word for it…like category that I want to go into?*
> (Orange Group, 3)

Though students in both Ralph and Shana's classes had had plenty of opportunities to work with mathematics in a science context, it is possible that the type of mathematics used in science classes was not the type of mathematics that was appealing to students.

Jobs in general. In addition to learning about physics-related careers, these girls revealed what is important to them when considering a job in general. Megan, Monet, Alisa, and Samantha all discussed that specifically the careers they were interested in (pediatrician, psychologist, therapist, and therapist, respectively) were ones that *directly* helped people with their problems. Megan, Alisa, and Samantha were specifically interested in working with kids or teens.

> *Megan:* *Um, become a pediatrician. Um, because, well, first of all, I love kids like us. Like, if you have a kid, you'll know more, but like sometimes when you grow up, you kind of, like, the kid doesn't understand what you're talking about, so like, my goal is to try to make the kid understand, like, what's happening to them as well.*
> (Blue Group, 3)

> *Samantha:* *I kind of like what you said, like helping kids. Maybe like a therapist, cause I kind of went though, maybe some of what they've been through.*
> (Blue Group, 3)

> *Alisa:* *I don't know why, but I've always wanted to kind of be a therapist for kids and teens, like mostly teens. I don't know, it's just like….I've just like…I dunno. I think I just kind of connect with,*

like, teenagers.

(Blue Group, 3)

The fact that these students were interested in working with others who were their same age somewhat shows the egocentric model that students at this age still function by, according to Piaget's theories.

These students also shared aspects of jobs that were important to them. More importantly, they shared that they were *not* necessarily interested in jobs that pays well, but one that would be intrinsically satisfying. They were overly concerned with suffering from being selfishly rich, "…cause you'll get cocky" (Zara). For example, Samantha pointed out

> *Samantha:* *I'm kind of like them [other students]. I'd like a decent amount of money to, like, actually help me through life, but not so much money that like [Megan: I'm rich!] ...where, yeah, you're kind of selfish and you don't really care about anyone else. And I'd like a job that I like and that I could, um, work for as long as I like until I retire or something.*

(Blue Group, 3)

In short, girls from the Blue group were more interested in finding jobs that would not leave them dreading their jobs. Megan pointed out, "Well, I'd like of like a little money, but not because, like…let's say I had a family. I still need to work for them – I'd be like so ok with not, like, getting paid and doing something I love." Someone (unknown) commented in response, "That's what everyone wants to do," addressing this need for an intrinsically satisfying job. Rachel also mentioned being treated nicely as something that was important to her. Lindsey remarked at having an exciting job, "I would want a job that I would like – something that, like, I'm excited for. Whether it's at the beginning or end of the day, I want something to look up to, to be excited for and have fun." It is clear that this belief about jobs and personal satisfaction is something that excites girls about their futures, and it is somewhat clear that they do not believe a career involving physics would fit this role.

The Orange group was similar in this regard. These girls were not interested in making lots of money but more interested in, according to Cass, "I want a job that'll give me money and will keep me in an area around my family." They were very much of the mindset of being able to support a family, but not be rich. Being close to the family, whether the term family referred to their future family and their current familial situation, was important. Zara summed it up the best by saying

> *Zara:* *I want to be able to, like, have a…not that I enjoy it…I kind of want to work with, like, maybe children or otherwise math. And I kind of want to be in like – it doesn't have to be in Minnesota particularly, but somewhere in the United States where, like, I can get enough money to support my family. And yeah. And a job that I enjoy, not one that I do because I have to.*
>
> (Orange Group, 3)

This reflects the opinions of the Blue group as well in the sense that there is a strong emphasis on the intrinsic satisfaction with a given career path. Though being close to family was important, traveling as part of a job that was appealing to some. Samantha voiced

> *Samantha:* *Another job that I'd like to do is kind of like travel. Since now I've been a lot of places in life – we travel a lot – maybe I could be, like, study plants or something and kind of travel everywhere, which I think I'd like. [I: Mhm] Or do like fun hikes and kind of like study things while you're on the hike.*
>
> (Blue Group, 3)

Zara also pointed out her interest in being in a job that will continue to challenge her to work on a variety of different tasks. The final exchange presented here on this topic between Zara and Ashlyn presents another belief about the nature of jobs in general.

Zara: *I kind of want to be someone, like, who like, their job, like, it's not like their working on one thing the whole time, like your job kind of like changes every once in a while. [I: Mhm] And I mean, I guess in science it's like that because you're going from like this experiment or thing to another, so it's like that. So, it's not like you're doing this one thing and like, doing one things – it's like a variety of different things that you're doing.*

Ashlyn: *I want a job where it doesn't, like, take up your entire day. [Zara: Mhm, yeah]. Like, if you started at like 6 and then get home at like 7 or 6, then I wouldn't want a job that would…*

Zara: *Yeah, I wouldn't either. That's a job for the dad to do. [others giggle at this]*

(Orange Group, 3)

This exchange likely reflects Zara and Ashlyn's own experiences. The fact that Zara's closing statement here elicits laughter from the other girls in the Orange group implies a belief that men are the breadwinners in a family, expected to work long hours.

Favorites in science class. When asked to evaluate their science course in terms of what they enjoyed the most, the majority of girls commented that the watercraft engineering design challenge and the *My Own Science* project were among their favorite. In short these were the favorite activities, "because last year in 5th grade the teacher just did them [experiments] in front of us" (Alisa) and, "because it was a lot of hands-on stuff that we did with that and it's not like writing notes the whole time" (Monet). The integrated STEM unit in particular was a favorite because of the tasks associated with it. For instance, Rachel pointed out, "It was very fun and we had a chance…it felt like we could actually do something." Here, she referred to the context of the watercraft challenge. She also pointed out the fact that she liked the competition between hours as opposed to between groups in the same class; she and her team members had benefitted from this when they used up their budget and needed more materials. Megan and Lindsey noted, “And there’s a lot to think about” (Lindsey), specifically, “We thought about the budget and what we’d get that’s really important” (Megan). Samantha enjoyed the fact that they were able to see whether their engineered designs would work in both the integrated STEM unit and the Candy Bag unit. Ashlyn noted that the boat design challenge was easier to do because it was in school. Lisa and Roberta also enjoyed the engineering design challenge.

The *My Own Science* project was popular because, “we had a lot more freedom” (Evelyn). Cass pointed out

> *Cass:* *I like My Own Science because you can pick a topic that interests you and do an experiment or create something or do something related to this topic and you still have…you still have to do this format sheet, but still, you get to do what you want.*
>
> (Orange Group, 3)

Additionally, students favored the fact that they were allowed to pick their own groups for the *My Own Science* project, though some students worked alone on this assignment. Brianna also brought up the fact that they had plenty of time to complete the assignment (two weeks).

The Blue group mentioned the boat challenge more than the *My Own Science* project likely due to the fact that they had not yet completed the project and were in the process of planning their project at the time of the focus group interviews. While this may be slightly limiting, their responses about the integrated STEM unit provide information about why these types of first-hand experiences are important – they challenge students and give them real data to reflect upon in a realistic context.

Comparison between all Three Rounds. The three rounds of interviews, when considered as a whole, tell the narrative of 6th grade girls’ experiences and perceptions of physics and science. The following list describes what instructional strategies impact the way girls perceive science in their classes. These claims will be explored further in Chapter V.

- First-hand experiences are important and engaging for girls, but are especially important when there is a bigger connection (i.e. a motivating context or a reason for doing things). This allows students to see applications of physics and how what they like to do in science class could potentially translate into a career worth pursuing. Traditional learning (in the form of notes) may be transformed into a more beneficial role if purpose is given. When a clear purpose is not made apparent, students end up bored or unmotivated in learning.
- Developing teamwork in a meaningful way helps students self-direct their own learning. Unfortunately, creating groups can be challenging for a teacher, but meaningful grouping is the way in which students can feel a part of the class. It gives them value within their group and allows them to feel as though their contribution to the group is necessary; they see active participation as necessary. Girls value this in their work, though are troubled when it is unclear what role they are to take in this work. By modeling for students that science and STEM fields are collaborative in this nature, it is possible that students will begin to see these fields as a non-isolated career.
- These students value "doing science" but do not necessarily see themselves as "being a scientist," even when conducting laboratories in class. This is further

evidenced by the fact that students were unsure of whether scientists perform experiments at all beyond the stereotypical scientist activities. Additionally, these girls were not familiar with the concept of careers that relate to or involve science.

- In 6th grade, girls are interested in careers that 1) directly help people and 2) are intrinsically satisfying. While there is some understanding that physicists and scientists help society at large, girls do not see a connection to helping people. It is possible that their career interests are more aligned with helping people *with their problems*, which is something that is difficult to see when considering careers in or involving science. The idea that taking care of a family and close proximity to that family was important to girls reflects a traditional gender role belief.

Boys

Round 1. As with the girls, this first round of interviews took place shortly after students completed the first survey towards the beginning of the school year.

Familiarity with physics. More frequently than the girls, the boys in the Red and Green groups associated physics with specific science concepts, such as gravity, motion, lights, engineering, forces, electricity, and atoms. Additionally, systems-thinking was discussed as something of interest to George.

George: *I think of, like, lights and engineering again. I also think of, um, I don't know the word is, but something where if you hit one thing it will make something else go.*

I: *Ok.*

Preston: *Like the domino effect?*

George: *And make something else move – like the domino effect.*
(Red Group, 1)

This is both similar and different to the way that the girls initially discussed physics in that while thinking of how the world works, George was more specific in talking about interactions within a system. Similar to the girls, these boys also related physics to being physical.

Preston: *I think of Einstein, but when I'm not thinking of physical science, I think of, like, being physical.*

I: *Ok. Being physical.*

Preston: *Yeah.*

I: *Like, like gym class? So that kind of relates to your saying you want to be a soccer player, almost.*

Jose: *I was going to say that, too, right now.*
(Red Group, 1)

Donovan from the Green group also thought of gym class, relating the actual word of physics to physical activity or physical education. Frank and John mentioned, "Matter. Atoms. That kind of stuff," and, "Electricity and atoms," respectively. Jimmy mentioned, "I like learning how things work sometimes," after saying that physics is exciting.

Science and physics in school. The Red and Green groups, unlike the Blue and Orange (girl) groups, had slightly different opinions on science in school. In general, they were not as eager and excited about science class as their female counterparts, but were extremely specific about liking science because of experiments. Boys from the Red group commented,

Robbie: *I like it.*

I: *Robbie, you like it? [pause] You have another?*

George: *Fun and…I like experiments. [nods from other boys]*

I: *Ok, fun and you like experiments. Robbie, you agree with that?*

Robbie: *Yeah.*

I: *Thomas? You kind of second that?*

Thomas: *Yeah, same.*

(Red Group, 1)

This idea of interacting with materials was shared by the Green group, and as Frank summarized, "It's ok – experiments make it a lot better." Preston made it clear, though, that his investment in science class was related to, "doing stuff with chemicals," despite the fact that their school science experience lacked anything with chemicals. Lloyd reinforced this idea by stating, "I kind of like the class, but I really like the experiments." Both Jimmy and John commented that their attitudes about their science class depended on the day and the content they were learning. Jimmy in particular was interested in, "Building miniature models of things." Further, there was an interest in the "wow" factor of science. Nate, who thought science in school was "a little boring," stated, "Um, I like experiments where, like, there might be blowing stuff up." There was a mischievous attitude towards science in school as well, as Preston shared, "And I wanna see how the shower-thing works," bringing up a fascination with the chemical spill station.

