Engaging Urban Students in Engineering Design to Determine Shifts in Attitudes Toward STEM

by

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This study directly pertained to the daily work of teachers of urban students in STEM (science, technology, engineering and mathematics) courses. According to a 2016 study, between 8-12% of students of color are interested in STEM (Neuhauser & Cook, 2016). However, growth in STEM occupations is expected to increase 8.9% by 2024 and STEM degree holders can have higher earning potential than non-STEM degree holders (Noonan, 2017). More importantly, skills learned through STEM are useful across fields. Lack of interest by students of color in STEM means they will miss out on both opportunity and critical skills. To increase student interest, educators may ask the question: *How do I engage more students of color in STEM?*

This study sought to determine shifts, if any, among student engagement in a physics course at an urban school. The teacher, who was also the researcher, engaged students in Next Generation Science Standards (NGSS) aligned mini-unit to monitor changes in attitudes towards STEM as a measure of interest through surveys, focus groups and student reflections. The purpose of this study was to understand how teachers can help improve students of color's interest in STEM through completing activities within their own classrooms. As a result of data gathered in this study three subgroups emerged amongst participants: STEM Persisters, Science Communicators and STEM Critics. Students showed interest in the use of critical school science to learn and showed knowledge of science content. However, students did not

show greater interest in pursuing science careers from the beginning to the end of the three-week study. Engaging students in critical school science has positive implications for their attitude towards STEM, but further longitudinal studies should be done to determine if their positive attitude can be maintained across STEM courses and through post-high school pursuits.

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Dedication

In dedication to my grandparents: Gennie Harris, William Penn Harris, Idabel Greene Jones and George Jones. Who all believed in the power of education, were wise beyond their years of school, were examples of strength in the face of adversities and never stopped believing in me. I am because they were.

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1.0 Problem Area

Low-income, students of color's achievement in science has consistently lagged behind higher income, non-students of color's achievement in science. In the latest science report card from the National Assessment for Education Progress (NAEP), 8th grade students who scored below the 25th percentile on the science portion were 67% black or Hispanic and 72% eligible for free or reduced lunch (NCES, 2012, p.11). The implications of lagging low-income, students of color's achievement are greater than performance on a test. Students from these communities are less likely to major in STEM fields and pursue careers in this area, leaving these fields with very little diversity. According to the 2016 US News/Raytheon STEM Index data, only 8% of African American students are interested in science and 12% of African American students are interested in engineering in high school. For Hispanic students 10% are interested in science and 17% in engineering in high school. This means that for the students surveyed, the majority of African American or Hispanic students do not see themselves as scientists or engineers. If students do not see themselves as scientists or engineers, they are less likely or unlikely to major in these subjects or persist into the STEM pipeline in the workforce. As a result, it is of particular importance to engage these students in STEM so that there is greater interest and self-motivation towards better achievement. The methods by which science is taught to all students, but especially urban students should be analyzed to determine what can assist in raising student achievement. Systemic inquiry in teacher education would be informed by: how students learn best and innovative science methods by practice and subject strand in science.

In schools where over 90% of students receive free or reduced lunch, the outlook may look bleak. A recent study on disadvantaged students in OECD countries noted "that disadvantaged schools tend to reinforce students' socioeconomic inequalities" (OECD, 2012, p. 107). Data from the PISA and TIMSS studies repeat the science data from the NAEP mentioned earlier, students from disadvantaged backgrounds perform lower and students in schools where there is less variability in socioeconomic backgrounds perform even lower (OECD, 2012). Yet, these schools still exist in across the United States from metropolitan cities to rural towns (Orfield & Ee, 2017). Based on this OECD data and the recent Civil Rights project report by Orfield and Ee, students in schools with homogeneous low socioeconomic range perform lower than students in schools with greater variability in socioeconomic status. They also have less educational and enrichment opportunities as a result. This recommendation requires a larger, more systemic shift for low income students and in a city like DC, that is not currently possible. As a result, individual schools and teachers must make other changes to improve outcomes for low income, students of color.

1.1 Problem of Practice

Every stakeholder to this problem has a different role, but all are connected. Rather than focusing on aspects of a student's life that a school cannot fix, there are in-school improvements that can be made. "Many urban, low-income students describe science as a discipline that generates sentiments such as boredom, anxiety, confusion, and frustration" (Basu & Barton, p. 466). While anxiety, confusion and possibly frustration come from a similar sentiment with regard to achievement, boredom likely does not. Whereas some students exhibit the same anxiety or confusion in science courses yearly, other studies have shown changes in student perspectives in science from one level to the next as their voice and interest are no longer validated or encouraged (Carlone, Scott & Lowder, 2014). Interest is defined by the Merriam-Webster dictionary as "a feeling that accompanies or causes special attention." Where students may have interest and excitement in elementary school, the interest and excitement wanes and disappears as students enter middle and high school science (Carlone, Scott & Lowder, 2014; Osborne, Scott & Collins, 2003; Vedder-Weiss & Fortus, 2012).

One form of interest in science education can be seen through the analysis of attitudes. Eagly and Chaiken (1993) define attitude as "a psychological tendency that is expressed by evaluating a particular entity with some degree of favour or disfavor" (p. 1-2). How students respond to science and what how they behave in science classes including their achievement can be attributed to their attitude toward it. This construct, attitude, is of particular importance as Reid (2015) describes attitudes to have three components: cognitive, affective and behavioral. Reid asserts that attitudes are challenging to measure because they must be inferred (Fig. 1), but are still an important focus for research. Reid also notes that issues with attitudes should be addressed from the standpoint of revising curricula to determine where students are positively affected because "it is … likely that poor attitudes towards the sciences are caused by the way sciences are presented at the school level" (p. 32). This is of particular importance to all science educators, but especially urban educators, who may teach science in a way that maximizes control over students (as encouraged by administrators), but does not shift student interest towards the subject matter temporarily or for the long term.

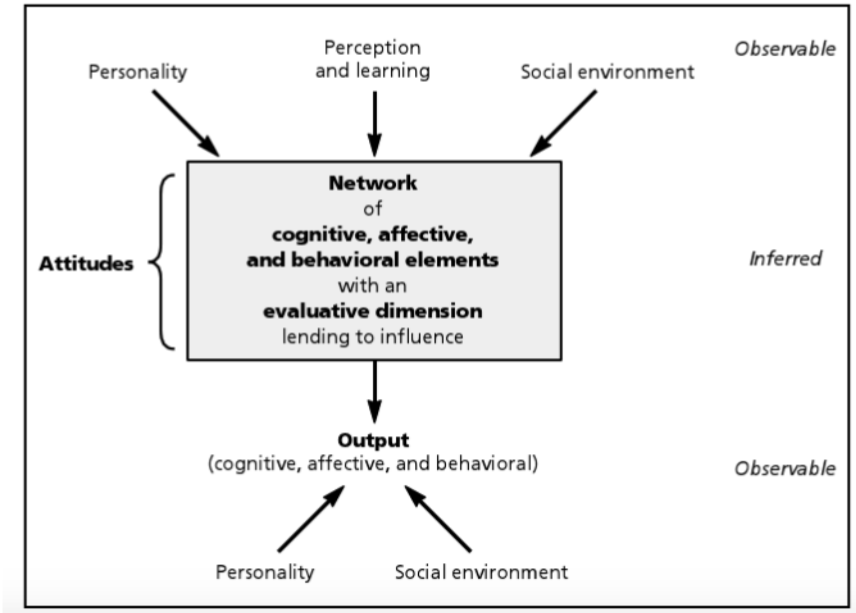

Figure 1 Nature of Attitudes (Reid, 2015)

1.1.1 Conceptual Framework

How science is presented to urban students has a direct influence on their attitudes toward science. Zacharia and Calabrese Barton (2004) characterize school science in three distinct ways: traditional (TSS), progressive (PSS) and critical (CSS). When observing a class that is engaging in one of these types of school science, very distinct patterns are visible. TSS classrooms find students in a position to follow rote lab procedures with little discovery of concepts, if any. Students are clear that it is the instructor/textbook that has all the answers and the students must know the answers as written. PSS classrooms are based on current reform methods and students are presented with information in a way that supports their discovery of concepts and processes similar to the practices of a scientist. Students learn the content in a meaningful way by being immersed in the habits required to obtain a holistic view of science and its applications to everyday life. Lastly, CSS classrooms are about science being connected to what students are doing every day. The experiences that students have outside of school are integral and interconnected to science knowledge and this positions them as knowledgeable from the inception, rather than after a unit is over.

Zacharia and Calabrese Barton (2004) outline six different components of each type ranging from: the nature of science to the goals and purposes of science education. Their table is figure 2 below. In evaluation of the three types of science outlined in the table below, the types of science that give students more voice, opportunities to learn in authentic ways and contribute to science through discourse and creation of new explanations would seem to be critical to improving student attitudes about science. Zacharia and Calabrese Barton found that in their study of middle schoolers, students did not perceive the CSS projects as science, but were positive about them. In contrast, they viewed the PSS projects as science because of their relationship to the school curriculum, but did not rate these projects as positively like they did the CSS projects. What students classified as "science" or not was influenced by their perceptions of what science is or is not from previous years of education and taking science courses.

Table 1 School Science Traditions (Zacharia and Calabrese Barton, 2004)

Type of Science	Traditional School Science	Progressive School Science	Critical School Science
Nature of Science	Positivist world view- scientific knowledge is an objective representation of how the world works.	Scientific knowledge is what scientist produce, and is broadly constituted across ideas, discursive practices, and habits of mind.	Subjective world view- scientific knowledge is a human made explanation of how the world works and therefore scientific knowledge is embedded with human values and characteristics.
Ways of knowing and evaluating science	Concepts are really explanations of natural phenomena to be mastered for tests.	Concepts are really explanations of natural phenomena that can be described and talked about in many ways. The focus on "ways of knowing" in school is primary upon students' conceptual understanding of "big ideas" but also upon their abilities to acquire scientific ways of talking and acting.	Concepts are subjective explanations of natural phenomena to be applied in everyday life activities. Science is a social activity and therefore it involves understanding of how human values and characteristics shape scientific knowledge and understanding.
School, science and society	Scientific concepts are seen as outcomes in and of themselves.	Scientific concepts are seen as a commodity for dealing with in-class science problems and scripted human applications.	Scientific concepts emerge from dealing with societal problems/real life and the needs of the local community, which are seen as fundamental to the creation and production of science.
Science as a school subject	Organized and tested knowledge must be "transmitted" through lecture and strict experimental procedures.	Organized and tested knowledge interconnected with mathematics and technology.	It includes content, process and discourse. It also involves the production of values and beliefs about how scientific knowledge is created and validated, as well as who we must be to engage in that process.
School science and student relationships	It positions students in a relationship where only they can change- one-way relationship.	It positions students in a relationship where only they can change – one way relationship.	It positions students in an articulated relationship where both science and students can change- two-way relationship.
Goals and purpose of science education	Students have to memorize scientific knowledge and procedures within the structure that was established. Science is for the scientists.	Students must develop the understandings and habits of mind they need to become informed citizens.	Students must understand that they are users and produces of science and develop the understandings and habits of mind they need to become compassionate and informed human beings.