Similar to the girls, the boys valued the first-hand experiences they gained from participating in science class. George specifically noted his interest in variable testing, stating, "I like to do stuff where, um, in an experiment where it's one against the other. Not so much to see if it, like, works, but one against the other." Preston confirmed this interest in hands-on activities, “I like...I like doing stuff with my hands. Like doing experiments where, like, you have to use your hands to like move the stuff around.” They also shared a specific interest in electricity. Thomas stated, “Well, in 4th grade, I liked doing things with, like, circuits and stuff.” George and Jose also liked electricity.

In addition to an interest in first-hand experiences, the boys noted the freedom often associated with experiments. For instance, George commented. “I like, uh, when we get to come up with our own experiments, not necessarily like he [Ralph] gives them – those experiments.” Frank also experienced that same feeling in Shana’s classroom, stating, “It’s not like you’re listening to someone say, ‘Do this, do this, do this.’ ‘These are the guidelines, do what you want with it.’” Joe pointed out that these activities allowed one to, “get more involved in it,” through measuring. Jimmy, who agreed with this, stated, “Sometimes you can’t really learn unless you, like, try it for yourself.”

At the time of the Red group’s interview, Ralph had assigned students to design an experiment of their own to develop their knowledge and understanding of scientific inquiry. The boys in the Red group discussed this excitedly, sharing their ideas to create a system that would do things like charge a phone or power an MP3 player. George shared his idea for the project.

George: *Ah…bl bl bl…oh, yeah! In science we get to make an experiment on our own…*

I: *Oh, ok!*

George: *…that’s due October 6. And me and my friend – we’re going to do, um, we’re going to see if, um, take a bowl of water, pour ice cold water into it…*

I: *Mhm.*

George:	*…with ice cubes. Salt. Um, and then put a watermelon in it and it can charge your phone.*
I:	*Wow. [positive responses from others]*
George:	*If it works. We're going to see if it works with salt and without salt.*
I:	*Ok.*
George:	*You're supposed to have salt, but it's an experiment.*
Preston:	*Wait, what are you doing?*
George:	*We're going to see if a watermelon can charge your phone when it's in a bowl of ice cold water.*
Robbie:	*That sounds really cool.*
George:	*It works – hopefully.*

(Red Group, 1)

Thomas then shared his idea of a similar experiment to use Gatorade and an onion to power an MP3 player. They were able to relate this to a previous conversation about renewable energy sources, stating, "Now we know what to do if, uh, the power runs out" (George). This fascination with electricity and circuits reflects Thomas' earlier intrigue with this topic.

Counter to enjoying hands-on activities, these boys very much did not like taking notes or, "long, boring lectures. On stuff you already know" (Frank). As Jose simply put it, "Anything that doesn't include, like, doesn't include…chemicals. Or something like that…experiments," was not interesting in science class. Specifically he named vocabulary and reading articles as activities that were not appealing. Jimmy further related this to sitting in a lecture, "Yeah, I can't focus, if, um, something kind of boring. I mean, I can focus for a while, but then I start blanking out and I miss directions." Nate agreed with this. Taking notes and studying were also not prized learning venues. Unsurprising, this meant tests were not valued either. There was a particular emphasis on avoiding repetition in class. George expanded on this to relate once again to hands-on experiments, stating, "I don't like writing, like, I'm a visual [learner]…I like to see what's going on. And I like to see what he's [Ralph] doing. What's really going on, so I'm one of those people." Preston agreed that he was also a visual learner.

Jimmy, who was rather outspoken about having the opportunity for hands-on experiences, stated, "I like to learn, but sometimes when people are messing around, I think maybe they should get, maybe like three warnings instead of, like, a lot of different ones because it distracts time from my learning." These "disruptive people" (Felix) were distractions for students who wanted to learn in class.

The boys somewhat valued working in groups, but only when all participants were cooperative. Preston stated, "Like, when we work in groups on an experiment, like, that you get to, like, help with stuff, so that way you don't, like, just do everything and then, yeah…." Groups were seen as a way to deal with a heavy load of tasks to complete. Only Frank mentioned the cooperative learning that takes place in groups, stating, "Like, if you're wrong and you're by yourself, then there's no one to say, 'No, I think it's this.'"

The Green group saw group work as another opportunity to collaborate with their peers, but similar to the girl groups, were slightly possessive about their work. Donovan mentioned he did not like when other students copied his notes. In a similar manner, Jimmy mentioned, "It's like, I'm trying…or just, they're just copying my work. It's like, sometimes I actually work better alone than I do with somebody who's going to mess my…mess me up…keep me from working." Frank, who clearly enjoyed working in groups, pointed out, "I like group projects because even if you are doing all of the work and you get a bad grade, it's not all your fault." Frank was clearly aware that there was an accountability that took place within a group. Several boys seemed to prefer working by themselves, and as Joe put it, "I'm an independent worker." John also enjoyed working alone in science class, pointing out, "I would prefer to work independently," because, "Well, I just really don't like to work in groups." Donovan also preferred working alone.

Science and physics as a career. When asked about pursuing a career involving science in general, boys' responses reflected how they felt about science in school and, overall, they shared the same general attitudes that girls shared in that there were not very interested in pursuing careers related to science. However, the boys offered something that was not present in the girls' interviews; they offered a "back-up" to science in the name of engineering. For example, George commented,

> *George:* *If anything, I wouldn't want to go in…necessarily into a science field, but if I would do it, I would probably want to be an engineer.*
>
> *I:* *You'd want to be an engineer, George?*
>
> *George:* *I like movements and engines and stuff like that.*
>
> *I:* *Ok.*
>
> *George:* *And stuff where you have to do stuff and other stuff works.*
>
> (Red Group, 1)

Robbie agreed with this sentiment, but Preston, who had already confessed his interest in chemistry voiced an interest in being a chemist only, "If I had to." Table 4.9 summarizes the comments about commitment to a science career. Four of the boys were already considering engineering as a field of interest to some extent. Unlike the girls, the boys were less inclined to say that a career involving science would be worth considering, unless it was engineering.

Table 4.9

Interest and Non-Interest in Science-Related Careers for Red and Green Groups

Interest Level	Excerpt
Some interest	John: I always wanted to be an engineer since I was, like, 6.
	Joe: Probably like an engineer or something.
	Jimmy: I might – I have different things I might want to be. One of them would be a therapist.
	Thomas: I find, like, the astronomy stuff cool. I mean, if I do it, I'd probably do that.
If I had to…	George: And I wouldn't want to go into a science field. I'm just not a fan – I like science, but not, like, as a career. If I were to go into a science field, I would definitely be an engineer.
	Robbie: Yeah, the same [as George]. I don't really want to be a scientist, but if I had to, I would choose engineering.
	Frank: I wouldn't do it like a scientist, but I would incorporate it into something else. Like being a doctor or something like that.
Not at all interested	Lloyd: I'm probably not going to do anything that involves science.
	Donovan: Um. I'm not interested.
	Felix: I wouldn't want to be anything in science.
	Nate: Probably nothing science.

When asked about interest in careers related to physics specifically, the boys who participated in focus group interviews not only were able to identify careers that related to physics, but also chemistry. One idea that was shared was the idea of being an "inventor" as representative of what a physicist is; it is not necessarily the same as an engineer. When asked to discuss this to greater detail, Jose and George discussed their desire to create inventions that help people.

Jose: *I don't know…like, inventions that work to, like, help people and stuff like that.*

I: *Inventions that help people. Ok.*

George: *Um…*

Preston: *Yeah, I forgot about that and I would like to do that. Like…*

George: *If I were an inventor, I would want to invent stuff that would help us from stop using fossil fuels.*

I: *Ok.*

Robbie: *And just use those for, like, emergencies.*

(Red Group, 1)

While there was not a direct connection to physics, the boys in the Red group were able to identify a desire to be in a science field that would help society and the environment. The Red group shared that they had had some experience in learning about renewable energy sources in 5th grade. Though going into a science career was something that the boys were not necessarily excited about, they were clearly interested in related fields. Though Jose talked about being an inventor, it is not entirely clear if he meant an engineer; it is possible that the lack of exposure to this field is part of the reason why he does not use this terminology. The Green group was more open about their non-desire to pursue careers involving physics. Nate reiterated, "Um, science just isn't that interesting to me. As, like, a whole." The other boys in this group were additionally not very interested in a career that related to physics.

Round 2. All of the boys from the Red and Green groups were present for the second round of focus group interviews, which occurred shortly after the end of the integrated STEM unit.

Integrated STEM unit. Students in the Red and Green groups discussed how the integrated STEM experience allowed them to continue doing the things they were interested in when it came to science learning. Jose, who had previously mentioned his interest in being an inventor commented, “Well, we…we get to, like, do something that’s like inventing or making stuff, so that’s the part I like.” George enjoyed being able to relate buoyancy to a personal experience, swimming.

> *George:* *I liked how he [Ralph], um, explained it like, like, we would think of it like jumping into a pool. As we go down, the water goes up. It’s cool to think about that because I swim a lot. So it was cool to think about it that way. And then I realized – and then I really thought about it, and then I was like, “Oh, I already knew all of this!”*
>
> (Red Group, 2)

Preston and Robbie were specifically interested in the way that they were able to test their watercraft after mathematically predicting how much they would hold before they sank. This experience also replaced, as Thomas pointed out, writing notes down. Further, students discussed how the experience they had with hands-on activities offered them something they do not gain from reading. For example:

> *George:* *I like working…I’m like of like what Preston said – I like hands-on because it’s visual and I like to see how it works so that I know how it works, where like reading and stuff – I could be thinking what it would look like, but I wouldn’t really know for sure. And I could be thinking something way wrong.*
>
> (Red Group, 2)
>
> *Jose:* *Well, with, like, hands-on you see, yeah, it’s like…I don’t like, well, I do like, it’s just kind of boring, like, reading articles and figuring out stuff like that.*
>
> (Red Group, 2)
>
> *Robbie:* *My favorite thing about doing the hands-on is because they’re fun.*
>
> (Red Group, 2)

Jimmy from the Green group noted of the integrated STEM experience, “It was kind of cool because we got to work with other people, but also, we got to hear others’ ideas at the same time. We also got to design. Like, we got to be an engineering ourselves.” John, the only student who was explicitly interested in pursuing an engineering career, reiterated, “I’ve always been interested in that stuff ever since I was, like, 4.” One important thing to note was that this STEM integration unit was the first time that these students had been formally introduced to engineering in school, and it was well received.

While overall, students were positive about their integrated STEM experience, they found there were some challenges. For example, while students were to create a watercraft and mathematically figure out its maximum capacity, they struggled to balance the craft, as Preston noted.

> *Preston:* *One thing I didn’t like – my boat wasn’t – we didn’t have them, but the film canister. How they only had a lid on one side. And then a lot of boats were, like, tipping and since we couldn’t put our boats in the water and see what was wrong – that was kind of hard.*
>
> (Red Group, 2)

Thomas was disappointed, “That we didn’t have enough time to make a full version of it – we just built a prototype,” and that he and his team ran out of money; Jimmy and Donovan also had issues with the budget. Donovan was also frustrated that, “All we did was some tin-foil stuff,” adding to Thomas’ complaint about only making a prototype. Other suggestions were to have more time or more materials to use. Students in the Green group also discussed the difficulty in calculating the maximum capacity. Donovan commented, “Our boat was perfect at what we measured, and then water started leaking through the bottom.”

In short, the boys were frustrated about the constraints they had for this challenge: time, budget, and materials. Unlike the Blue and Orange groups, the boys did not take full advantage of the individual task testing days and felt they only had two class periods in which to build their product. The Red group excerpt below shows evidence of this.

> *George:* *But yeah, again…more time because we only had like one…two days, I think, and it was hard because, like, we already had a little bit of an idea of what we know we wanted to do {I: Mhm}. But we like thought about it and we thought about the money, and like…oh…*
>
> *Preston:* *But since we could only use…*
>
> *George:* *And now we only have x amount of materials, then it didn't work out, like, how we wanted to do it.*
>
> *I:* *Mhm. Ok.*
>
> *Robbie:* *Yeah, cause like normal engineers have like year…er, like months to do it and we just had, like, two days.*
>
> *I:* *Ok.*
>
> *Jose:* *No, like, we didn't have, like, two days. We had…because those two days we…we did it like in a group.*
>
> (Red Group, 2)

The small group test days was not taken advantage of in terms of being able to test the materials, as noted by their frustration with not having enough time. The excerpt above also shows an understanding of what engineers do, and as George eventually pointed out the budget, "…made it more real-life, I guess." It is evident that the nature of an engineering job was somewhat known to these students, who recognized that the constraints in the classroom were not just for the sake of the classroom, but actually reflected how the field of engineering works.

In particular, the groups that students worked in was seen as an advantage. Preston and George thought this was especially useful.

Preston: *I also liked, um, how when we – since we had the teams –then we wouldn't, like, have to worry about, like, having to do everything ourselves. And then we would have different ideas to try.*

George: *And I also liked how – kind of like Preston said, but different – like, he had us do different things for each person. {I: Mhm} So, like, four different groups and then when you come back, everybody knew what they wanted to do with their part of the boat. {I: Mhm} And then it brought it together really well, I think. So, I think that's what helped and that's what I liked about it. So, everybody's not like…has the same idea, everybody had different ideas because they're all thinking of different things and different ways to make the boat better. So, that's what I liked about it.*

(Red Group, 2)

Frank mentioned, "Yeah, I like working in groups 'cause you just get to collaborate." In general, many liked the jobs aspect of this design challenge. Nate pointed out something unique when he mentioned that the division of jobs was ok, "Oh, 'cause, like, for the adhesive control everybody, like…if one person wanted to be it, but, like, they weren't mature enough to be it?" Nate referred to the fact that some students who were allowed to use the hot glue guns for their watercrafts were sometimes found messing around with the glue; in fact, Felix admitted to being one of those students.

The Red group was able to focus on the idea that coming to a consensus was something necessary for the way they worked in their groups, but this was challenging for them. While the individual testing days were helpful for the group as a whole, they recognized that time spent "arguing" over creating the boat was less time they actually worked on building.

Jose: *Well, the ideas. So, if each person {I: Ok}…*

Robbie: *Mhm, so, like, if you wanted to do one idea and someone else wanted to do another and you couldn't, like combine them {others giggle}.*

Preston: *Same as them – like, how we would have, like, same ideas…er, different ideas and then you would have to try and decide and that would waste time. {I: Ok} And then so you would have less time to do your boat.*

George: *Um, kind of what, like, Robbie said – um, the fact that, like, somebody from Math Masters might have an idea of how to make the boat better for the math, but maybe you don't think it's good or they have an idea for you, but it's your…like it's your part of the boat and you know it's not that good of an idea, but they keep fighting you on it and then wasting time.*

I: *Ok, so it's disagreement…you were wasting time. Ok. And that was something that is sounds like all of you picked up on.*

Jose: *Mhm.*

Preston: *They didn't really, um, my group wasn't really arguing, we, um, I wasn't in boat design, but um, Liam and Theo were in my group, and they both wanted to do boat design and then, so, um, so then we were…they were arguing and then Liam, um, was boat design and so he made a boat and Theo was like, "That wasn't my idea, though." And he said – Theo said – that he was boat design first. They were arguing about that a little, but then it was only for like a little bit of the first day.*

(Red Group, 2)

In addition to arguing within a group, others were distracted or otherwise did not want to participate. Jimmy stated, "So many people were, like, talking at once sometimes you couldn't hear." Jimmy was passionate about this, further stating

Jimmy: *Sometimes the people in your group – they would start slacking off and then you'd be the only one who wanted to – that was actually, like, focusing cause like the three people I was with were like really good friends [I: Mhm]. So they were like messing around…*

(Green Group, 2)

In response to this, Felix admitted that, "I was probably one of the people messing around."

Students talked about being able to choose their own groups wherein the general consensus was that they wished they had had some control over this. They realistically pointed out a lack of motivation in some of the group members, as Donovan noted, "Some people, just, um, didn't want to do stuff." He and Joe had worked in the same group, and there was some tension between them. Donovan also commented, "But like, when you pick your jobs, like you had adhesive control and stuff, and when people were picking their jobs, like, um, design manger did, um, 'No, I'm the one who's supposed to make the boat.'" Jimmy added to this by explaining that others were controlling of their groups, "Some people would say, 'I'm the adhesive manager,' or 'I'm this, I'm that' and they wouldn't let anyone else, like, give a say in what they are." While overall, the jobs were beneficial, the boys tended to get competitive and possessive about them.

There was also the issue of choosing groups. Though Shana allowed her students to suggest partners, Frank, a student in her class, thought, "I think we should have gotten to pick our own groups," extending this comment to students in his group not being there the whole time. Donovan disagreed with this, stating, "Cause if I were…if we would have picked our groups everybody would have probably picked their best friend and nobody would have made a boat." Jimmy suggested that groups, if not selected by students, should be created based on personality.

Frank: *Yeah, but you can get the serious people in one group, so they get what they want [I: Ok.]. And maybe kids that are messing around…*

Donovan: *But you're probably not going to pick those people.*

Frank: *...let them fail. They'll learn from it, I guess.*

(Green Group, 2)

Frank, who had previously talked about the accountability that occurs within group work saw the advantages of learning from failure. This demonstrated a more sophisticated understanding of what it meant to be an engineer.

Revisiting careers in physics and science. Similar to the girls, it was important to understand what students thought people in science related careers do on a regular basis. The Red group identified that scientists worked out problems and, "They know how to, like, fix things and stuff" (Robbie). George acknowledged that different scientists do different things depending on what they studied, but this focused on hands-on activities. Donovan mentioned Albert Einstein before Frank commented that, "Chemistry is kind of a stereotype," after someone commented, "There's mixing things together." This then launched into a conversation about jobs that might include some science, such as computer engineering, engineering, and pharmacology. Students in the Green group were also able to identify that people in science careers: "try to fix problems" (Nate), "researching" (Felix, John, Lloyd), "helping others" (Jimmy), "testing" (Joe), and "engineering" (Frank)

When asked to once more consider a career that involved physics, the Red group identified building as something that would be appealing to them. Preston specified what he meant by stating, "I want to build, but I don't want to, like, have to come up with the design myself cause that's, that's challenging for me." Thomas was interested in specifically building technology. Robbie reiterated his desire to be an engineer and Jose mentioned once more his desire to be an inventor, related it to past experience.

> *Jose:* *Well, I always wanted to be an inventor, because like, every time…well, when I was little I used to, like, make these…I used to make toys, like…you know those remote control cars? I used to break them and try to build something else, but nothing ever happened.*
>
> (Red Group, 2)

John was able to reiterate that he was already considering a job that included physics because he wants to go into engineering. Nate, who took advanced level mathematics, commented that nothing could change his mind to consider a career involving physics because he wanted to go into a mathematics career. Both Donovan and Lloyd commented that blowing things up would make them more interested in a physics-related career. Donovan, Joe, and Nate all seemed to agree that they liked mathematics and sports.

Working with the girls. Though in both cases the integrated STEM unit was completed in single-sex groups, when asked about working with girls in science class, the boys in the Red and Green groups were ambivalent about this. For example, Robbie stated, "I wouldn't care," and Nate commented that it's, "Basically the same," as when working with other boys. Only John and Jimmy had slightly negative comments to say, Jimmy noting, "It depends on if they're going to focus or not," and John rehashing, "The last time I worked with a girl she ditched me. She quit the whole thing."

Round 3. All students in the Red and Green groups with the exception of George were present at the third and final meeting.

My Own Science. The majority of the boys in the Red and Green group, similar to the girls in the Blue and Orange groups, were interested in pursuing *My Own Science* projects that allowed them to engage in scientific method experiments. Appendix G provides short descriptions of students' chosen projects. As with the girls, many of these were science-like, but those that were better aligned to real science questions were related to physics, specifically force and motion. All but one of the projects were in the broader field of physical science (physics and chemistry). For instance, Nate and Joe paired up to test whether a baseball thrown with or without leg power would be faster. They both played baseball and were able to find a way to incorporate this into their project, perhaps testing a theory that had been etched into their minds from their baseball coach.

Robbie and Thomas both discussed projects that related engineering to physics, again, specifically to force and motion. Jose and Donovan were the only two who choose to not do any hands-on activities, but for different reasons. Jose was interested in learning more about jaw profiles of sharks, so he chose to read an article with a partner. Donovan, who, when reflecting on what he did, was unmotivated to do this project, very much against doing something at home. Perhaps the reason for this was because it was too difficult to come up with an experiment at home. Another reason could have been that reading an article was easy, a reason that several of the other boys shared as reasons for picking the projects they did. They also mentioned that there was not enough time for the projects, even though they had two weeks and were not required to complete anything they had not already done in class (i.e. they were familiar with the templates used).

What about physics now. When asked to consider what the word *physics* meant to students during the final interview, the responses were consistent with the ways they talked about physics from the first focus group interview, for instance mentioning states of matter and sublimation. Jose postulated, “Well, I think of, like, really hard things to do,” while Preston mentioned, “I also think of algebra. It reminds me of all the numbers and letters.” This notion that physics is hard and requires math reflects the general public’s view of physics, and is not necessarily the same that students thought at the beginning of the year. Robbie and Thomas thought of stereotypical images with Thomas mentioning Albert Einstein and Robbie stating, “I think about, like, the chemicals and you have them, like, in the jar and you put in chemicals.”