2.0 Literature Review

A review of the literature was conducted to determine existing research around attitudes and school science. Until this point, much of my interest is organic, out of direct experiences within the classroom, from the last 14 years. Students come into my high school science classes interested in what engaging thing I may show them, but not necessarily interested or prepared to complete more complex tasks. However, I always wonder, how did students get to this point? What causes some to be interested in what a teacher may show while others insist on “book work” and packets? There is a vast body of research from national to international settings that investigates student interest, attitudes, motivation and instructional methods. This review is not exhaustive but attempts to hone in on studies that are most connected to my own educational setting when possible. The review first summarizes specific factors that influence interest levels of students in science. These factors can have both positive or negative effects. The review then summarizes instructional or curricular methods teachers, researchers or organizations employ to increase student interest in science.

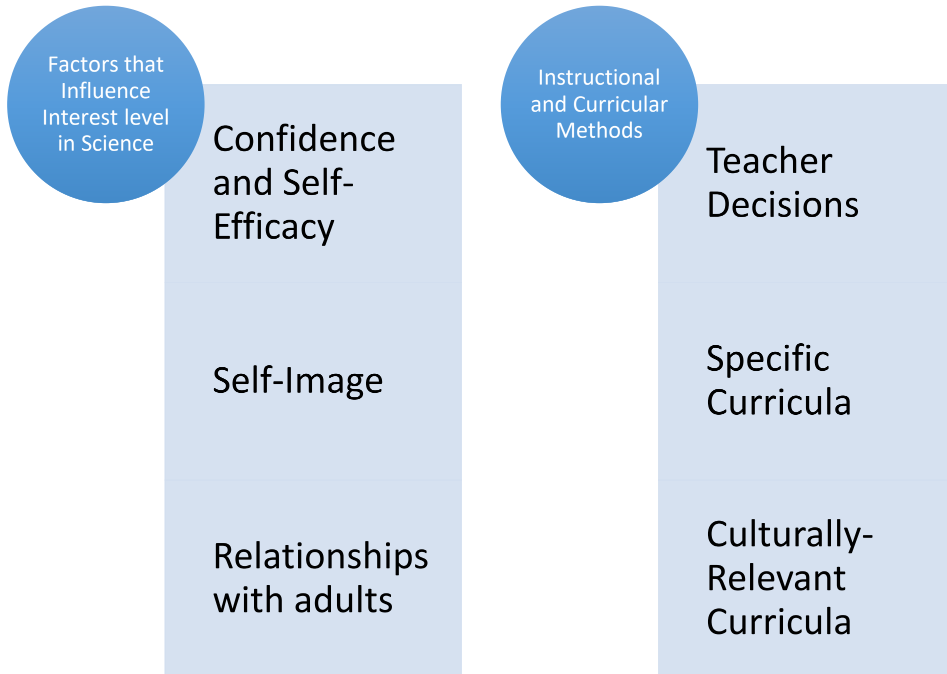

Figure 2 Organization of the Review

The following questions guided the literature review:

1. What causes students to have or lack interest in science in secondary schools?
2. How do different instructional methods and curricular materials impact students of color's interest in science?

2.1 Interest or Lack Thereof in Science

From my experience, students' interest in a subject can change student achievement and perseverance with difficult tasks in a subject. The literature was analyzed to determine if these experiences are similar to what the research says for why students persevere in subjects like science. In addition, the literature was analyzed to identify the factors that promoted or lessened interest.

2.1.1 Confidence and Self-Efficacy

Self-efficacy is defined as one's ability to believe that he or she can complete a task or accomplish a goal (Bandura, 1997). The implications of this are integral to attitudes towards STEM and more broadly, achievement in STEM. Self-efficacy is noted as a key factor in students' perseverance in a particular subject area regardless of academic achievement (Bandura, Barbaranelli, Caprara & Pastorelli, 2001). Sheldrake's (2016) study on student confidence showed that student confidence was directly related to their attitude toward STEM from self-efficacy or self-concept. The purpose of Sheldrake's study was to make connections between confidence level and goals to study science beyond compulsory education. Sheldrake states "Considering students' confidence may help ensure that their future choices are not unnecessarily constrained" (p. 1270). While the goal of this study was not to encourage students to continue studying science beyond high school, researchers found other implications. Sheldrake realized that having an interest and positive self-efficacy has implications for current achievement. Therefore, the achievement students reach will continue to allow a path for further aspirations beyond high school.

2.1.2 Self-Image

How students feel or imagine themselves in science has an effect on whether they want to achieve or persevere in STEM. Common characteristics of students who are interested in science further are students who felt included in the classroom culture and therefore believed that they were scientists (Christadou, 2011). Further, students who were high achieving, whether for good grades or being rewarded for compliance also identified as scientists presently or being interested in science as a career (Aschbacher, Li & Roth, 2009; Brickhouse, Lowery & Schultz, 2000).

While some students did not see themselves as scientists because it was too complex, (Archer, Dewitt, Osborne, Dillon, Willis & Wong, 2010) these same students identified interest in science because of activities they participated in. However, students in studies noted that there were places where science can be a tremendous amount of fun. Studies cited out of school science whether with a specific program (Franklin, Conrad, Aldana & Hough, 2011; Tan, Barton, Kang & O'Neill, 2013) or through their own investigations at home (Archer, Dewitt, Osborne, Dillon, Willis & Wong, 2010) as two places where this may occur. It should be noted that this did not always mean that science was safe with regard to lab materials and chemicals. Actually, in some instances it was unsafe with regard to lab materials and chemicals, but students felt a greater level of enjoyment rather than in school science.

2.1.3 Relationships with Adults

For many students, studies consistently showed that parental support helped to continue or increase their connection and prolonged interest in science (Archer, Dewitt, Osborne, Dillon, Willis & Wong, 2010; Aschbacher, Li & Roth, 2009; Brickhouse, Lowery & Schultz, 2000; Tan, Barton, Kang & O'Neill, 2013). These parents are cited as encouraging hobbies, supporting understandings at home or being engaged by the school to participate in science activities and doing so. This shows not only a level of family engagement, but also a level of interest in science from the parents themselves.

Other studies cited that students saw particular classroom teachers as having interest in them and their prolonged success in science in a way that continued to propel them forward (Carlone, Scott & Lowder, 2014; Cristadou, 2011; Kanter & Konstantopoulos, 2010; Meyer & Crawford, 2015; Tan & Barton, 2009). Other students found their interest through out of school volunteers, staff members and scientists who were able to encourage them and lead by example to increase interest in science (Franklin, Conrad, Aldana & Hough, 2011; Tan, Barton, Kang & O'Neill, 2013).

2.2 Instructional Methods and Curricular Materials

Educators have attempted to shift classroom methods in an effort to increase interest or attitudes. Instructional strategies like teacher decisions to allow students to do projects based on interest, integrating their own culture or allowing additional time outside of class to work on science related projects are important in fostering interest (Bang, Warren, Rosebery & Medin, 2012; Basu & Calabrese Barton, 2006; Carlone, Scott & Lowder, 2014). This connects to both PSS and CSS science, but not necessarily at the same time. Projects can be based on student interest, but not necessarily start with the outside world or make direct connections to what students understand about their life outside of school.

Some specific curricula has been used, but while it may have served one goal like achievement, it did not always result in a positive change in student attitudes and interest. In the Kanter and Konstantopoulos (2010) study, students used the PBL curriculum "I Bio" to give teachers professional development and track student achievement and attitudes and interest in science careers. The "I Bio" curriculum connects to students' everyday life with analysis of school lunch and its connections to biological processes in the human body with a series of lessons. While this study did show increases in student achievement, there was a decrease in students' attitudes and science career interests as a result. For game-based learning, 5th grade students engaged in playing Crystal Island to see shifts in student achievement and self-efficacy (Meluso, Zheng, Spires & Lester, 2012). Positive outcomes were seen with regard to increasing self-efficacy and student achievement. However, the game play could be solitary or team based and positive outcomes were still seen.

There has been another study of culturally relevant computer science curricula. While this study does not focus on the use of computer science exclusively, it was a way to engage students in particularly challenging content, that is high interest, but also usually out of reach to students of color due to lack of exposure. These curricula connected culturally relevant themes from ancient Mayan cultures and Latino culture and was used in a highly populated Latino area of California. Because of experiencing the curricula, while academically challenging, 43% of students had increased interest in computer science. Also, greater than 90% enjoyed and learned a lot about computer science as a result of participating in the program. This program was after school and not during regular school hours for another example of when students find greater interest in the way science is presented outside of traditional school.

2.3 Discussion

The research on students' interest and attitudes in STEM is extensive. It includes a variety of ideational and relational factors to explain why students have positive and negative perceptions of their achievement in these areas. Unfortunately, the need to make connections to the outside of school lives of students of color is not disconnected from the research, but has been seen as a topic that is not connected to what students do in school science. (Bang, Warren, Rosebery & Medin, 2012). Therefore, educators must actively make these connections and changes to the curriculum to keep students interested. Some may feel that this is a tactic for younger students, but if students are still academically behind when they enter high school or disengaged from the activities of school, there is still a need to ground the work students do in school, especially in STEM, to their lives outside of school. Mickelson (1990) who theorized the attitude-achievement paradox among African American students states that an "often-neglected but critical factor in the level of achievement may well be the student's perceptions of what her or his efforts and accomplishments in school ultimately will bring from the larger society" (p. 59). If students do not feel, especially in high school in their last sheltered preparation to enter the world, that what they learn in school has implications and will help them to be successful in the world, then their attitude and achievement will not increase. While Mickelson relates this to society's interest in hiring African Americans, it can also be said that if African American students felt that what they learned in school could help to solve problems and make advancements within their own communities, then they might display more positive attitudes and demonstrate achievement gains. Students need to know that they can and should use STEM to solve problems and make improvements within their communities. Unfortunately, students in urban schools rarely believe that science has those answers.

Further, many studies show a positive effect of relationships between adults (parents, teachers, mentors, volunteers) and student interest and attitudes but few studies have focused on student peer relationships in the classroom If we want our students to see their classmates as resources, then we need to focus on peer relationships as well as adult-student relationships.

My review of the research showed gaps in the specific effects of engineering design challenges with high school students and especially their use in traditional K-12 classrooms rather than after school programs or summer programs. This study sought to fill in those gaps by conducting a small-scale case study. The focus of this study was on the impact of student engagement in critical school science (CSS) through a debate and engineering design challenge on their attitudes towards STEM. It also described features of the classroom instruction that may have enhanced or constricted that impact.

2.3.1 Inquiry Questions

1. How are high school student attitudes towards STEM affected by engaging in critical school science (CSS)?
    a. How are individual students versus the collective of students affected by engaging in CSS?

2. What factors in a CSS classroom environment contribute most to changes (if any) in student attitudes towards STEM?

3.0 Methods

3.1 Inquiry Approach

The research questions were evaluated through two levels of case study. One looks at the classroom as a whole as its own case. The other level looks at the cases of individual students as their own case within the classroom with the task. Robert Yin (2018, p.10) notes that "'how' and 'why' questions are more explanatory and likely lead to the use of a case study… trace operational processes over time." This study sought to do that with specific time constraints. The case study looked within a classroom, implementing a complex CSS engineering task to see how attitudes towards STEM of eight urban focal students are affected by physics class activities. Both student responses to the task as well as changes to the classroom environment as a result of engaging in CSS versus TSS and PSS were analyzed.

This study was completed within my classroom so I acted as both a participant and a researcher. All eight focal students who participated were informed of the research and assured that changes and data gathered is for the betterment of the classroom room environment and their learning and will not increase or lower their grade.

Task

The inquiry looked specifically at one unit of study that includes a problem students are solving with the creation of a solution. Students were open to determine how the proposed solution would minimize impact to the environment, but also solve the problem. Students were all in one physics course which meets every other day for 80 minutes.

Connections to Standards

The urban city where this study takes place adopted the Next Generation Science Standards (NGSS) in December 2013 instead of the then state adopted science standards to improve science instruction for area students. Every science classroom in the city uses NGSS to guide instruction for students. NGSS consists of three main components that allow for three-dimensional learning: disciplinary core ideas (DCI), crosscutting concepts (CCC) and science and engineering practices (SEP) (NRC, 2011). DCI are most similar to the previous, traditional science standards and are a description of the science concept a student should know. CCC are ideas that can be applied across any scientific domain and need to be highlighted so students recognize the applicability across various domains and lessons within a domain. Lastly, SEP are the habits that students should have when engaging in NGSS to learn, analyze and communicate findings. These dimensions connect to performance expectations (PE) that are what students are expected to do within a unit to show they have experienced these 3D learning cycles.

Instructional Model

In implementing these standards, it is encouraged by researchers that teachers use the 5E instructional model with students (Bybee, 2014). School district and state level administrators echo this sentiment and have encouraged it within the district for all science teachers. The 5E instructional model was created by a team, including Roger Bybee, at the Biological Sciences Curriculum Study (BSCS) as a research based instructional model that encourages the development of ideas through students' engagement in five stages: engage, explore, explain, elaborate and evaluate. While the model was created over 25 years ago, it has continued to be implemented across a number of academic levels within K-12 and new applied to methods needed to teach NGSS. NGSS and the 5E instructional method govern science instruction within all schools in DCPS indifferent to the type of school science that is implemented. While the 5E instructional method is widely known as a reform method (Bybee, 2014), its use has sometimes been incorrect allowing for more traditional methods posing as the reform based 5E model.

The mini-unit supports student understanding of the following NGSS Performance Expectations: *evaluate the claims, evidence and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other* (HS-PS4-3) and *design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering* (HS-ETS1-2) (NRC, 2013). These two performance expectations were supported within specific disciplinary core ideas, science and engineering practices as well crosscutting concepts for 3D learning as discussed previously.

The mini-unit follows the engineering design process found in figure 3 below (NAS, 2018). Students were presented with a question, "Should teenagers keep their cell phones in their bed at night?" Students were presented with research to determine the validity of the problem. Students were presented with two sides of an argument regarding the effects of cell phone radiation on human cells and asked to take a side. Students from opposing sides had a debate and then made a plan of action together on what to do next. The grounding of the unit in a problem students grappled with leans the unit towards critical school science from progressive school science. This was integral to driving their solutions and the solutions of others, therefore it remained within the critical school science classification rather than the progressive school science classification. The general conceptual flow and 5E plans of the mini-unit can be found in appendix A. As a result, the work that students did through this group project of 3-4 students, across 3 weeks within the classroom.

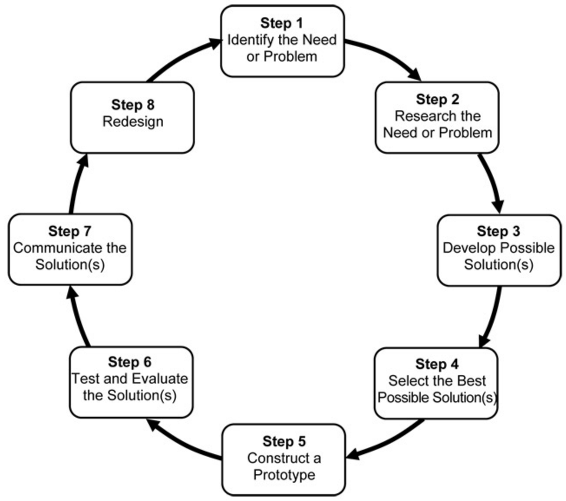

Figure 3. Engineering Design Process (NAS, 2018)

3.1.1 Positionality

I am an African American woman who went to public schools, of varying quality, my entire K-12 career in a number of different states. I can remember times where science was taught in a way that was very engaging to me and I can also remember times when science was taught in a way that I found very boring. However, from a very young age STEM subjects were of major interest to me and my parents cultivated it for my siblings and myself. For most of my childhood, my father was a service manager for a large computer corporation. I remember having a computer in my house at the age of 5 in 1987. My mother was an elementary school teacher who insisted that learning could help through many means in the most and least expected places. I always loved science and math and usually enjoyed doing STEM related projects far more than I enjoyed writing papers and sometimes even reading. My brother would do science experiments in the backyard and I would watch and join in awe of learning new things about the world and the way things worked. Yet, in school, science was not always engaging, but I was determined to succeed.

Unfortunately, my peers, other students of color did not feel the same and I can distinctly remember doing peer tutoring at my chemistry teacher's request. I made it my goal, in the 11^{th} grade, to be a science teacher and help students of color to know that they too could achieve in math and science if they wanted to. Once I graduated from high school, I attended Howard University and majored in chemistry graduating with honors in four years and then attended graduate school in science education at University of Pittsburgh to receive my teaching certification. My goal has remained the same throughout the last 14 years, ensure that every student, no matter who they are or where they come from, knows they each are capable of achieving in subjects like chemistry, physics and mathematics and teachers will be there to support them on their journey if and when it gets challenging. As a result, I've had some students go on to college and major in nursing, biology, chemistry, engineering and computer science. Yet, all of them do not complete their studies. My questions on what truly motivates students to pursue and persevere, even in high school courses are what led to this study.

3.1.2 Inquiry Setting

The inquiry setting is in a high school in an urban district in the US. The high school has the pseudonym Freeway for the purposes of this study as it was located close to the freeway. It is one of 113 schools run by publically. Freeway had approximately 700 students during the time the study was conducted. Students who attend Freeway, come from many neighborhoods in across the city both assigned to attend and those who are assigned to attend other schools, but have received permission through a school lottery to attend. Every student at Freeway HS receives free lunch. In 2018, the racial make-up of the student population is 4% Hispanic and 96% African American. In April 2012, Freeway HS was rated one of 40 lowest performing schools in the district and whereas the basis of that rating was from a state assessment of math and reading, the scores for science show very little difference if not more deficiencies. Freeway HS fits the broader problem of low achievement in science. In 2014, the last year the science DC state assessment was given, only 36% of biology students at Freeway were proficient or advanced on the assessment (OSSE, 2017). This was 8% less than the district average of 44%. Following 9th grade physics, students go on to take two to three additional science courses, only 66% of students graduate from Freeway within four years of entering ninth grade and this likely contributes to the lack of contributions to the STEM pipeline.

3.1.3 Participants

Participants in this study range in age from 14-17 years old with the majority being between 16-17 years old and in the eleventh grade. Students have come from a variety of backgrounds with some attending middle schools that specialize in STEM education and others simply attended their neighborhood middle school. All have taken biology, but some have also taken chemistry. The principal made a decision to change the course sequence for science from biology, chemistry and then physics (or other science courses) to biology, physics and then chemistry (or other science courses). From an instructional standpoint, the hope was that students would get more support in their mathematical reasoning skills as deemed necessary from assessment scores. As a result, there are some students who are taking physics as their second high school science course and some are taking it as their third or fourth science course. A couple of students are also concurrently enrolled in another science course including: environmental science, AP Biology, forensic science or biochemistry. Further, some students are also enrolled in the engineering program where they take a Project Lead the Way (PLTW) course each year or a Computer Science Principles course.

In this class, there were 27 students total and 15 students were on the CTE Engineering track and 12 students were not on the CTE Engineering track. Their position, on or off this track did not have a direct correlation to their interest in science or achievement. Instead, it reflected their position in a defacto honors program (where most classes are separated) and/or their (or their parents') interests when entering high school two to three years prior. On initial (informal) interviews with students, there are varying levels of experience with inquiry, engineering and creating their own products/investigations without explicit instruction from a teacher. Initial instances of this in physics classes were met with opposition as this was a notable difference from other classes where the teacher gives all the information and students were simply expected to regurgitate what was said by the teacher. The group nature of the work resulted in wasted time as students managed teacher expectations, the assignment as well as group dynamics.

Student volunteers for this study were requested across varying groups: gender, CTE track, grade level and achievement. While students were not explicitly told about these differences as need for the study, discussion will include the differences. Since students volunteered and were not coerced into participating in the study, it was difficult to get equal amounts across the varying groups, but the study was explained to students and their assistance was requested in making science instruction better for them and future students with the publishing of this research.

Pseudonyms have been given to each student as the study was anonymous as approved. The information provided here is a combination of what was shared and what was already learned of them prior to this point in the academic year. While, many students were interested in attending the focus groups and 12 came at least once, only eight students came to all the focus group sessions and those are the students who are written about in detail. In total, there were 7 young ladies and 1 young man. All identify as African American although not all are exclusively from the United States. Six students were in the 11th grade at the time of the study and 2 students were in the 10th grade at the time of the study. Two students were not in the CTE –Engineering Track, while 6 students were in the CTE – Engineering Track.

Table 2 presents the relationship between the full class demographics and the focus group participants. The demographics of study maintained the similar composition percentages in each category, but do not match identical magnitude because students volunteered and were not required to participate in the study. While there were only eight focus group participants, students had a unique understanding of the entire class outlook. Students attended this class every other day for the entire academic year. Because of the timing and frequency of the course, students had information to share about their perceptions of other students when working on tasks as a part of telling their own story and having other smaller experiences like the study task during other parts of the year.

Table 2 Classroom Demographics vs. Study Demographics

Category		**Full Class**	**Case Study Participants**
Gender	*Male*	41%	13%
	Female	59%	88%
Grade Level	*10th*	41%	25%
	11th	63%	75%
Race	*Non-Black*	0%	0%
	Black	100%	100%
CTE Track (Engineering)	*No, not on track*	44%	25%
	Yes, on track	56%	75%

3.1.3.1 Jabari

Jabari is an immigrant from a small Caribbean country. He was in the 11th grade at the time of the study and has been in the states for a quite a few years, but was not born here. When asked for three words to describe himself he said: "funny, intelligent and kind." Jabari was asked how his parents would describe him, he mentioned that they would describe him as lazy, but has gotten better. His parents would also say he has always been good at math and STEM because he has always gotten As and Bs in those areas. Physics is Jabari's third science course after biology and chemistry. He already had a lot of passions which are related to a future job in cybersecurity or some other connection to computer science. In 11th grade, he was elated to take computer science for the first time and is also enrolled in combination of honors and non-honors classes. He also hopes his school will offer more of these classes in the future, that focus more on coding as he wants to have a lot of skills before entering college. Jabari is a good student, but openly admits that he can be lazy at times. He works slowly on projects that he has a lot of interest in and frequently admits that he knows he goes beyond what is required for projects in computer science and engineering because it means a lot to him. He does not feel this passion in other courses, but still maintains honor roll.