Nate thought physics was, “Boring. I did this last year.” Joe and Frank agreed with this as some of their 5th grade science standards covered introductory physics topics. Students indicated a level of disengagement whenever something was repeated because they could not see a reason why they should bother learning something again, even if it was at a deeper level. Donovan talked about how in 5th grade, “Science was, like, laid-back boring. But Ms. Shana is like a dance-y type person. She dances a lot. Yeah. Yeah, she makes it cool.” Similar to the *My Own Science* project that Nate and Joe had chosen was the idea that physics would be appealing if it related to sports. Donovan rehashed a show he had watched at home, which several of the boys were familiar with.

Donovan:	*I think like, there’s this one show, it’s like Science of Football, I think. I don’t know. It’s on ESPN, but I dunno, I forgot what it’s called. But it’s like some type of science thingy…*
Frank:	*Sports Science.*
Donovan:	*Yeah, Sports Science.*
I:	*Ok.*
Frank:	*And it’s got like, the physics of doing, like, a bicycle kick, like in soccer, and football.*
I:	*Okay. So, this was something you saw in school or at home on ESPN?*

Multiple: *At home.*

I: *At home. Okay. So, that was something that was interesting to you?*

Frank: *Yeah.*

(Green Group, 3)

This notion that physics can be related to sports may be an avenue for students to pursue studies in physics. It may also be why at the college level, many times there are lectures or invited speakers that talk about the physics of baseball.

What about a career in physics? Students were asked to revisit what they thought about careers involving physics after having spent several months immersed in studying this discipline in their science classes. With the exception of John, whose only career aspiration was as an engineer, the boys were still not interested in careers involving physics. However, Jimmy reiterated his previous attitude stating, "I mean, I would really want to, but if that was my only option, I would." Lloyd commented that engineering or, "Something that has to do with that," would be a way for him to participate in a career involving physics.

When pursuing this question, it became apparent, once more, that there was a distinct difference between one who uses physics in a career and a scientist, where a scientist only represented stereotypical images of a chemist.

Preston: *Like, someone that works with, like, chemicals…kind of like a scientist. Like, somebody who tries to find…like, kind of like someone who tries to find cure to a sickness.*

I: *Ok. But instead of a cure to a sickness, they're finding?...*

Robbie: *Like, new things to like research.*

Preston: *Like, different kinds of chemicals.*

I:	*Okay. Okay. So, Preston – I'm going to pick your brain for a little bit. Um, cause you said a physicist was someone who was like a scientist. So, what do you mean by the word "scientist" then?*
Preston:	*I think of, like, somebody that, um, uses like chemicals, and different colored water things like those, that try…that finds out new things about stuff.*

(Red Group, 3)

This exchange shows an example of students continuing to think of stereotypical images of scientists and physicists in general. Indeed, this image may be responsible for casting physics in a certain, misrepresentative light. Thomas pointed out that science careers may have a component of research with computers and Robbie mentioned, "Like, figuring out…I don't know." Here lies an element of knowing that science careers involve solving problems, but not knowing too much about what exactly this entails.

Jobs in general. The Red group was interested in finding jobs or careers that were fun, but did not necessarily pay lots of money. For example, Preston stated:

Preston:	*I wanna, like, have fun with it. Like, I wanna be a professional soccer player and that pays a lot, but I also want to have fun and not just, like, sit there and do whatever I'm told. Like, "do this, do that," I wanna be able to, like, make my own choices. Yeah.*

(Red Group, 3)

Students in the Green group were also interested in a career that allowed for freedom, Jimmy citing that being an entrepreneur would allow him this flexibility because he could be his own boss. This idea that freedom is important reflects how these students felt about the activities in their classroom, which is further examined below when considering students' favorite instructional strategies so far in the school year.

Favorites in science class. This idea of "intellectual" freedom was echoed in students' responses regarding their favorite activity they had done so far in science class.

As with the Blue and Orange groups, students chose the engineering design challenge and the *My Own Science* project. The watercraft design was seen as a favorite because of the first-hand experiences and the group work involved. Jose, in agreement with Robbie, mentioned, “Making boats with my classmates. It was actually fun because, um, my, my class, and the other class get to like, you know, get to a competition.” Preston emphasized, “I liked having to figure out how to make it, and then, like, testing it.”

The word *independence* was used by four of the boys in the Red and Green groups to describe why the *My Own Science* project was their favorite, simply because, “You could choose a project to do and anybody you wanted to do it with” (Lloyd). Only Felix mentioned a different activity, and he was interested in learning about particles and the states of matter. These students valued the work associated with these activities because of the first-hand experiences and flexibility in the assignment.

Comparison between all Three Rounds. Considering all three rounds of these interviews describes boys’ perceptions of physics and physics-related careers. The following list, which will be explored further in Chapter V, outlines the important features found in these interviews.

- First-hand experiences are important for learning because they allow boys to interact with material in a way that is impossible when just taking notes or listening to a lecture. Traditional learning is not seen as beneficial because it leads to unmotivated learners. Hands-on activities are valued by boys because they can confirm or deny their own beliefs and misconceptions.

- Boys did not see the value of re-learning material in science class. Similar to the results of traditional learning, students become unmotivated and unwilling to participate in class.
- Developing teamwork is complicated for boys. Assigning specific tasks or roles in group work is territorial, much akin to students needing ownership of their work (i.e. feeling threatened when others just copy what they have done). In particular, these boys were concerned about being in charge of certain parts of a group project, unwilling to cooperate with others who "threatened" their position in the group. Accountability seems to be of some concern, but more so than that, boys want to make sure that they work with whom they deem as a good group member.
- Boys are more open to considering careers in science than girls are, but only when it is engineering that they are open towards considering. At the same time, boys were more closed to the idea of considering a career in science that girls if the connection was *not* engineering. In this vein, it was not the idea that, "It sounds interesting, but…," but was more aligned to, "I'd rather do…." To some extent this leaves little room for flexibility as they have already crossed pursuing a science-related career off of their list.
- These students value "doing science" but do not necessarily see themselves as "being a scientist," even when conducting labs in class. This is further evidenced by the fact that students were unsure of whether scientists did experiments at all beyond the stereotypes scientist activities. However, the

boys recognized that engineering was a science-related career, and some even considered this to be a potential career choice.

- Freedom and independence, even outside of the classroom, are ideals that boys hold with regards to their career aspirations.

Differences and Patterns Between Girls' and Boys' Perceptions

In all, these 6^{th} grade girls and boys had very similar personal experiences in science, but with very discreet differences. These differences, though seemingly small, may expose the subtleties in instruction that could make all of the difference. For instance, it is clear from these interviews that students have a strong preference for hands-on activities and for many of the same reasons (e.g., it sticks in your brain, it's fun, visuals are a better way to learn). The small difference here, though is that girls were more interested in hands-on activities that had a *purpose* to them, for instance, and engaging and motivating context provided through an engineering design challenge. This context was *never* discussed by the boys, though it is clear that being able to relate physics to sports was interesting to them. However, those boys who were interested in the potential to pursue a science-related career (i.e., engineering) and wanted to do something that would help society through the use of creating new technologies. What is interesting is the difference in how the girls and boys talked about helping people. Boys were interested in tools that helped people, whereas girls, when talking about what makes jobs appealing to them in general, mentioned helping people with personal problems was an avenue of interest (e.g., choosing therapist, doctor, teacher, etc.).

While both girls and boys valued group work in science class, there were differences in how it was discussed and how it was observed in the classroom. Girls were very focused on the collaborative nature of group work and saw the need to make sure that everyone participated. For instance, observations of the engineering design challenge showed that girls were capable of sharing their ideas with one another to come up with one final design. While boys mentioned collaborative work, their focus was more on distributing work rather than sharing ideas. The boys were not as troubled when their teammates were off goofing around, and at times they themselves were the ones who were misbehaving, but were more frustrated when disagreement occurred. During the engineering design challenge, for example, it was common to see the all-boy groups either arguing for their personal designs or creating multiple designs simultaneously when consensus on a design was not made.

What is drastically different is the fact that girls were overtly excited about science class compared to boys, yet girls were also more likely to backpedal when they could not see themselves as pursuing a science field. Boys, on the other hand, were more likely to say they would consider a science career, but only if it was more like engineering. Girls were more likely to say, "It would be interesting, but…." It was only after engaging in the integrated STEM experience that girls even discussed engineering, but more as an admiration, not as a career aspiration. Since engineering was new to these students in 6th grade, this has major implications in looking at how bring engineering and integrated STEM to K-12 education may influence students' perceptions of science-related careers.

Quantitative and Qualitative Comparison

Differences Between Girls and Boys

At the beginning of the year, girls' and boys' responses on the survey were similar, with the exception of two items. Boys were more likely to agree with science being one of their favorite classes (Item 5) and were more agreeable to seeing physics relating to their everyday lives (Item 7). These results were somewhat surprising when considering the focus group interviews, especially the conversation that the Blue group had about astronomy, a discipline that is thought to be the gateway to science (Hechter & MacDonald, 2015). Girls were much more open about their fondness for their science class, but this result may be a residual of the limitations of this study in which volunteer bias plays a role. However, it was also clear that in the first round of interviews, boys were much more familiar with science concepts and were better able to see connections to the world around them compared to the girls.

After the STEM integration unit, the only item of significance related to students being interested in careers that involved physics (Item 4) with boys favoring this item over the girls. It is possible that by explicitly connecting physics to engineering, boys who were unfamiliar with this career suddenly were able to see these connections.

The final survey once again showed that boys out-favored the girls in indicating that science was one of their favorite classes in school (Item 5). Again, this is somewhat counter-intuitive to the findings of the interviews in which boys were not as excited about science class as the girls. It is possible that while girls may be excited about science, in comparison to their other classes, it is not of the same caliber. Males also favored learning how things work compared to girls (Item 1). From the focus group interviews, it was clear that engineering had become something to admire for boys, especially with respect to design, building, and testing. Finally, boys were more agreeable to using mathematics to solve physics problems in science class (Item 12). While never explicitly discussed, the focus group interviews showed how the boys enjoyed making the predictions about their watercraft, but girls were more frustrated by this.

The two highest scoring items on the survey, consistently, were items related to group work and hands-on activities - Items 11 and 13, respectively. This finding is not surprising given the praise that focus group students had with respect to these instructional strategies. It was clear from interviews both group work and hands-on activities played pivotal roles in the way students interacted with science material.

Differences Over Time

Over time, two items were significant for girls and those items related to an interest in a career involving physics (Item 4) and enjoying physics as it related to everyday life (Item 7). While the average of the Likert-scale responses for Item 4 remained low ($M = 1.92$), this quantitative finding reflects the conversations of the girls. That is, girls were more and more open to considering a career involving physics, especially if they were able to see how it could connect to helping people. The second item of relevance on the survey for girls showed an increase in agreement that physics can be helpful in everyday situations. Exposure to applications of physics, such as the engineering design challenge, opened up these girls' eyes to how physics can be useful.

For the boys the two items of significance related to the intersection between math and physics such that there was agreement that math was necessary for physics (Item 9) and boys enjoyed using math to solve physics problems (Item 12). Both of these items shifted from a level of general disagreement to somewhere between neutral and agreeing with the statements. From the conversations, boys were interested in the mathematics to some extent, enjoying applying it to their engineering design challenge.