Outside of regular school hours during 11th grade, he served as the manager for the girls' soccer team and held a job in the hospitality industry. Jabari was also a member of a science quiz bowl competition for the school with the team competing for the first time in recent history. He enjoys playing games and listening to music but, prides himself on the differences between his gaming and music interests in comparison to other students. For his required science fair project as a member of the CTE Engineering track, he completed a project on a participant's ability to break a code. Jabari enjoys being involved in programs facilitated by teachers he enjoys and is frequently described a funny, go with the flow kind of student. Teachers describe him as someone willing to help others understand material. Nevertheless, if given his choice, he would select working with students who know what they are doing, to avoid having to worry about their responsibilities within the group.

3.1.3.2 Nailah

Nailah was an 11th grade student on the CTE Engineering track during the study. While 11th grade went well for her, she would not describe herself as a good student across all classes and frequently thinks she does not quite measure up to her friends academically. Physics was Nailah's third science course. When asked for three words that describe her, Nailah had difficulty coming up with three words to share. On further thought, she came up with "independent, athletic and chill". Nailah said her mom would say she is a procrastinator, but will get her assignments done eventually. She shows interest in engineering and science, but when asked would not choose engineering as a future field. Nailah openly admits that she likes classes more when she connects with the teacher, but will stay pretty quiet in class no matter what. Frequently having the answer, but not always raising her hand to contribute until she feels truly comfortable.

Outside of regular school hours, Nailah is involved in sports and extra -curricular activities as well as supporting her family. Nailah really enjoys sports and was on the soccer and softball teams during 11th grade. She is very passionate about being a member of the team and takes the responsibility of being a student athlete seriously. She was also involved with the robotics team and while she was not technically named the team captain, her contributions to the team would warrant this delineation. Nailah could be seen focusing the team on the task at hand and being willing to learn new skills like driving the robot during competition. Nailah can also be seen taking defeat to heart and can be very sensitive during certain situations, which seems different than the outward, independent way she describes herself. Nailah is frequently responsible on the weekend for helping to take care of her niece and sometimes brings her to school on the weekend when she has practice for robotics or another activity where she can try to monitor/participate in both.

3.1.3.3 Peace

Peace was an 11th grade student on the CTE Engineering track during the study. The three words she would use to describe herself are: “funny, talented and laid-back". She prides herself on getting the best grades she can get in high school, but openly admits that it has not always been this way. Physics was Peace’s third science course and she was also concurrently enrolled in Biochemistry. She said that mom would note that she has come “a really long way from the past”. In middle school, Peace said her grades were average, but not a reflection of what she could really do. She is proud that now her grades are so much better, but there are some classes that are more challenging than others. Her favorite class is drama even though sometimes she doesn’t get along with the instructor. She finds the class fun and challenging and is happy she got an opportunity to take it. Peace enjoys being on the stage, although she is in the engineering track at school. When she is talking about drama class her eyes light up even when she is frustrated with how something went with it or if something transpired poorly between her and the instructor. This happens with Peace across other classes too and it seems to happen when Peace cares a great deal about the class, but gets frustrated with a low grade or challenging content and then causes her to have an attitude or outwardly show her frustration in a disrespectful manner. She also does not like when she feels like instructors get an attitude for no reason and will openly speak up about it giving back what she feels she was given. Peace is excited that has been able to move through a couple of these incidents with instructors during 11th grade.

Peace is most passionate about being involved in the cheerleading squad and has been on the team for a couple of years in high school. She will come to many other after school events and come to games even if she is not cheering at it. Peace enjoys supporting her friends by attending games, but is also very excited about what senior year and beyond will hold for her. She can frequently be found speaking optimistically about all that is to come, even though she also notes that sometimes her associates are involved in too much drama.

3.1.3.4 Amare

Amare was a 10th grade student, not on the CTE Engineering track at the time of the study. She took courses that would put her on the child development track, but she was not particularly interested in that either. Physics is Amare's second science course in high school after biology. She openly notes that three words to describe herself are "live, talented and cute". Amare's interests are not school and she knows this comes out in how she approaches what she does and does not do in class. She feels like some classes are just quite easy and she likes it because it means she does not need to work too hard. One of her favorite classes is one where there is a long-term substitute as the permanent teacher and she said it is better than having a real teacher because they just do work from a textbook. Amare feels like a lot of school is challenging, especially math and science. She recalled that her mom mentioned that math and science are not going to just go away when she was struggling with both subjects in the 8th grade and encouraged her to figure it out. Amare's goals in class are to be more social than studious. Not because she does not care, but because being social is more engaging, more fun and always keeps her up on the latest high school gossip. Even though math and science are not her interests she is in both physics and computer science as an elective. The computer science class surprised her because it was not a course she put on her interest form, but she's found some parts of it that are as bad as she thought it would be.

Amare is not involved in many school activities and notably lived a far distance from school at the start of the school year. She enjoys hanging out with her friends after school, even if it sometimes gets her into trouble because she is outspoken in virtually all situations. Amare enjoys more artistic outlets than school usually provides. Her only school activity during 10th grade was the poetry club. As a part of her work with poetry club though, she was able to perform a local poetry event and a couple of open mics. She also enjoys photography and brought her camera to school to both have a photoshoot and show off her skills for her others. She noted that some of the classrooms are a good backdrop because they have so much natural light with floor to ceiling windows. Amare hopes to be more involved in school activities next year, but really just wants to get through the year passing to 11th grade. During 10th grade she felt she got into a lot of drama that was not always fully her fault and was a little too focused on a young man.

3.1.3.5 Imani

Imani was an 11th grade student on the CTE – Engineering track at the time of the study. Physics was her third science course after biology and chemistry. Imani is motivated and usually gets good grades, but notes that she never experienced success in math until the 11th grade, for pre-calculus, for as long as she can remember. Her math teacher noted that it was surprising, as her skills do not seem to have large deficiencies or gaps. Imani's self-described words are: "goofy, dramatic and clumsy." Other students seem to see her as having these traits as well, but would also add that she is smart. In classes, especially with underclassmen, they gravitate toward her because she has a motherly nature, but also an ability to re-explain content and help others to understand. She was surprised to receive good grades in physics in the beginning of the year because the heavy inclusion of math made her think that it would also make physics a challenge in addition to pre-calculus. Imani noted that her mom would say she came a long way from being downright bad. Her mom would say that now she is hard working and always gets her work done as grade show. Imani's mom checks the online grade system with fidelity. Imani is determined to ensure that mom never sees a bad grade when she checks the online grade system, but if she does, Imani knows her mother will let her know quickly.

Imani was involved in after school activities and was notably voted to the homecoming court, which she was very excited about. Imani noted that her after school activities are not academic and that does not really bother her because she focuses on that during the day and with her homework. She had her share of drama across the year, but said that really did not feel atypical of a high schooler because everybody gets caught up in drama sometimes.

3.1.3.6 Lelani

Lelani was an 11th grade student on the CTE – Engineering track at the time of the study. Physics was her third science course in high school, but she was also concurrently enrolled in biochemistry. Lelani said three words that would describe her are "funny, talented and laid-back." Lelani is a good student, but she said she would not describe herself as stellar. She knows at times she gets behind on her work and has to play a little catch up, but never too far behind. It is apparent that Lelani enjoys her friend group not just because they are funny and like similar things, but the way they support each other academically. Lelani said her family would describe her as both hard working and lazy and she totally agrees. Lelani makes honor roll most of the time, but usually has grades that span a range to make her qualified and not clustered in the exact same letter grade.

Lelani was involved in cheerleading during her 11th grade year, but no other sports or activities that are school based. Lelani has a good number of friends and enjoys school, but usually does not want to let adults know how much she really likes it. Lelani was a part of a group that won a special competition later on in the year for a design thinking solution for a local business along with Peace and Belle. Lelani, in particular, really shined as a part of this opportunity through her engineering course and it allowed her to be a little more involved and hold a leadership role that she may not have typically sought out.

3.1.3.7 Zola

Zola was a 10th grade, non-CTE-Engineering track student at the time of the study. Physics was her second science course in high school after biology. She has a number of friends, but none of them is in physics, so she spent much of her time attempting to work alone and having to be coerced into working in groups. She is less likely to speak up when she needs help, but does typically understand what is going on with little extra instruction. Her three words to describe herself are “quiet, funny and calm.” Zola said her mom would describe that she can do better in school and she is not fully working as hard as she could, but her grades are ok. Typically, when Zola is with friends she lights up and can be observed having a good time. When they are not around, which happens through a couple of classes, she is reserved and to herself.

Zola was not involved in any school activities in the 10th grade, but has many interests. Sometimes, during assemblies Zola tried avoid attending because she “just didn’t feel like it”. Advisory is something the school implemented some, but Zola could have benefitted from having it more consistently to ensure that she and students like her made more connections between herself, other students and the school community as a whole.

3.1.3.8 Belle

Belle was an 11th grade CTE- Engineering Track student at the time of the study. Physics was the third of high school science courses and was concurrently enrolled in AP Biology. Belle said the three words to describe herself are “social, intelligent and goofy”. She was vying to be in the top five of her graduating class during her senior year and it shows through all of what she does. At the end of the year, she was accepted into a college prep program where she gets the opportunity during senior year to take a college course for credit. Belle’s notebook is meticulous and she makes sure to ask questions when she does not understand. She had quite a few absences, but was always very diligent in asking for work if she knew she would be out and getting the work and completing it after if she did not know. Teachers appreciated her commitment to her education as seen through her actions and devotion.

Belle was involved with the cheerleading team in 11th grade and was a part of the school’s winning team for an entrepreneurship solution for a local business. Other than those two big events, Belle was not involved with many other school-based activities, but noted that she really enjoys just getting together with friends over the weekend. Belle noted that her mom would say she has come a long way because in high school she did not care about school or how she acted. She talked a lot in class and was not very focused. Any high school teacher of Belle’s and adults who only knew her as a high schooler would have a difficult time picturing her this way.

3.2 Inquiry Methods

This study utilizes five methods of analysis to determine changes in attitudes before and after the inquiry activity. Attitudes were measured by pre and post survey, focus group interviews, written student reflections, researcher reflections and lesson plans. From the analysis of other studies and the desired inquiry questions, the need for triangulation in case study research (Yin, 2014), these types of data: surveys, focus group, written participant (student) reflections, researcher reflections and lesson plans were most important to complete a thorough analysis. The table below summarizes the data collection activities completed.

Table 3 Data Collection Activities

Component	**Description**	**Frequency**	**Author**
Survey	CLES survey that groups statements into 7 categories	Pre and Post	Students
Focus Group	Small meeting with 8 focus group students for reflection on classroom experiences during the study	Once a week for three weeks	Students
Participant Reflections	Written responses by participants about class tasks and four responses to statements	Each day class meets	Students
Researcher Reflections	Written response by teacher/researcher about how class tasks went and other information about what was happening in the school/city community	Each day class meets	Teacher/Researcher
Lesson Plans	Written plan of what happens in the classroom each day	Each day class meets	Teacher/Researcher

3.2.1 Survey

One survey was administered pre and post of the engineering unit. The Classroom Learning Environment (CLES) survey (Taylor, Fraser & Fisher, 1997) was given before and after the engineering task. It consists of 42 questions in which students complete a Likert scale. Since this particular task is longer than other tasks given this academic year (and possibly previous ones students have been given in previous years of school science) as well more classifiable as CSS than PSS science, students will be presented with a different type of classroom environment. For example, the "Learning about the World" section of the CLES survey has a statement "My learning starts with problems about the world outside of school." This statement would elicit a response of "almost always" in a CSS classroom while only sometimes in a PSS classroom. As the PSS classroom would make connections to the outside world, but would not need to start with it. However, the CSS classroom is grounded in the outside world because CSS is interconnected to the outside world not tangential or separated from it. The pre and post frequency of this survey seeks to determine if those shifts are apparent to students and what changes this may show on their selection of choices for each statement. Taylor, Fraser and Fisher (1997) validated the use of this tool during action research as it was able to "identify multiple learning environments within one classroom" (p. 300). Researchers used multiple other sources and were able to find validation of what they found in the survey data.

3.2.2 Focus Group

Methods of direct voices from participants could include participant observations or individual interviews as well as focus groups. Focus groups gave the researcher the ability to hear student responses, but also not take the same amount of time as individual interviews to get through the same number of participants. Osborne and Collins (2001) note that focus groups enable students to continue to participate in the group dynamics, similar to the way the class is structured, as well as having the safety and security to not have to respond to every question given. Focus group questions are outlined in Appendix C. A total eight students were targeted for focus groups. Students met for the focus group after school, each week for a total of 3 weeks. The focus groups were audio taped by two sources, my cell phone and computer, placed in two different locations near the focus group. Two sources of audio ensured that all voices were picked up and a backup in case one device failed or lost power for any reason.

3.2.3 Participant Reflections

Participant reflections from the observation period were collected. Each class period, students completed an exit ticket with the following prompt "How would you rate your experiences in class today and why?" Student responses were on class as a whole and the productivity of their group as no new content was presented during the mini-unit. There were also five statements for students to agree, disagree or say they are not sure modified from Test of Science Related Attitudes (TOSRA) (Fraser, 1981). The full TOSRA has seventy items that can be grouped into seven categories: social implications of science, normality of scientists, attitude to scientific inquiry, adoption of scientific attitudes, enjoyment of science lessons, leisure interest in science and career interest in science. These statements are a mix of positive and negative towards or against each category. For the end of the reflection, statements were chosen from: attitude to scientific inquiry (2), adoption of scientific attitudes (1), enjoyment of science lessons (1) and leisure interest in science (1). These statements can be found in Appendix D.

3.2.4 Researcher Reflections

As stated earlier, the researcher was also a participant in this study, so my field notes and research journal were important to a well-rounded understanding of what happens in the classroom each day. While I could not, as the teacher, take copious notes during class, I could after class take 20 minutes to write about what happened during the class period, field notes. These field notes focused, mostly, on the focal students and the work that they did during the class period and how I generally felt the lesson went. In my research journal, I also focused on extraneous factors like school, district changes, events happening in the city that may impact students and overall attitude of the class. When analyzing other data, these field notes and research journal proved interesting to pose further analysis as the notes paint a fuller picture of the moment that may not be captured solely from memory by the time data analysis occurs.

3.2.5 Lesson Plans

The lesson plans for this mini unit are included in Appendix A and detail the length of time of each aspect of the 5E plan and what will occur in class on that day. The analysis of these plans in juxtaposition to student reflections and the field note is important as it brought to light differences in the planned curriculum, the enacted curriculum and the received curriculum. Were students aware each day what needed to happen and do their reflections/work show that they adhered to that stage during that class period? Why or why not?

3.3 Method of Analysis

The initial survey, CLES, was analyzed for pre and post analysis for each student. The entire survey was given before and after the mini unit to look at how this mini-unit (in general) affects shifts in responses on the Likert scale of the items. Reid (2015) notes, however, that ordinal responses should never be added, subtracted, multiplied or divided as attitudes are "multi-faceted and any attempt to reduce measurement to a final score for each individual will tend to give a meaningless number" (p. 28). So, individual responses will be analyzed pre and post to individual questions rather than an overall before and after.

Focus group responses as well as daily reflections were coded for analysis. To begin, each was coded using descriptive coding. Saldana (2016) describes descriptive coding as "basic labels to data to provide an inventor of …topics" (p. 97). It would be interesting to look at the student's classroom observations in this way as my classroom has not been defined any particular way all the time. The statements students were responding to help students to differentiate between classrooms where their voices are heard, encouraged or grappled with regardless of opinion or not (Taylor, Fraser & Fisher, 1997). I know that based on the confines and expectations at my school, it is not always the case that the classroom is student centered even when I desire for the classroom environment to be. I specifically analyzed for those factors that came up in my literature review. Do students mention or allude to their own: confidence, self-image, self-efficacy or relationships with adults as the reason they are interested? Or will other factors come up as important them and their persistence in physics for this project? How does this project compare to other projects they completed this academic year or in previous academic years in science?

Lastly, in the open response portion, participant reflections were analyzed through coding. The reflections all have one open response question that was analyzed for patterns. Students completed a modified version of the TOSRA. These were rated according to Fraser's guidelines. For positive items, the responses are rated from 5-1 on the Likert scale while negative items are rated from 1-5 respectively and any omitted or invalid responses are scored with a 3 (Fraser, 1981). Since the full, robust survey was not used, individual students were analyzed for their changes over time with these statements rather than making an average on each category which is also in line with recommendations against this for attitude responses (Reid, 2015). Responses to statements helped to correlate to the factors found in the literature review. If a student says that they agree with statement 3 from the TOSRA, then they say that they have the confidence and positive self-image to know that they are capable of doing science. In statement 52, positive answers would show a lack of self-confidence, but may also show a positive relationship with the teacher because they want to find out from the teacher if their answer is correct. Statement 53, will show inaccurate confidence and a lack of scientific reasoning, if students are positively responding that they do not want to change their answers even if the evidence is poor. Statement 32 and 41 both show an interest in promoting conversations with others as a way of learning more and showing interest in science by listening to others and talking about science outside of school.

Table 4 Triangulation Matrix

Research Questions	Surveys	Focus groups	Participant Reflections	Researcher Reflections	Lesson Plans
How are high school student attitudes towards STEM affected by engaging in critical school science (CSS)?		X	X	X	X
What factors in a CSS classroom environment contribute most to changes (if any) in student attitudes towards STEM?	X	X		X	X

The matrix shown in table 4, shows how the data collected and its correlation to (Yin, 2014) the inquiry questions were used to draw conclusions about the data. I analyzed top down categories based on types of interactions: student to teacher and student-to-student as well as overall interest in science/STEM. Bottom up categories emerged from close analysis of the data. Analysis of the data also led to groupings of students. These groupings became profile categories because of data analysis. To determine subgroups within the data, the survey was analyzed for trends within categories looking at both the total score for items in a section and change. From that analysis, preliminary subgroups were formed and then another data set, focus groups, was cross referenced for trends. In focus groups, patterns for similar interests and reactions were analyzed. Following the analysis of those two data sources, the reflections, both participant and researcher reflections were analyzed for positive vs. negative outlook of or by students. The frequency of certain topics that students brought up in participant reflections was also analyzed. As a result of the data across multiple types for students, some initial subgroups were collapsed as long as measures were matched from two or more data sources. Finally, the subgroups were named based on behaviors.

4.0 Findings

To provide context about students' responses information about the results of the debate as well as what students created is vital. From the debate, students made a number of action steps. Some students felt they should create an app that reminds you to move your phone out of the bed when it is a certain hour and the phone is no longer in use. Other students felt that they should create a device where the Wi-Fi signal can be blocked at night from being drawn to the phone in one's bed. The last possible action step was to create a public service announcement helping students to understand their risk. As a class, students decided on creating a device where the Wi-Fi signal can be blocked at night by placing it inside. Student groups then brainstormed possible ways to create a device that does this blocking. They tested different materials that were provided from thick rubber to aluminum foil. From their tests, they decided, created, tested and iterated on designs to determine the best solution and wrote it up.

All students in the course participated in the survey, tasks and participant reflections, but only the focus group participants' data was reported here as they are a part of each data set with the inclusion of the focus group sessions. In the findings that follow, reporting for trends across cases by data collection type and inquiry question are presented first. Following trends, individual cases are reported by subgroups of students based on their data.

4.1 Trends Across Cases

4.1.1 Survey

Inquiry Question: What factors in a CSS classroom environment contribute most to changes, if any, in student attitudes toward STEM?

The CLES survey was needed to determine what factors in a CSS classroom environment contribute most to changes in student attitudes. Within the survey data, across participants, many noted no change from pre to post test. This makes this data insufficient for full analysis as students maintained their stance in many subareas of the survey. Table 6 outlines the differences between pre and post for the survey. Table 5 outlines individual data per student in each subarea across the survey pre and post. Higher average changes within the “learning about the world,” “learning to learn,” and “learning to communicate” sections of the survey with average changes being 0.25, 0.7125 and 0.4125 respectively. One section also had a negative average in changes, which was “teacher support in learning science.” The full survey can be found in appendix B. Based on this data with some small changes in “learning about the world,” some students did feel that there was a greater emphasis on worldview in this task. Worldview as a term includes problems steeped societal issues and this inclusion of this aligns this task making a greater shift to critical school science (CSS) from progressive school science (PSS) as outlined in table 1. “Learning to learn” is another area that saw growth, with the growth being the highest from pre to post for any one subarea. This is particularly impactful as the questions in this subarea are around student ownership in the classroom and students’ ability to inform the learning, how long activities will last, etc. Growth in this area from pre to post shows that students have greater ownership because of participating in this task. Lastly, growth on “learning to communicate” shows that students were able to have additional opportunities to share their thinking and listen more to the thinking of others for the tasks. This shows a greater level of student-to-student interaction that students were able to rate more positively than in the pre-test because of participating in the unit.

Table 5 Classroom Environment Survey Data (Mean)

	Learning About the World		Learning about Science		Learning to Speak Out		Learning to Learn		Learning to Communicate		Interest in learning science		Teacher Support in Learning Science	
Participant	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Jabari	4.5	4.5	4.7	4.7	4	4	3.3	4	3.7	4.5	4.2	4.2	5	5
Nailah	3.7	4.2	4.7	4.5	3	3.3	1	2.5	2.5	3.3	4.3	4.3	3.8	4.2
Peace	4	4.3	4.2	4.2	5	5	4.2	4.5	4.5	5	4.2	4.5	4.5	4.5
Amare	2.5	3.3	3	3.7	5	5	1.2	2.2	3.3	4.5	2.5	2.8	5	5
Imani	3.2	3.2	3	3	5	5	3.7	4.2	4.8	4.8	5	5	4.8	4.7
Zola	4.7	4.7	4.8	4.5	4.5	4.2	2.3	2.8	4.7	4.7	4.8	4.8	4.7	4.7
Lelani	4	4	4	4	5	5	1.2	1.7	5	5	5	5	4.7	4.2
Belle	3.3	3.7	4.5	4.7	4.7	4.7	3.3	4	5	5	4.3	4.5	4.3	4.3

Table 6 Average Change from Pre and Post Data – Focus Group Participants

Category	Average Difference from Participant Pre and Post Survey
Learning about the World	0.25
Learning about science	0.05
Learning to speak out	0
Learning to learn	0.7125
Learning to communicate	0.4125
Interest in learning science	0.1
Teacher support in learning science	-0.025

4.1.2 Participant Reflections

Inquiry Question: How are high school student attitudes toward STEM affected by engaging in critical school science?