The chapter that follows extends the findings presented here in order to directly address the research questions. Further consideration of cross-case data findings (both with respect to girls and boys as well as across the data types) will be addressed. Additionally, implications of the research are discussed, as well as limitations and suggestions for future work.

CHAPTER V

Conclusions, Implications, and Future Research

The purpose of the work presented here was to identify how science teacher practices of girl-friendly and integrated STEM instructional strategies impact middle school students' perceptions of physics and physics-related careers. To this effect, this work focused on the patterns and difference that exist between the perceptions of girls and boys. The final chapter first extends and discusses the findings presented in Chapter IV. Second, implications of this work are presented with respect to classroom instruction. Third, limitations of the research are addressed, which inform future research directions; one of the suggestions is to consider additions to the literature on girl-friendly strategies, specifically revolving around the need to allow students to learn from failure. The chapter concludes with closing remarks for teachers and teacher educators to consider as the science education community strives to continue to improve science and STEM education.

Conclusions

Both the quantitative and qualitative data presented in Chapter IV show that differences between the perceptions of 6^{th} grade girls and boys are relatively small. The quantitative findings show that boys tend to favor their science class over the girls in their class, possibly related to the fact that they also enjoy learning how things work, enjoy using math in their science class, and are slightly more interested in careers that involve physics. When considering changes over time, the exposure of these science classes shows that girls became more agreeable to pursuing a career involving physics and seeing how physics relates to their everyday lives. Boys became more interested in the connection between math and physics. These findings were somewhat in conflict with the qualitative findings, which showed that girls were more positive about their experiences in science classes compared to the boys, and that they were also more open to considering science careers. Boys were open to considering a career involving physics only if it was in an engineering context.

Despite the fact that, overall, this is a rather positive finding suggesting that middle school girls and boys have similar perceptions of physics and physics-related careers, the concern rests in how these small differences have the potential to evolve into larger differences over time as these students continue with their K-12 education. It is perhaps these small differences that have led to the small numbers of women who pursue careers in physics and other underrepresented STEM careers, such as engineering (APS, 2010). Further, by reflecting on the research questions, it is possible to diagnose how K-12 science education may help to change these numbers in the future. The research questions guiding this study are reviewed here before expanding on the conclusions found in Chapter IV. The questions guiding this study were:

- *In what ways do teacher practices affect the way middle school students view their role in the physics classroom as well as their perceptions regarding a physics-related career?*
    a. *What girl-friendly and integrated STEM instructional strategies do teachers use that influence student perceptions?*

b. *What patterns arise in girls' and boys' perceptions towards physics and physics-related careers?*

c. *What differences exist between girls' and boys' perceptions of physics and physics-related careers?*

Before addressing the overarching question, it is useful to address each of the sub-questions (a, b, and c), as addressed by the following headings, respectively: The Role of Instruction, Patterns and Similarities in Girls' and Boys' Perceptions, and Differences Between Girl's and Boys' Perceptions.

The Role of Instruction

From the analysis of the classroom observations, it is clear that Ralph and Shana used multiple girl-friendly and integrated STEM instructional strategies (see Table 5.1 as a reminder of the theoretical framework used in this study). A review of Appendix E shows that in the integrated STEM unit alone, Ralph and Shana used each of these strategies in turn. By considering the findings of the survey and focus group interviews, it is possible to pinpoint the specific strategies that influenced students' perceptions, which is discussed below when addressing sub-questions (b) and (c). As addressed in Chapter IV, first-hand experiences were extremely powerful for students, and for girls, the importance of a motivating and engaging context was related to their career aspirations. By allowing students to see how physics is applied, perhaps in an engineering design challenge, they were able to make connections between physics and everyday things. One of the biggest impacts for girls was the emphasis on teamwork and communication and the collaborative nature of their work in science class. It is clear that these strategies have a large impact on the way that students perceive their science class, but the extrapolations to careers are extremely important and are discussed in the implications for practice section.

Table 5.1.

Comparison Between Girl-Friendly and Integrated STEM Strategies

Girl-Friendly Strategies (Häussler et al., 1998; Newbill & Cennamo, 2008)	Integrated STEM Framework (Moore et al., 2014)
1. Provide opportunities to be amazed.	1. Motivating and engaging context.
2. Link content to prior experiences.	2. Inclusion of mathematics and/or science content.
3. Provide first-hand experiences.	3. Student-centered pedagogies.
4. Encourage discussion and reflections of the social importance of science.	4. Engineering design challenge or redesign.
5. Physics appears in application-oriented contexts.	5. Learning from failure.
6. Relating physics to the human body.	6. Emphasis on teamwork and communication.
7. Experience physics quantitatively.	
8. Engage in collaborative learning.	

Patterns and Similarities in Girls' and Boys' Perceptions

To address the second research sub-question, examining the quantitative and qualitative findings helps to identify the patterns and similarities between girls' and boys' perceptions of physics and physics related careers. As presented in Chapter IV, each of the key findings were two-sided such that there was some overlap between girls' and boys' perceptions as well as indications to the subtle differences. This section will discuss the patterns and similarities with regards to first-hand experiences, choice of *My Own Science* project, group work, and career options.

First-hand experiences. Unsurprisingly, girls and boys both felt that first-hand experiences through laboratory activities and engineering design challenges were valuable in their learning; this is reflected in both the quantitative and qualitative data findings. These types of activities have been a well-established piece of reform-based classrooms (e.g., Cohen, McLaughlin, & Talbert, 1993; Darling-Hammond & McLaughlin, 1995; Porter & Brophy, 1988). Further, these first-hand experiences ignite the positive responses to "doing science" as noted by other researchers, which contributes to students' positive perceptions of science at a young age (Archer et al., 2010, 2012; Jenkins & Nelson, 2005).

Choosing science projects. Both groups associated the *My Own Science* project with a sense of freedom. Freedom and independence, even outside of the classroom, were ideals that boys held with regards to their career aspirations, and girls particularly appreciated as part of their science class. This is why the *My Own Science* project was a favorite for these students in addition to the integrated STEM unit. Most of the interviewed students completed projects that they identified as scientific inquiry, but the content focus on the project varied across the girls and boys.

Group work. As one might expect, both girls and boys valued group work, and as the quantitative findings showed, this was the item rated the second-highest, second only to first-hand experiences. Both girls and boys felt that with the integrated STEM unit, groups were necessary in order to address the engineering design challenge.

Career options. On the whole these girls and boys were not interested in pursuing careers in science. While students were happy with "doing science" in their school, many could not align with "being a scientist" (Archer et al., 2010), possibly because of their limited understanding of what scientists do. Additionally, students' limited understanding of science-related careers blocked their ability to see connections of "doing science" without necessarily "being a scientist."

Differences in Girls' and Boys' Perceptions

This section, which focuses on the differences in girls' and boys' perceptions, mirrors the previous section by addressing the differences of perceptions relating to first-hand experiences, choice of *My Own Science* project, group work, and career options. This section additionally addresses the differences when it comes to the role of mathematics in the science classroom.

First-hand experiences. While this study showed that boys preferred hands-on experiences in general, likely related to their interest in learning how things work as indicated in the survey, the girls' responses during focus group interviews indicated a connection between hands-on experiences and what makes a science career interesting. Girls made connections from hands-on activities to *purpose* and *motivation*, whereas boys did not mention or indicate any importance relating to a motivating and engaging context. The boys did, however, allude to some importance of applications of physics content through an understanding of engineering, which appeared to have been established prior to any engineering-related activities in Ralph and Shana's classrooms; showing some evidence of prior exposure to engineering. Additionally, though never explicitly stated, the connection between physics and sports was appealing to boys, but not a requirement. The context of the watercraft challenge – saving people's lives by creating a watercraft prototype for use in floods - may also be why Rachel preferred that challenge instead of the Candy Bag engineering activity because, "It felt like we could actually do something" (Rachel). This once more emphasizes the need for a motivating context or a way for students to see connections between physics and its application in their everyday lives, both features of the literature about girl-friendly science and the integrated STEM framework (e.g., Baker & Leary, 1995; Häussler et al., 1998; Häussler & Hoffman, 2000; Labudde et al., 2000; Moore et al., 2014b; Rosser, 2000; Stadler et al., 2000; Yanowitz, 2004).

The importance of a purpose or motivating context connects to girls' interests in jobs that directly help people; they were interested in becoming therapists, doctors, teachers, or interior designers. Many of these careers are associated with directly helping people with their problems. Though the focus group interviews indicated that, overall, the girls did not see the intersection of helping people and applying physics through engineering design challenges, the survey data (Item 4) indicated a significant shift in the larger group of girls being more interested in careers that involved physics. Though never directly addressed by the students, it is likely that the instructional decisions of Ralph and Shana contributed to this shift as students learned about physics via girl-friendly and integrated STEM instructional strategies, specifically around those presented in the framework (Table 5.1) (Häussler et al., 1998; Moore et al., 2014b; Newbill & Cennamo, 2008). Though the girls' stance was still neutral after the third round of surveys, the positive shift over time does indicate that it is possible to positively affect the perceptions that girls have about careers involving physics.

The engineering design challenge had a different effect on how the boys started to look at the intersection of physics and a potential career. From the beginning, they seemed to be more familiar with engineering as a whole and had said that if they were going to consider a science-related career, engineering would be fitting. They were interested in applied physics such that it would be a way to create *technology* that could help society at large. This seemed to be a major influence on how they viewed first-hand experiences in their classroom, especially the watercraft challenge.

Choosing science projects. Many of the girls selected science-*like* activities for their *My Own* Science project that were aligned to stereotypical female activities, such as cooking. With the exception of Rachel and Lindsey, the girls did not choose to focus on physics topics. The boys, on the other hand, mostly chose physics-related projects, specifically around force and motion. This begs one to ask the question of whether there is an inherent masculinity associated with force and motion, as well as with respect to the bigger culture of physics (Archer et al., 2010, 2012; Hazari et al., 2010, Scantlebury, 2014). It is also possible that girls had a more difficult time in finding appealing contexts for force and motion, and thus were dissuaded from pursuing projects about that particular physics content. This was not the case for boys. For instance, Nate and Joe, who were not necessarily interested in science and physics, created a project that had a *context* and application they were interested in – baseball. Again, it is important to note that perhaps this context is what is missing for girls – that they need to see how they (or others) would directly benefit from physics.

Group work. While students were positive about group work, there was one important difference. Girls were more focused on the *collaborative* nature of group work, specifically concerning the integrated STEM unit where students had assigned roles/tasks to give each of them accountability within their group as, "[Group members] can help if you're struggling with something" (Brianna). Only Frank shared the same general vision of group work as the girls did, "…cause you just get to collaborate." George saw the benefit of the separated roles because, "…everybody had different ideas because they're all thinking of different things and different ways to make the boat better." These two boys saw how teamwork would benefit the watercraft design as a whole, while most of the other boys shared negative experiences with working in a group of boys, who tended to be possessive about their roles they selected. This collaborative nature of group work, which was emphasized by the girls, is present in both girl-friendly and integrated STEM strategies (Newbill &Cennamo, 2008; and Moore et al., 2014b).

The single-sex groups could have had a lot to do with the way that these groups functioned. The girls tended to share an appreciation for sharing ideas and collaborating with one another, but voiced that they would have been stressed or frustrated if they had been working with boys, who, according to them, "…have a short attention span" (Roberta). The boys were open to working with girls in their class. What was impressive was that through this conversation, students of both sexes identified that when they are with their friends, they tend to be easily distracted or off-task. Meaningful grouping (as discussed in the Implications below) may alleviate some of this (Kowalski, 2007; Rosser, 1998)

Career options. The motivations behind not being interested in science and physics careers were surprisingly differently. Though boys were able to relate what they do in science class with what scientists do, girls were unsure of whether scientists performed experiments at all beyond the stereotypical scientist activities. Cass' comment about thinking that scientists took notes regularly because that is what they do in science class was heartbreaking, as this had previously been identified as something that was an unattractive feature for science learning (and thus for a job). Realistically, girls had a more difficult time in seeing how what they did in science class translated to a career in science or relating to science, but once more their responses indicated that by the instructor making connections for them with a context would be worthwhile.

Girls were interested in careers that 1) directly help people and 2) are intrinsically satisfying. While there is some understanding that physicists and scientists help society at large, most girls did not see a direct connection to helping people. It is possible that their career interests are more aligned with helping people *with their problems*, which is something that is difficult to see when considering careers in science. The idea that taking care of a family and close proximity to said family was important to girls reflects a traditional gender role belief (Archer et al., 2012).

Boys were more open to considering careers in science than girls, but only when these careers related to engineering. At the same time, boys were more closed to the idea of considering a career in science than girls if the connection was *not* engineering. Girls thought a career involving science or physics might be fun and interesting, but had other aspirations in mind, indicated by the pattern of *It sounds interesting, but…*. The boys were more direct by saying *I'd rather do…*, where it is clear they are not open to entertaining pursing a science career. To some extent this pattern in boys' responses leaves little room for flexibility as they have already crossed pursuing a science career off of their list.

The role of mathematics. Though Häussler et al. (1998) suggest that students experience physics quantitatively as part of the girl-friendly instructional strategies, it was the boys who showed more positive attitudes about the role of mathematics when it came to physics perceptions, as indicated by the survey results. The girls indicated that they normally had no issues with the mathematics in their science class, as did the boys, but felt that the mathematics involved in the integrated STEM unit was challenging. The boys also did not like this component, but complained more about the fact that the mathematics they used to predict the maximum capacity still did not prevent their watercrafts from sinking. It was not the mathematics itself that was challenging for boys, but rather the fact that there was a difference between what they predicted and what happened when they tested their watercraft. The survey results showed that over time boys perceived a growing importance of mathematics in physics, but also enjoyed that they were able to use mathematics in their science class.

Implications for Practice

This study has multiple implications for teacher practice. One of the most important findings of this research is in dissecting what students enjoy about hands-on activities and what makes a science career appealing (or, in some cases, not appealing); these two findings aid in identifying how to increase students' interest in physics careers. Two recommendations emerge from this study: 1) creating contexts/applications for science and engineering to expose students to career options in STEM and 2) meaningfully developing teamwork and communication skills during group work. Though these ideas may not necessarily be novel concepts, the importance of implementing these strategies in the classroom address how to improve science experiences for both girls and boys, adding to the literature regarding girl-friendly instructional strategies. As our nation is moving towards *integrated* STEM education instead of the individual pillars that currently dominate K-12 education, research such as that presented here is important in assuring that this new approach to education is inclusive of both sexes.

Developing a STEM career identity. As Archer et al. (2010) indicate, middle school students lack the ability to see themselves as scientists, and thus do not often pursue these careers. Others have noted the same, and for girls, aligning their identity to the identity of a scientist is incredibly difficult to do (Archer et al., 2012; Hazari et al., 2010; Jenkins & Nelson, 2005). By accessing what career values students have (e.g., helping people) through the use of including something along the lines of early career counseling in science classes, students may be better able to identify with a career in science. For instance, Halpern (2007) offered that for girls, seeing role models was enough to help encourage them to pursue STEM careers, but others have denied that simple exposure has any huge impact unless identities are addressed (Archer et al., 2012). It is possible that by providing female role models and *also* discussing career values there would be a significant impact on girls' perceptions as they would be able to identify with these role models. This suggestion reflects a combination of the recommendations for girl-friendly instructional strategies provided by Halpern et al. (2007) and Newbill and Cennamo (2008).

The findings presented here show that girls value a science career that directly helps people and boys are interested in a science career that involves producing a piece of technology to help people, may indicate the imbalance we see between careers in STEM fields such that physics and engineering are dominated by men and biological sciences are dominated by women (Britner, 2008; Halpern et al., 20087; Heilbronner, 2012; Makarova & Herzog, 2015; Matson, 2013; Scantlebury, 2014; Sikora & Pokropek, 2012). By exposing all students to these types of opportunities, it is possible that simultaneous to increasing the numbers of women pursuing careers in physics, there is also an increase in males pursuing careers in biology and other life sciences. In terms of instructional practices, by providing students with experiences that allow them to apply physics content in a meaningful way via a society context, this can be accomplished.

Meaningful teamwork. Though complicated, the idea of intentionally creating groups has been proposed as a way to facilitate meaningful discussion in physics classrooms (Kowalski, 2007; Rosser, 1998). Using the girl-friendly and integrated STEM framework presented here, it becomes more imperative to include all students' voices during group work. For instance, creating individual tasks within a group enables students to feel valued, which creates groups that are productive. From this study, developing teamwork in a meaningful way helped students self-direct their own learning. While creating groups can be challenging and time-consuming for a teacher, it appears to be highly beneficial; meaningful grouping allows students to feel as though their peers rely on their participation. It provides students value within their group and allows them to feel as though their contributions to the group are necessary. Girls value this in their work, though are troubled when it is unclear what role they are to take in this work. By modeling for students that science and STEM fields are collaborative in this nature (Newbill & Cennamo, 2008), it is possible that students will begin to see these fields as a non-isolated career, once more having the potential to increase the numbers of women pursuing careers in physics.

Developing teamwork skills is more complicated for boys. Boys saw these specific tasks or roles within group work as something they needed to be territorial about; this may be related to their need of ownership of their work (i.e. feeling threatened when others just copy what they have done). In particular, boys were concerned about being in charge of certain parts of a group project, unwilling to cooperate with others who "threatened" their position in the group. Accountability seemed to be of some concern, but more so than that, boys wanted to make sure that they worked with whom they deemed as a good group member; this has the potential again connect to teachers needing to meaningfully create groups (Kowalski, 2007; Rosser, 1998).

Sharing the knowledge gained here regarding students' perceptions of physics can open up teachers' eyes to the important role they have in assuring that students work together to achieve a given goal in the classroom. The collaboration that Ralph and Shana used in their classroom that seemed to have the biggest impact on the way students engaged in science and engineering content was 1) creating meaningful jobs/tasks for each member of the group and 2) mitigating competitiveness in the class by competing with students in other classes rather than with student within the particular class. This allowed for not only small groups to develop their teamwork and communication skills, but also allowed the class to learn how to work together to accomplish a goal.

Limitations

Several limitations exist in this study that may limit its generalizability. These are addressed below and lend a hand in identifying where future research may follow.

Volunteer-basis focus groups. The first limitation is that the findings of the focus groups interviews are limited by the fact that, by nature of the study, interviewed students were volunteers. Further, there was a requirement for parents to provide consent for their child to participate in the study. Therefore, it is possible that this final selection of students is heavily weighted to those who: 1) were interested in science to begin with and 2) had parents/guardians who wanted to push their child to be a participant. These students may also have been high-achieving in science class, which brings up the next limitation.

Unknown academic achievement. As this study focused on the intersection between perceptions, gender, and instructional strategies, gaining knowledge of students' academic achievement was not a goal of this work, and was thus not considered for data collection or analysis.

One suburban school. The simplicity of this work to focus on the 6th grade students at one suburban school in the mid-west, though enlightening, limits the results of the findings presented. Students in this study may be at an advantage compared to similar students in a rural or urban area. To extend this study further, examining across different demographics may be beneficial and applicable to more areas. However, it is important to notes that for the girls who participated in the focus group interviews, the minority students were often the ones who were more positive about science in school and as a career (e.g., Rachel, Megan, Monet, Raylen). This was not true for the boys.

Female interviewer. The fact that that interviewer was a woman may have had some impact on the way that students in the focus group interview answered the questions. Anecdotally, the girls were much more talkative than the boys and this effect could be a result of the fact that the interviewer was a women, thus the girls were more comfortable in conversation. It may also just have been the personality of these students, as the boys from Ralph's class (Red Group), though quiet, often gave thoughtful responses to the interviewer's questions. Should this study be repeated, it may be the case that a male interviewer would be tasked with collecting interview data from all-boy groups.

Future Research

The limitations discussed above drive ideas for extending this research. Scaling up this research with multiple covariates by considering both academic achievement and student demographics could shed light on how students' abilities may be related to their perceptions (looking more into self-efficacy, etc.). Demographics could include simply looking at different ethnicities, but moreover, examine different school demographics (such as adding in rural and urban schools) to extend the findings and compare between these different environments. Additionally, socio-economic status, which has often been considered one of the most important influences to student achievement, may help to further understand the types of opportunities different students are given.

Though retention rates with longitudinal studies with students often mean that few of these types of studies are completed, gaining an inside look at what happens over time regarding students' perceptions of STEM fields is highly important. Short of a longitudinal study, repeating this study across multiple different grade levels simultaneously may be another way to track the typical path of student perceptions over time. The one concern regarding both of these is the influence of any given teacher, especially with regards to the framework used here. Unless a larger project, such as the EngrTEAMS project discussed in this study, provided professional development to support teachers in gender-equitable instructional strategies was present, this type of research would be flooded with uncertainties about teachers' understanding of these types of frameworks. In this light, developing a refined framework of girl-friendly instructional strategies with clear definitions may be necessary instead of pulling from various sources. An in-depth literature review on this subject matter may need to proceed any such future study of this kind.

The integrated STEM curriculum discussed in this study clearly aligns with many aspects of girl-friendly instructional strategies. Curricula like this and others need to be published and shared with the science education community to provide examples of curricula that are gender-equitable. As the curriculum discussed here will be published as a result of the EngrTEAMS project, a follow up study will more formally present the case that this is a curriculum worth using in the classroom to ignite interest for both middle school girls and boys.

There is a need to examine the importance of learning from failure in engineering design challenges (Moore et al., 2014b). This tenant did not have a direct alignment to the literature of girl-friendly strategies, but focus group interviews indicated that students benefitted from having the opportunity to work on testing the materials through certain tasks before working in their groups for their final prototype watercraft design. There is a need to further examine whether this approach has significant benefit to girls, which may add to the literature of girl-friendly strategies.