Participant reflections help to analyze how student attitudes toward STEM are affected by engaging in CSS. For participant reflections, these were completed at the end of class each day during the project in place of a more traditional or customary exit ticket specifically on content. From their written reflections, students wrote that they did not enjoy class as much on preparation days versus the day when they did the debate in class. Students felt the day they did the debate was enjoyable and felt it was an interesting way to see what everyone was thinking. This was especially true for students who said they would never change their position about a cell phone being in their bed at night. Interest waned again when students were choosing their solution, but had added interest with positive words to describe science class like “interesting,” “surprising” and “fun” when describing the creation phase of the solution. A few participants noted that the actual testing was a bit discouraging. Student created devices took various forms and even though students only had access to the same materials, some groups ended up with working prototypes while others did not. This supports why students expressed positive changes in sections of the survey.

Students were also asked to respond to a series of statements each day at the bottom of their reflections. It seemed that this would be a beneficial way to complete the reflection, especially thinking about specific statements. However, student answers to these questions were inconsistent. On some days, students did not circle a response to the statement and on other days, the response stayed the same from day to day. The data collection time period for these statements did not allow for changes to be tracked as easily as originally intended when selecting this data source.

4.1.3 Focus Group

Focus group data can attend to both inquiry questions sought out by this study. Certain questions within the protocol are most closely matched to certain inquiry questions. However, open-ended responses allowed students to speak freely and bounce ideas off each other to clarify their desired meaning. As a result, responses to individual questions would not necessarily be appropriately tagged to simply one inquiry question or another based on the content of responses that were given.

Inquiry Question: How are high school student attitudes toward STEM affected by engaging in critical school science?

Many students noted that the debate was an engaging part of this unit (focus group 3). While a few participants did prefer the engineering task, there were greater responses and positive reactions about the debate than about engineering task. When probed further about their interest in the debate, participants noted that it allowed them to be social, but also to argue in a somewhat controlled environment like a classroom. Focus group participants noted that the debate was something that scientists do, but maybe not engineers. Belle responded to another student's response stating, "debate is still important to communicating science concepts and trying to get other people to take your side on a particular problem" (focus group 3).

Students felt overall positively about the unit and what they were asked to do, but this did not change everyone's opinion of whether they would like to pursue STEM further or not beyond this course. In general, it seemed that students were interested in considering their possibilities for school, but no one was swayed more strongly to discipline specific careers like those pertaining to physics, radiation or engineering by mentioning it. The survey results allude to a similar finding, but it is difficult to compare those more generic responses with the more targeted remarks made during the focus group.

Inquiry Question: What factors in a CSS classroom environment contribute most to changes, if any, in student attitudes toward STEM?

Through analysis of many responses, it is clear that students greatly enjoyed and benefitted from group interactions. This was reflected across focus groups 2 and 3. Students were able to articulate that even students who did not participate in the focus group contributed to the (focus group student's) learning. Also noting that some of those same students who did not always feel so "smart" did a good job of contributing to this project. This allowed those students to feel empowered because they were heard by others, especially to those who they perceived to be were smarter than them. Student to student interaction was very important to contributing positive attitudes in STEM. Imani noted, "I really did not want to be in a group with who you put me with. But, they have really good ideas, sometimes they just don't trust themselves. Our idea didn't come from me, it came from <<another student>>" (focus group 3). This is supported by the survey with positive changes pre and post in the "learning to communicate" section.

The other major trend across multiple students was students were able to have greater self-efficacy when they were the ones in charge of their learning. Students cited that they had to lead the debate and decide a plan of action. "Doing things like the debate helped me to like physics more at a point in the year when I was ready to check out" (Amare, focus group 3). During this unit, students noted that it felt more student led and impactful that they were able to contribute to multiple aspects of the lesson sequence especially in brainstorming and creating solutions that solves a particular problem. Jabari stated, "I did not think you would let us do what our action step was. Mine got voted down, but I liked that we got to choose and it wasn't chosen for us" (focus group 2)

4.1.4 Researcher Reflections

As the teacher and researcher, I was able to think reflect about what was done each day in the classroom and other extraneous observations that helped to paint a full picture of day-to-day classroom activities. The researcher reflections can attend to answer both of the inquiry questions.

Inquiry Question: How are high school student attitudes toward STEM affected by engaging in critical school science?

I made constant comparisons from this unit to previous units that are more PSS than CSS. We did a unit on motion at the beginning of the year and students analyzed the length of the yellow lights in the school neighborhood. This helped us to have a real-life application, but they did not really propose a solution or get to be heavily involved in how we tested/observed. PSS units were shorter, sometimes being able to be finished in a day and maintained student interest. In previous units, I can think back to times when students were disconnected from the work because they thought that no solution could be found or when students were preoccupied by interpersonal or non-academic concerns.

Students seemed to have an added level of frustration because of engaging in this task. I noted a comment from a non-focus group participant in my reflection, "A student said today, "this is bad, but there is no solution. Cell phones and beds are not going to go, anywhere." I wonder how I can help them to feel more empowered to make change?" (researcher reflection, April 5, 2018). Unlike some other lessons in the year, participants were working on the same project, with the same group, for a number of different weeks rather than class periods. This impacted student interest and attitude toward the work as they sometimes were frustrated with their group and no longer wanted to participate in the unit.

Inquiry Question: What factors in a CSS classroom environment contribute most to changes, if any, in student attitudes toward STEM?

There were a number of different factors that came up as themes through the researcher reflections. The themes varied in that some were positive and beneficial to the study, while themes were negative. For instance, from my perspective, students were easily frustrated by their peers, especially when they have been absent from class. This specifically caused difficulties in groups that were more prevalent during the engineering task than in the debate. Since the debate used less instructional time, scholars did not need multiple days of good attendance to be able to do well. Unfortunately, the engineering task occurred across many class periods. Thus, student absences made their classmates very frustrated. The frustration seemed to come from the feeling that they were overburdened in doing the necessary work.

Students were very engaged during the debate portion of the unit, but students seemed more engaged during the engineering design sequence of the unit according to researcher notes. I saw students assisting each other to a greater degree and being willing to persevere on the project, especially if all group members' were present. Groups that had more consistent attendance, regardless of the reasons that kept students out of the classroom, did a better job on the project and its completion.

4.2 Participant Subgroups

In considering individual case data looking closer from the overall trends across data collection types discussed above, a number of different subgroups could be identified. The subgroups that I identified were: STEM Persisters, Science Communicators and STEM Critics. Subgroups were determined by figure 1, The Nature of Attitudes (Reid, 2015) and the data collected. These titles pertain to the "attitude" students have towards STEM, especially physics.

It should be noted that while some groupings are in line with what I thought may happen, the results reported her are directly from the data collected. Some students were in different groups than I may initially hypothesized before starting if the subgroups were already created. However, the subgroups are from the triangulation of data. Everyone brings their own prior knowledge and experiences into the classroom, so that is always present.

4.2.1 STEM Persisters

The STEM Persisters group has an overall positive attitude toward STEM, STEM tasks and engaging in STEM work both in class and out of class. Members of this subgroup are Jabari, Nailah and Lelani. Based on their data (focus group responses, survey data, participant reflections and researcher reflections) it appeared that these students have interest that may allow them to persist in STEM for college and career.

Career Interests and Activities

Their career interests and activities are not identical, but do bear some similarities. Jabari already shows an interest in STEM and Nailah is involved in after school activities with STEM.

Lelani does not do either of things, but competed in a competition where she put her STEM skills to work by creating a prototype for a local business using VR technology. Beyond the interests and activities they have shown, these three students were frequently found working or testing after the bell during the second part of the unit related to engineering design (researcher reflections, April 13, April 18 and April 20, 2018). On their survey, each showed high responses "often" or "almost always" when explaining answering the section on "Learning about the World." They already see how science connects to their lives and that they find that learning interesting.

Relationships with Others

Students in the STEM Persisters group did not feel that relationships with others were the most important part of the work they were doing. In class, they can sometimes be found working alone, even if they are very social people (researcher reflection, April 20 & April 24, 2018). In the focus group, Jabari noted "he likes working with others, but if they are not there, he can still figure it out" (focus group 2). Lelani expressed interest in being around friends, but her behavior in class when working on task shows her leadership and determination regardless of her group's interest or disinterest (researcher reflection, April 11, 2018).

Self-Efficacy

All students in this subgroup have a positive self-image of who they are in science. When Nailah rated her work on April 20, 2018 she said "I would rate today 8. I did exactly what I needed to do for my group to get further along with our project". Jabari, Nailah and Lelani all think highly of themselves in STEM and know what they are capable of doing. This is confirmed through the way other students treat and perceive them in class when being sought out for ideas or opinions (researcher reflections).

4.2.2 Science Communicators

The Science Communicators group is motivated, hard-working and high achieving. However, they really do not know if science is for them in the end. This does not mean they do not have any interest, but their other interests may be stronger. Members of this subgroup are Peace, Imani and Belle. Based on their data, this group of students has the staying power to do well in STEM, even if it is tough, but not necessarily the interest to maintain that persistence.

Career Interests and Activities

Peace, Imani and Belle are all involved in activities out of school and while they will stay to finish an assignment like an exit ticket (researcher reflection), they will otherwise be amongst the first to leave at the end of the period. They have a big interest in other activities like drama for Peace or taking college courses while in high school like Belle. Yet, they are good at their ability to communicate scientific understanding to others. During the day where students showed their prototypes of feedback, each of these students did a good job at helping others to understand what their group had created and elicit feedback (researcher reflection, April 18, 2018). Across the survey in multiple categories, Peace and Imani had some of the lowest responses as it pertained to interest in science, but still showed interest through their work in class.

Relationships with Others

Peace, Imani and Belle have good relationships with others in class. When it comes to peers, they are usually willing to work with anyone and see what other people have to offer to the group. Imani is especially good at this as she worked with a group of 10th graders for this project and stated in the focus group "they just don't know how smart they are" (focus group 3) when asked by a peer why she doesn't mind being in that group. Peace and Belle prefer to work with 11th graders in class, but are always willing to do the work and communicate with others as seen in the "Learning to Communicate" category on the survey.

Self-Efficacy

Peace, Imani and Belle were usually the most vocal in focus groups, especially Peace. By focus group 3, they all knew and expected that they could do well in science. They seemed willing to complete their projects due perhaps to parental support/monitoring or their own monitoring. All three participants are meticulous in how their work looks in addition to its content (researcher reflections). Their desire to do well in science comes from their desire to do well, but for Peace, not always because of her interest in learning science (survey).