Closing Remarks

Though this study shows rather small differences in the perceptions of 6th grade girls and boys, the concern moving forward is in how these small differences may increase over time. It is possible that these small differences are what go have gone unnoticed, thus leading to the underrepresentation of women in physics. For instance, it is possible that girls never see the actual connection between science/physics and helping people. At the same time, it is possible that boys never get to see the connection between science/physics and designing/making technology to help people. These subtleties need to be addressed before students become completely disengaged from science. In short, it is important to prepare science teachers to will enlighten and motivate students to continue with their natural curiosity that exists at young ages to create career aspirations that relate to STEM fields.

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APPENDIX A

Student Survey

Name: ______________________ Hour: ______

Date: ______

Please indicate the gender you most identify with: Female Male

Please use the given scale (0-4) to indicate how strongly you agree or disagree with the following statements. Complete <u>all items</u> by circling your answer. There is no right or wrong answer. Below is a description of physics that may help you answer the items.

What is physics?

Physics is a science that studies matter and its motion through space and time. It also deals with everyday things like force and energy. The goal of physicists is to understand how our universe works. They study things like: electricity, magnetism, waves (light and sound), forces, gravity, astronomy, and atoms. People who study physics can go into all kinds of careers!

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. I like learning about how things work.	0	1	2	3	4
2. I am interested in the topics we will be learning in science this year (e.g. particles, light, sound, motion, forces, energy).	0	1	2	3	4
3. I like to learn about physics topics outside of school.	0	1	2	3	4
4. I would like to have a career where physics plays a role.	0	1	2	3	4
5. Science is one of my favorite classes in school this year.	0	1	2	3	4
6. I easily understand physics topics.	0	1	2	3	4
7. Learning physics can be helpful in my everyday life.	0	1	2	3	4
8. Anyone can be good at physics.	0	1	2	3	4
9. You have to be good at math to understand physics.	0	1	2	3	4
10. Physics is just a subject to learn in school.	0	1	2	3	4
11. I prefer to work in groups in science class.	0	1	2	3	4
12. I like using math to solve science problems.	0	1	2	3	4
13. I prefer hands-on activities when learning science.	0	1	2	3	4
14. I like participating in class discussions about science.	0	1	2	3	4
15. I like when I can relate to the topics we learn in science class.	0	1	2	3	4

Figure A-1. Student survey.

APPENDIX B

Focus Group Meeting 1 Semi-Structured Interview Protocol

Focus Group Round 1

Welcome:

- Thanks for joining. As you know, my name is Emily Dare and I'm a PhD student from the University of Minnesota.
- I'm here to talk with you about science, specifically physics, which is the type of science you're learning this year. This study will help me (and other teachers) understand what students like you experience in the science classroom and what you think about science careers.
- Today there are no right or wrong answers. I just want to learn about your thoughts and opinions. I expect everyone to have different things to say, even if they are negative.
- One person talks at a time.
- Your name will not be attached to any of your comments (one of the first things I remove).

Suggested Questions:

1) Two words to describe how you feel about science in school.
2) Two words to describe how you feel about science as a career.
3) What do you think of when you hear the word *physics*?
4) What do you think about careers/jobs that include physics? (i.e. would you want one?)
5) What types of activities do you like to do in science class? Why?
6) What types of activities do you not like to do in science class? Why?
7) [*Optional:* Describe how you participate in science class.]
8) [*Optional:* What did you draw for "I am a scientist"? Why?]
9) [*Optional*: How do other students in your class make you feel about your ability to do well in science class?]

Figure B-1. Focus group 1 interview protocol.

APPENDIX C

Focus Group Meeting 2 Semi-Structured Interview Protocol

Focus Group Round 2

Welcome:

- Last time we met we talked about a variety of things concerning science in school and science as a career.
- Today I might ask a few of the same questions, but I'm also going to ask new questions based on our conversation from last time.
- Same rules as last time – one person at a time. No right or wrong answers.

Suggested Questions:

1) In a recent activity in science class, you engaged in an engineering design challenge that involved the topic of physics, namely forces.
    a. What did you like about the way you learned about forces? Why? Not like? Why?
    b. When we last left off, we started talking about group work in science class and you talked a bit about what you liked and didn't like. In your most recent science activity, you worked in groups on a STEM/engineering project – what did you like about this? Not like? Why?
    c. [*Optional:* What do you like the most about labs?]
2) Last time we talked about careers in science and whether or not you would be interested in one.
    a. On a broader level - what do you know about jobs/careers in science?
    b. Some of you indicated interest in a job that uses physics, but had other careers in mind. What would make a career involving physics more interesting to you? [What would it take for you to change your mind and more seriously consider a career that involves physics?]
3) Why is it that you are interested/not interested in your science class in school? What makes you excited about science? [e.g., topic, labs, group work, etc.]
4) [*Optional*] How do you see yourself in your current science class?
5) [*Optional*] What do you think about the other boys/girls in your class?
    a. How do other students in your class make you feel about your ability to do well in science?
6) [*Optional*] How do you see yourself in science outside of school? How do you engage in science outside of school?

Figure C-1. Focus group 2 interview protocol.

APPENDIX D

Focus Group Meeting 3 Semi-Structured Interview Protocol

Focus Group Round 3

Welcome:

- Last time we met we talked about a variety of things concerning science in school and science as a career.
- Today I might ask a few of the same questions, but I'm also going to ask new questions based on our conversation from last time.
- Same rules as last time – one person at a time. No right or wrong answers.

Suggested Questions:

1) What are you planning on doing for you're my Own Science project?
   a. In terms of – science topic (i.e. what kind of science)
   b. In terms of – activity
2) What interests you in this chosen topic/activity?
3) Describe what you think of when you hear the word *physics*.
4) Think about all that you have learned in your science/physics class this year. Have you at all more fully considered a career involving physics?
   a. What is important to you in thinking about a career?
5) Think about all of the things you've done in science class so far this year – what has been your favorite and why? (include topic!)
6) [*Optional*] How do you position yourself in your science class this year? (i.e. are you good/bad at science? What about outside of school?
7) [*Optional*] What is the most important thing you think you will learn in this year's science class?
8) [*Optional*] After having science every day for about half of the school year, what do you think about science?

Figure D-1. Focus group 3 interview protocol.

APPENDIX E

Day-by-Day Breakdown of Integrated STEM Unit by Fellow, Including Codes

Day	Ralph		Shana	
	Description	Codes	Description	Codes
1	Students were introduced to forces by first taking notes. Ralph described different types of forces by relating to real-world contexts that students were familiar with, building on their prior knowledge as well. Instruction included teacher presentation and class discussion, demonstrations, and short activities in which students worked with partners and spring scales.	LINK AMAZE FHE APPL SCPed CONTENT CONTEXT	Shana introduced the engineering design challenge and allowed students to come up with engineering definitions. She related this to the candy bag unit. Students analyzed the client letter to identify what science and mathematics concepts they need to learn. Instruction included discussion, working in small groups, and building teamwork skills.	LINK DISS COLL CONTEXT SCPed TWComm
2	Introduction to buoyancy through five different laboratory stations, including pushing empty bottles under water to "feel" buoyant forces. Goal of the labs was for students to either quantitatively or qualitatively experience the buoyant force on different objects in laboratory stations.	AMAZE FHE HUMAN COLL SCPed CONTENT TWComm	Students are reminded of the engineering design challenge. Shana leads the class in understand the relationship between cm^3 and mL, reviewing students' prior knowledge of volume. Shana shows students a video made by Ralph that shows him connecting cm^3 to mL in order to measure volume.	AMAZE QUANT LINK CONTENT
3	Student review the laboratory activities through teacher-led class discussion, relating buoyancy to volume. Ralph relates volume to the cube activity from a few weeks earlier. Students watch a video that Ralph made, relating buoyancy and volume and graph this relationship using a best-fit line, as well as relating to experience. The class reviews their knowledge of engineering, coming up with definitions for terms.	LINK DISS CONTENT	Students review from the previous day and are introduced to measuring volume of irregular objects through displacement. Shana relates this phenomenon to real-world experience (ice to a full glass). Students engage in first-hand experiences to measure the volume of irregular objects using displacement to draw an understanding of displacement.	LINK APPL AMAZE FHE COLL CONTENT SCPed TWComm
4	Students are formally introduced to forces vocabulary, where they write and relate to previous notes and/or demonstrations. Students are introduced to displacement through a laboratory activity including the centimeter cubes and graduate cylinders. This is related relate to volume and further to understand the mass of water.	AMAZE LINK FHE QUANT COLL CONTENT SCPed TWComm	Students review measuring volume through displacement and are introduced to forces and force diagrams, relating to real-world experiences and also to the engineering design challenge. Students take notes, but also engage in discussions, demonstrations, and first-hand experiences with spring scales and buckets.	LINK DISS AMAZE FHE COLL CONTEXT TWComm

Day	Ralph		Shana	
	Description	Codes	Description	Codes
5	Continued discussion about using displacement of water to measure the volume of an object. Ralph introduces students to maximum capacity, where he tests this in front of the class as a demonstration.	LINK AMAZE CONTENT	No observation was conducted on this day.	X
6	Students create a foldable which allows students to write their own definition for vocabulary word. Students share examples to the class. Ralph does a demonstration of Archimedes' principle, which students relate to by sharing their prior knowledge.	AMAZE LINK COLL SCPed TWComm CONTENT	Students review displacement and buoyancy through definitions and also relating to Archimedes' principle. Shana uses a triple beam balance to show this principle. She also relates this to watercraft challenge, during which she discusses how to calculate maximum capacity.	LINK AMAZE QUANT HUMAN DISS CONTEXT CONTENT
7	Ralph shares a magazine with the students that highlights the story of a high school student who built a submarine, which focused on engineering and buoyancy. Students take a brief quiz and watch a Bill Nye video on buoyancy.	APPL AMAZE CONTENT	Students are reminder of the engineering design challenge, and prepare for a quiz. Students are reminded of the maximum capacity equation, which is needed for the challenge, and practice doing this calculation. Students also do practice collecting data at laboratory stations after a demonstration.	FHE LINK QUANT COLL CONTEXT SCPed CONTENT TWComm
8	Students are introduced to the engineering design challenge – create a watercraft prototype that could be used in a flood. Introduction to engineering design challenge. Students are introduced to the journal, where they are to write down daily goals as well as the design of the group work such that there is a competition between classes. Students learn about the materials and relate certain items to buoyancy and volume.	QUANT FHE COLL CONTEXT CONTENT TWComm EDC	Students learn about the materials they will be able to use and discuss what they might need them for. Students learn about the jobs, which Shana relates to engineering. Students come up with questions to test and plan for materials testing in their groups. Students take a short quiz.	LINK COLL SCPed CONTEXT TWComm EDC
9	Ralph reviews how students are to use with engineering journal and reviews the client letter, focusing on the goals, which include an emphasis in calculating the maximum capacity correctly. Students are introduced to roles and begin brainstorming in groups of the same role. Ralph helps the math masters figure out how to measure volume of materials.	QUANT FHE DISS APPL COLL CONTEXT CONTENT SCPed TWComm EDC	Students work in their groups and test materials, recording data and observations. Students spend time reflecting on learning and prepare for their first day of building, when they will be allowed to test in the aquarium in the room.	FHE QUANT DISS COLL CONTEXT CONTENT SCPed TWComm Fail

Day	Ralph		Shana	
	Description	Codes	Description	Codes
10	Students individually write down their responsibility to their engineering group. Students confirm with each other that they know what their constants are in testing their individual pieces of the watercraft. Groups work on their task, collecting data.	FHE APPL QUANT LINK COLL CONTEXT CONTENT SCPed Fail TWComm EDC	Shana stresses the importance of engineer's journal to keep track of progress and reflections. Students discuss their results from testing, and move forward with planning their. Students talk in small groups before sharing with the class.	FHE APPL DISS LINK COLL CONTEXT CONTENT SCPed TWComm EDC
11	No observation was conducted on this day.	X	No observation was conducted on this day.	X
12	Students work in their groups to finish drawing their watercraft design and creating a shopping list. Student begin build their watercrafts. Students are reminded that they are competing with other classes and should talk between groups. Ralph reminds students that they need to calculate volume in order to calculate max capacity.	FHE LINK QUANT APPL COLL CONTEXT CONTENT SCPed EDC TWComm	Students work in groups to build their watercrafts. They also work on calculating the volume of individual pieces, and Shana guides students through this quantitative work. Shana reminds students that they are to work together, that they are competing with other classes.	FHE LINK QUANT APPL COLL CONTEXT CONTENT SCPed EDC TWComm
13	Students finish building watercrafts, calculating volume, drawing, and calculating max capacity. Ralph reminds study of the of safety factor that will be used in testing. Ralphs draws student groups to focus on the quantitative table that included calculations of volume. Emphasis on being a team player.	FHE LINK QUANT APPL COLL CONTEXT CONTENT SCPed EDC TWComm	Student finish building, calculating volume, and calculating the maximum capacity of their watercraft. All students work on a "final report" page, which needs to include details and labels on the design drawing as well as information about volume, mass, and maximum capacity.	FHE LINK QUANT APPL COLL CONTEXT CONTENT SCPed EDC TWComm
14	Students focus on design drawings and identifying forces. Students use a digital scale to find the mass of their watercraft, calculate the total volume, and calculate the maximum capacity. Ralph enforces that groups should be working together. Ralph gives students information on testing procedures.	FHE LINK QUANT APPL COLL CONTEXT CONTENT SCPed EDC TWComm	Students test their watercrafts. Shana adds mass equal to the predicted maximum capacity of each watercraft, minus the safety factor of 20g. Students spend time reflecting on their watercraft in their journal.	LINK FHE QUANT COLL CONTEXT CONTENT SCPed EDC Fail TWComm
15	Students test their watercrafts. Ralph adds mass equal to the predicted maximum capacity of each watercraft, minus the safety factor of 20g. Ralph reminds students that each member of the group needs to have their journal complete.	LINK FHE QUANT COLL CONTEXT CONTENT SCPed EDC Fail TWComm	No observation was conducted on this day.	X

APPENDIX F

Descriptions of Blue and Orange Groups' My Own Science Projects

Name	Project	Science	Influences
Rachel:	*Um, I'm making my own battery with nickels, pennies, vinegar, salt, and a digital multimeter.*	Engineering Physics	Father Website mentioned by Ralph
Megan:	*And they gave, like, a list and since I like cooking, I went to the cooking things. My mom and me were looking through it and it said, "How much sugar does a fruit have?" So, we were like, "How do you – how do you determine that?"*	Science-like Chemistry	Mother Website mentioned by Ralph
Monet:	*Um, so I let her [friend] do it and she wanted to build, like, like bath bombs, like on the website. I was build you own bath bombs, but switch up some of the ingredients and everything. But then you needed, like acid, and, like, all sorts of stuff and we didn't really know where to get it. So, when it was, like, due the other day ago, we have to, like, quick change it and Mr. Ralph just told us to, like, measure some bubbles. So, we're gonna, like, dump, like, a cup of soap or something into, like, a bowl, and then we're gonna dump hot water over it and measure the amount of bubbles.*	Scientific method Science-like Chemistry	Ralph's suggestion due to time
Samantha:	*Um, I'm doing an egg drop [ED: Okay]. You make a box and one has, like, cotton balls, and the other has bubble wrap, and maybe another one with fabric or something. And we drop it from a ladder and see if the egg – cause we put an egg in it – and we have to see which one, if the egg breaks or not.*	Scientific method (student identified)	*Samantha: I kind of like doing random stuff and experimenting with things.*
Lindsey:	*Um, I'm doing a baking soda and vinegar rocket experiment. So, like, I'm going to take a rocket and I'm going to measure, like, I'm kind of stuck on what I'm measuring, but I decided to do it by seconds. So I re…um, so I time how long it takes for it to go up and down.*	Scientific method Physics Chemistry	*Lindsey: Well [chuckles], last summer, I would do a lot of rockets and stuff with my brother. It was really fun, so I decided to do it.*

Name	Project	Science	Influences
Alisa:	*But we're thinking of like, making marshmallows with different ingredients and then what people would actually, like, use, like, manufacturers like Kraft and stuff. [I: Okay]. And so we just – we're going to do, like, different, like, ingredients and stuff. That's what we're going to do, but we're still not very sure yet.*	Scientific method Science-like	*Mr. Ralph told us about it and we just kind of, Alisa: Ok, we should do that," because we still didn't know what we were going to do.*
Cass:	*Ok, so what I did – I made rock candy and I varied the water and that's a scientific experiment…a scientific method experiment because you're changing a variable.*	Scientific method Science-like	*Cass: I was craving rock candy*
Evelyn: *[Ashlyn]*	*I did a paper mache volcano. It was a scientific experiment [Ashlyn: We were partners] because we were changing the amounts of baking soda and vinegar we were putting in the volcano to see the effects of it.*	Scientific method Science-like	*Evelyn: "And I did it because…a paper mache volcano was kind of like the stereotype of the science experiment, but I've never actually tried it."* *Ashlyn: "Yeah, we just thought it was a cool idea because a lot of people have done it on TV shows, and, um, so we just wanted to try it."*
Brianna:	*And we made, like, a jacket, well, not really, not a jacket, but we made…we sewed some mittens to a jacket because it's…so you can text easier when it's cold outside.*	Engineering-like	*Brianna: Um, we kind of just thought, like, when it's like winter time people don't like when their hands get cold when they start texting. So we wanted to like…that.*
Roberta:	*Well, I was gonna, um, make a bouncy ball and test how the Borax affected it.*	Scientific method Chemistry	*Roberta: Well, I did it before, so I just knew how to do it.*
Zara:	*So, my friend has two bunnies, so what we did was we took…we made a maze for them. And then we attached some food onto a string and then lured them through it to see which one was faster. Like, if the size of the bunny affect it's, like, it's ability to go through the maze. [I: Okay] And so we did that. And it was a scientific experiment.*	Scientific method Social sciences	*Zara: Um, well, we were kind of interested to see if, like…cause she has a fat bunny and a sort of not so fat bunny {girls giggle} and we were seeing if the fatter bunny would go through faster or if the smaller bunny would go through faster.*

Name	Project	Science	Influences
Raylen:	*I did, like, an egg drop challenge. It wasn't a…it wasn't an engineer project. I did scientific method. I tried three different things: bubble wrap, cotton balls, and yarn for some reason.*	Scientific inquiry (student identified) Physics	*Raylen: Well, I had done the engineer part of it [I: Okay]. I wanted to see what it would be like with scientific method.*
Lisa	*We were going to see if baking soda made a difference instead of baking powder when you make pancakes.*	Science-like Chemistry	*Jessica: Well, we just wanted to bake something.*
Jessica:	*Yeah, so, we made half of the batch with baking powder and half with baking soda. And we found out that the pancakes with baking soda are thicker.*		

APPENDIX G

Descriptions of Red and Green Groups' My Own Science Projects

Name	Project	Science	Influences
Preston:	*We're gonna make marshmallows. And then, like, change the ingredients or take some out and see how it turns out.*	Scientific method Science-like Chemistry	Website mentioned by Ralph
Preston:	*And then, uh, on that – it had, like, uh, this topic that was "in the kitchen" and it had, like, making marshmallows and so I thought we would do that and, like, change the ingredients. I wanted to dye them pink and put sparkles on them.*		
Frank:	*And we used the scientific method [I: Okay] and we were comparing, like, using or not using sugar or using flavored gelatin and not flavored gelatin.*		
Robbie:	*Um, I wanna build, like, a mousetrap car. He showed it on, like, a website. The thing about doing it was like having, like, three mousetraps on each side and three strings on each one…er, three strings on each mousetrap. I said that wrong. Three mousetraps with three strings. And having them – the strings – all connected to the wheels. And then, like, have someway to like snap down the mousetrap, so then it, like, shoots out.*	Scientific method (student identified) Physical science	Website mentioned by Ralph
Jose:	*Well, I'm doing the jaw profile of a crocodile and a tiger shark. And I'm trying to find some things, like, websites, and things.*	Life science	Personal interest
Thomas:	*It's called like a matic machine. It's kind of like a crane. It's, it's like an air pressure powered popsicle stick. Where, like, I pump air through the one and then it pushes the back end and it pushes the popsicle stick.*	Engineering design challenge Physics	Website mentioned by Ralph
Donovan:	*I read an article. It was like, like the friction of a skateboard, I think.*	Physics	*Donovan: I did because I didn't want to do no project.*
Nate: *[Joe]*	*Um, Joe and I did speed, like scientific method. Um, we had a radar and a tennis ball, like, and we were throwing it, like, using our leg power and not using our leg power. and seeing how, like, that affected the speed of it.*	Scientific method Physics	*Nate: We both play baseball.*

Name	Project	Science	Influences
Lloyd:	*Hmm. We took this basketball and we dropped it from 50 inches high and we would…we did it on linoleum, wood, and carpet and we saw…we, like, caught the ball on the first bounce at the highest point. And we'd see, um, what was the highest. Like, what was the highest bounce.*	Scientific inquiry Physics	*Lloyd: It looked pretty easy.*
Jimmy:	*Um, well, I had two other partners and what we did was – we took, we bought a slingshot. We had…we took a bouncy ball, cardboard, and one of my friends...one of my partners' arms and we like slung, like slung the, um, the bouncy ball at a cardboard box three times and recorded the data, then did the same with his arm. We timed it, recorded the data. Once he was done throwing it, we calculated the averages.*	Physical science Scientific inquiry	*Jimmy: I don't actually know, cause, like, Ms. Shana, when we had the first thing, we were going to do something with a catapult then we were like, why are we going to build a catapult. Why don't you…why don't we either build a slingshot or just buy a slingshot because it would be a lot quicker and a lot cheaper.*
John:	*It's basically a rock candy experiment testing between regular sugar and brown sugar. And they both pretty much failed.*	Physical science Science-like Scientific method	*John: I've done it before except it actually worked. The other time.*
John:	*Um, well, I mixed them in, like, a half-cup of water and then tied string to a pencil then laid the pencil on top of the jar and then covered it in saran wrap and let it sit for six days.*		
Felix:	*I made ice marbles.*	Physical science Science-like	*It was easy.*
Felix:	*I put food coloring and water in a balloon and let it freeze for 5 hours*		