4.2.3 STEM Critics

The STEM Critics group does experience some success in science. However, it is normally sporadic and based on individual class periods/lessons and not topics or units. This group includes the only two 10th graders in the study and likely could have included other 10th graders in this physics course based on the responses of other participants in the study. This group includes Zola and Amare.

Career Interests and Activities

Zola and Amare do not express interest in science outside of school, although they did volunteer to be a part of this study. Zola and Amare had lower scores in "Learning to Learn" on their survey. This showed that they do not feel much ownership over what is done in science even after the unit ended. Zola and Amare's career interest do not pertain to science and it is apparent in the type of work they did as the year progressed in science (researcher reflection).

Relationships with Others

In this area, Zola and Amare are very different. Amare is extremely social and enjoys being around other people at all times. In contrast, Zola shows her socialness outside of class and does not usually want to work in groups if she can help it. These two are grouped together because they both seem disinterested in communicating about science with their group. However, they show their inclinations in very different ways. Amare stated in a focus group "I don't mind being on task, but I would rather be off task. Sometimes it just isn't as interesting as what I want to talk about" (focus group 2). Zola has stated on participant reflections that she does not really care for her group and they do not like to work that hard.

Self-Efficacy

Both Zola and Amare expressed interest in learning science on the survey, but the way they act in class does not always how this. In addition, Zola and Amare both struggle with completing assignments in physics, like the write-up for the engineering task for this unit. (researcher reflection, April 26, 2018). Based on past experiences, Amare is sure that she is not really good at science and prefers classes where she does not have to work as hard (focus group 1). Zola just seems to have a lack of interest and knows she can work harder, but sometimes does not (focus group 1).

5.0 Discussion

Overall, students were able to experience critical school science (CSS) in a classroom that is more typically a progressive school science classroom (PSS). Allowing students to have this opportunity is particularly impactful as the unit is connected to their everyday life. I expected some of the themes that emerged from my data (e.g., enjoying and gravitating toward student-to-student interactions during the unit and enjoying hands on aspects that made them feel like a scientist/engineer). Other themes were unexpected: student interest in the debate. Based on my past experiences, debates can be either a positive or negative event for students. Students sometimes become too connected to what is discussed and have a difficult time being calm when discussing their opinion. The debate had always been a part of this unit but took more prominence in the write up because students felt a connection to it as written in their participant reflections as well is in their focus group responses.

5.1 Importance of Social Relationships

While some students will tell you that some classes are not interactive or do not allow them to have productive conversations with other students about content. However, adolescents and young adults enjoy being social and it is developmentally appropriate for them to have time to converse with others. It also helps to build important skills of working with others, respecting differing opinions and responding appropriately, even when one may disagree. This study is impacted by students' ability to have social interaction within the unit.

5.1.1 Relationships with Adults

As recorded in many studies (Carlone, Scott & Lowder, 2014; Cristadou, 2011; Kanter & Konstantopoulos, 2010; Meyer & Crawford, 2015; Tan & Barton, 2009) relationships with the classroom teacher are important. These relationships help students to take academic risks and see themselves as scientists or engineers. While students had minimal notations about receiving assistance from me, their strongest parts of the work were not centered on this. Participants felt like they could ask me questions, make recommendations and get support from me as seen in the survey when they responded positively to statements like "The teacher goes out of his/her way to help me" or "It's OK to question the way I am being taught".

However, participants did not always feel that way. In some participant reflections, participants voiced concerns that I did not come to help their group enough during the engineering design/solutions portion of the unit. Only half of one group noted something similar to this on their reflections that day, but it is still worth noting. I think other students did not have this same response because even in a more PSS framework in my classroom, they knew what positive teacher assistance looked like. Positive teacher assistance does not look like giving you all the answers and doing the work for you. Positive teacher assistance looks like allowing students to receive help by asking probing questions that get students thinking and supporting their learning through feedback on their work. All of my students should have been accustomed to this by the time in the year when this unit transpired. Furthermore, a good CSS classroom allows students to take the driver's seat in forming their own understanding of the content and learning from each other (see Table 1). In this unit, students are authoring their learning and students had the ability to do that work through forming what the solution would be after the debate and working on how their solution actually meets the needs of the problem to begin with.

5.1.2 Self-Efficacy

A student's ability to persevere in a particular subject area, especially STEM is related to their perceived self-efficacy in a particular area (Bandura, Barbaranelli, Caprara & Pastorelli, 2001; Sheldrake, 2016). Students showed this self-efficacy through both the debate and engineering design task. Participant reflections at the end of the engineering design task included responses like "Our group is rated a 10 today, because we were able to complete our design and test it." (Jabari, participant reflection, April 24, 2018). Even Amare's participant reflection (April 26, 2018) noted her commitment to seeing the project through to the end "I didn't think our cell phone blocker would work at all. It didn't work all the way, but some tests blocked the notifications from coming." Showing self-efficacy at the end of the engineering design task, which lasted more instructional days, versus the debate was more substantial. The debate only went across two class periods with less of a need for perseverance through the task.

The debate did require a resolution at the end of a class period but the process was very contentious. Belle noted in her participant reflection (April 5, 2018) that "I would rate today a 5. Some people got heated during the debate and didn't want to agree." A portion of the protocol to the debate required students to create an action because of the debate. All student groups were able to conclude at the end of the debate. This was noted in the researcher reflection (April 5, 2018) "Students hated having to come to an action with other students who were on the opposing side, but they all completed it with encouragement." Students' self-efficacy was shown through both resolve and perseverance in the two components of this unit.

5.1.3 Culturally Relevant Curricula

This unit sought to target the culture of my students being born into and living in a technological age. Even students who do not have cell phone service on their phone, have a phone. If it is not a phone, it is a tablet. Students were very interested in the subject matter from the time of the debate to the time of testing their devices. Many student groups wanted to try to create more prototypes that could block the signal for devices that had various sizes, but due to time constraints, student groups did not act on this specific solution. This seems similar to activities in other culturally relevant curricula (Franklin, Conrad, Aldana & Hough, 2011; Meluso, Zheng, Spires & Lester, 2012). The curricula helped to maintain student interest in STEM especially for students of color to see their own identity.

5.2 Engineering Task vs. Debate

This unit's two main components did not require or receive equal instructional time. The bulk of the cognitive work that students needed to do was about the application of their knowledge from before the study started and life experiences. The debate is a part of the unit because it helped to ground students in the problem to help them find scientific data to support or refute a behavior many of them admitted to, sleeping with technology in your bed. However, what was found through data was that many students felt more connected to the debate than to the engineering design task. During focus group 3 on May 8, 2018, students felt that the debate was truly their favorite part. Due to scheduling constraints with students' after school activities, the last focus group had to happen a couple of weeks after the unit actually concluded. One of the benefits was that students were able to reflect without having immediately finished the unit and be a bit more thoughtful. However, I was surprised that about 50% of students cited the debate higher than the task of creating their signal-blocking device.

When probed further, students felt that the debate was “engaging” and “made them really think.” I question whether this is because of the strategic set up of the debate process or the set-up of the engineering design task. From my past experiences, students have an impression that the use of simple materials to create prototypes lessens what the “realness” of the task for them. However, students can analyze many products on the market that are not always made with sophisticated materials. If the device works, does that not show that the prototype is effective even with simple materials? I did not explore this with students further, but my impressions from both middle school and high school science in past academic years support that students find more sophisticated materials increase the scientific authenticity.

5.3 Importance of Peer to Peer Interactions

Research analyzed for this study highlighted the important of student relationships with adults as a key factor in both their interest and achievement in science (Carlone, Scott & Lowder, 2014; Cristadou, 2011; Kanter & Konstantopoulos, 2010; Meyer & Crawford, 2015; Tan & Barton, 2009). However, one of strongest student responses was the importance of peer-to-peer interactions. During the focus groups, the survey results and participant reflections were instances of students citing the assistance, good ideas or positive interactions with peers as part of their determination to finish the task, enjoy class or improve their ideas. Nailah in a participant reflection “I would rate today a 7. Our group got help from <<another student>> and his idea helped us to get better on our prototype" (April 20, 2018). Jabari, Nailah, Peace and Amare all had positive increases in the "Learning to Communicate" questions on the CLES survey and none of the focus group students had a lower mean on the post rather than the pre in this section.

Not all instances of peer-to-peer interactions were positive though. Zola's participant reflections rated the task lower during a couple of workdays with her group. "I would rate today a 2. My group barely did anything and you gave us feedback. They still did not want to do it" (April 18, 2018). On the subsequent day's participant reflection for Zola she stated "I would rate today a 5. My group did a little today and we finally have the first part of a prototype" (April 20, 2018). The rest of Zola's group were not participants, but this gives a valid picture, that not all students were engaged all the time, in the tasks for the unit.

5.4 Limitations of the Study

While the study sought to thoroughly investigate how student attitudes can be modified due to teacher moves in the classroom, there are limitations to the study. In both data collection techniques as well as actual design of the study, certain limitations should be noted. Limitations of data collection include across focus groups and surveys. Limitations in study design include the topics of timing, sequencing and third-party research.

5.4.1 Limitations of the Data Collection Techniques

The use of particular data collection techniques were chosen in regard to study participant age level as well as inquiry questions. However, due to confines of the study design and inquiry setting some data collection techniques still felt stretched to adequately give the most authentic information. All efforts were attempted to minimize error in light of these limitations.

5.4.1.1 Focus Group

Focus groups are a way to get a lot data at once instead of doing each interview separately. I think this initially helped students to feel comfortable with this type of data collection as many of the participants had limited experience with focus groups. We spent a little time before recording on the first day to discuss the protocol and what the process would include and most participants were intrigued. However, during some focus groups, like focus groups 1 and 3, participants seemed to sometimes just agree with someone else's response. This caused some responses to seem redundant. It was sometimes unclear if a participant truly agreed or simply did not want to give a response or could not think of one. If time would have allowed me to follow up on specific statements by individual students or run individual interviews, this may have helped. I wanted to ensure that what everyone shared was their own opinion. We discussed how it was not related to course grades, but it was still a challenge to determine the authenticity of some responses in light of the redundancy.

5.4.1.2 Survey

I think the survey had many good statements to try and track student understanding and changes too. However, the surveys were only given three weeks apart. While the unit was engaging for students and enabled everyone to access it, it was challenging to truly see a change. Some students marked the exact same response before and after. They were not given the pre- survey back to take the post, but maybe the survey did not have enough time to monitor change. Administering the survey in the beginning of the year or the semester and then the end of the year or the semester may be more enlightening. Extending the time between administrations of the survey would allow for more time for change to happen.

5.4.2 Limitations of Study Design

With only 180 mandated school days and 85 minute classes every other day, teachers at Freeway and all over the country have to make difficult decisions when designing curriculum and units taught during the traditional academic year. This study acknowledges this lack of time and it is exacerbated by also collecting research within this unit. Teachers also do not typically begin academic years knowing much about their students unless they follow the student to the subsequent grade level to teach new content in the discipline. Therefore, shifting unit design and sequencing could have a different, more beneficial effect in light of student profiles if teachers knew what they learned about students later in the year, earlier in the year. The three main study design limitations are: timing, sequencing and third-party research.

5.4.2.1 Timing

Since this unit was situated towards the end of the academic year, the students and I already knew each other well. We were more than familiar with work ethic, mood, actions, workload and more. I am curious about how data and student responses may have been different if the unit studied was the first unit of the year. There would have been less familiarity between the students and me, but there were would have more opportunities for change especially within the survey about classroom environment. I also wonder how the survey data, focus group and participant responses would be different if the unit lasted longer or tracked changes across two units. A longer unit may not have maintained student interest overall. However, tracking changes across two units could allow for more insight to how a different topic in physics affected change when it came to CSS vs. PSS units.

5.4.2.2 Sequencing

By the time students completed this unit, they had already completed quite a few units with me. They were well versed in the general way the classroom and units were set up. These units were not CSS units, but their impression of high school physics may have differed if their first unit was CSS. Would students feel differently about physics in terms of empowerment with content and how the content is presented? Would they feel that this different content could help them make change within their community? The sequence of the content for physics largely stays the same from year to year, but the type of unit that is targeted for that content could change. The way in which students respond could form interesting implications for the remainder of their academic year in physics.

5.4.2.3 Third Party Research

Students were assured that their responses to anything and everything would not affect their grades in the course. Only the students with whom I had a positive relationship participated in this case study. Therefore, I do not know how much of their responses, written or otherwise, may have been shifted as result of their relationship with me. I tried to reassure them that they could say whatever they wanted as it pertained to the curriculum and class. In addition, I reiterated that their responses would not cause any retribution. Yet, did they believe me? Nothing in the data states that they were worried about my response to their responses but having a third-party researcher lead the focus groups especially would have allowed me to see if they had different responses in my absence.

5.5 Implications for Future Study

As a mid-career teacher, this work is essential. Helping students of color to increase or maintain their STEM identity is important. It can help them open doors for themselves as well or apply STEM skills to other types of careers where the skills would be extremely useful. Future study on this topic should analyze the following topics: what grade band is best for this work, how transformative can culturally responsive units truly be especially for students with chronic absences, possibilities of transfer between groups of students within the subgroup profiles.

5.5.1 Middle School vs. High School Participants

When this study was originally imagined I was teaching at a middle school, but by the time the study was implemented, I was teaching at a high school. Middle and high school teachers have some similarities, including that most courses are discipline specific and students take courses in all of the disciplines. In addition, teachers in DC can be certified to teach middle and high school with one certification, 7-12 in a particular science content area. However, that is where many similarities end. Middle school students have a particular interest in a subject area and meet many school topics with interest as much of it is novel. High school students are a different story, by the time students get to high school they may be more apathetic. High school students may be interested in doing well, but may have developed habits about their level of engagement and their academic goals. This is especially true, in my experience, beyond 10th grade. Further study on how a CSS unit is received by a middle school class versus a high school class would be an intriguing study. Would there be any differences? Would middle schoolers be more interested? How would feelings of apathy be present or not present if this was done in a middle school classroom? Quite a few studies cite the middle school level or late elementary specifically when tracking how students are encouraged to stay, persevere or maintain interest in STEM (Archer, Dewitt, Osborne, Dillon, Willis & Wong, 2010; Bang, Warren, Rosebery & Medin, 2012; Basu & Calabrese Barton, 2006; Carlone, Scott & Lowder, 2014). Studies about high school students' interest in STEM are also done (Aschbacher, Li & Roth, 2009) but often pertain to career interests and not always to particular classroom shifts that teachers make.

5.5.2 Impact of Absenteeism vs. Culturally Responsive Units

One impact direct to my study, but also to my course over all is high school absenteeism and dropout rates. Dropouts usually start from a pattern of high school absenteeism. A study about high school dropouts had a number of reasons why students dropout (Bridgeland, J., DiIulio, J., & Morison, K., 2006). Reasons include boring classes, lack of interest and personal responsibilities outside of school. Therefore, can culturally responsive units and critical school science (CSS) increase student interest and keep students interested and in school? What other structures would need to be in place in a school to help ensure that students receive these opportunities, can learn the content of the grade, and can remediate any deficient skills. Some innovative school models that do more of this type of study, like High Tech High in California could provide important answers to some of those questions. Classes are very non-traditional and are project based to increase student interest. Further research should be done to determine if over time this model can still meet the needs of urban students who have deficiencies, but also keep their interest in school and more specifically in STEM as a result.

5.5.3 Changing a Student's Category

The subgroups that came out of the data were not far from what my predictions may be having known my students since the beginning of the academic year. Yet, the answer still remains, how do you get students to shift between those groups? Students did move positively within the category. If put on a continuum, after the study, even the STEM Critics group would be closer to the Science Communicators group rather than farther away. However, can they ever fully switch? When does that process need to start? How many factors would need to change within schools versus outside of schools (especially family support) with STEM? Lastly, how do you ensure that STEM Persisters do not move from their group depending on the science teachers and classes they have? Will their persistence always be strong?

6.0 Conclusion

Teachers have the power to make change within their classrooms and improve outcomes for students when given the autonomy to do so. This study shows that even in a short period, teachers can gather data and learn more about their students in hopes of designing the ideal classroom for students that assists in helping them become productive citizens and empowering them to make a difference. As a result of this study, subgroups can be identified for goals in differentiation within the classroom and the subgroups also have greater implications for the need to have heterogeneous classes to promote equity between students.

The subgroups determined in this study are similar to subgroups created by Aschbacher, P. R., Li, E. & Roth, E. (2009). There are students who have a persistent desire to achieve in STEM, students who achieve in STEM with ease, but are not that interested and students who struggle even if there is some interest found in STEM disciplines. While some groups I could have predicted, others were a surprise and seemed to be established because of the nature of the task. Will these groups persist? If curriculum continues as this one did, I believe that students can move out of their original groups. Teachers must make constant choices at engaging students in culturally responsive units (Franklin, Conrad, Aldana & Hough, 2011; Meluso, Zheng, Spires & Lester, 2012) that are constantly modified and varied from year to year to align to student interest and changing times. If a teacher were to follow student to the next grade level and continue to teach science, this would allow for a beneficial relationship and facilitate more movement between categories. I propose that the looping nature would allow for findings in a study like this to allow me to continue to guide Amare and Zola to leaving the category of STEM Critics and at the very least become Science Communicators. It should be noted however, that the use of this might be more impactful in middle school. High school faculty could potentially be combatting years of instruction where students like Amare and Zola are not engaged in STEM in a way that increases their interest. Science Communicators like Peace, Imani and Belle can continue to hone their science aptitude and be introduced to new possibilities that assist in seeing new potential in existing or future science careers. I would, because of what was learned in this study, be able to continually differentiate to target both the groupings of students within the study and the class as a whole. Students who were not in the study fall closely into the STEM critics category particularly the young men who are on longer interested in school.

Working in groups has strong implications for students to become productive citizens. Often in schools in which I have been employed, administrators want a level of quiet or a level of designated content talk that limits student interaction. Encouraging and implementing CSS demands that students work in groups and learn to work with each other. Jo Boaler (2008) has discussed the value of group work concerning respect, responsibility and support. She calls this “relational equity.” Relational equity allows students to learn to respect and value others, but also understand that “they could solve complex problems through persistence and collaboration with others” (p. 190). While the work that Boaler did at Railside was in a mathematics classroom, the idea of relational equity is transformative and applicable across disciplines, but especially for STEM. STEM seeks to explain and solve problems that can be especially challenging. However, just as students saw within this study, working together and gathering the ideas of others can increase a sense of self-efficacy. It can also increase your class achievement and find beneficial solutions that can improve people’s quality of life like the cell phone blocker. It can also inspire students to persist in finding solutions and working together to make life better for all.

Appendix A

Lesson Plans and Timeline

Next Generation Science Standards (NGSS) aligned units used within this study. Both written in the 5E lesson plan format with number of class periods for each stage

A.1 Debate

5E Lesson Cycle Objective: **SWBAT construct an argument in response to a question about cell phone position at night while sleeping using data from texts, science knowledge and personal experiences.**
NGSS: *Performance Expectation:* **HS-PS4-3**: Evaluate the claims, evidence and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. *Disciplinary Core Ideas:* PS4.A Wave Properties - Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up. PS4.B Electromagnetic Radiation - Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. *Crosscutting Concepts:* Systems and System Models *Science and Engineering Practices:* Engaging in an Argument from Evidence, Obtaining, Evaluating and Communicating Information
CCSS: RST.11.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. RST.11.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. RST.11.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

RST.11.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.		
5E Stage	***Number of Class periods***	***Explanation***
Engage	½	**Question: How important is your cell phone?** A discussion of the importance of cell phone as a result of the do now responses. Students will then be asked where do they put their cell phone at night when they are sleeping. Questions will be probed of why their cell phone is in that place and could it be anywhere else at night and why. This all leads to the debate and essay prompt question of: Should teenagers sleep with their cell phones in their beds at night? Why or why not? Students respond to the prompt in their notebooks.
Explore	½	Students participate in an exercise on choosing appropriate evidence to support or refute an argument about a different scenario/topic. This is evaluated for consistency across groups to determine if students placed evidence in the for or against the sample argument column and if they have appropriate justification to support. Students are given articles and an infographic that gives data to support or refute the hazardous effects of cell phone radiation. Students will use multicolored highlighters to highlight parts of the articles that are for or against their argument to use in the outline for their essay. The goal for today is simply to choose appropriate evidence to support and refute their claim.
Explain	½	Students are asked to think about the articles they previously read and make connections to the science we have been learning about, waves. How does this relate? Why does it relate? In what way is what we studied supported in the article and in what ways is it not supported? Does this relate to any previous science classes you've taken? Why? The questions above are used to facilitate discussion in small groups as students make connections to a real world problem and science we've been learning in physics.
Elaborate	½	Students create outlines and write essays in response to the question: Should teenagers sleep with their cell phones in their beds at night?
Evaluate	1	From the essays written in the previously class period, students have a debate using a protocol. Students are grouped with other students who have the same choice (pro/con) in response to the question. Students use their essays to construct a verbal argument (on notecards) to

		present to the other team and gather data they may want to save for a rebuttal to something the opposing side says. Due to the size of the class, three mini debates will occur across the class to support more student engagement. At the end of the debate, both sides must come to consensus with an action step on what to do next related to this problem.
Total	**3 class periods**	

A.2 Engineering Task

5E Lesson Cycle Objective: **SWBAT design and construct a solution to the problem posed during the preparation for the debate.**
NGSS: *Performance Expectations:* **HS-ETS1-2**: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering **HS-PS4-3**: Evaluate the claims, evidence and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. *Disciplinary Core Ideas:* ETS1.C Optimizing the Design Solution – Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. PS4.A Wave Properties - Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. PS4.B Electromagnetic Radiation - Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. *Crosscutting Concepts:* Systems and System Models, Interdependence of Science, Engineering and Technology, Influence of Engineering, Technology and Science on Society and the Natural World *Science and Engineering Practices:* Asking questions and Designing Problems, Constructing Explanations and Designing Solutions, Obtaining, Evaluating and Communicating Information
CCSS:

RST.11.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.		
5E Stage	***Number of Class periods***	***Explanation***
Engage	½	***Question: Define the problem in your own words and who are the stakeholders.*** Presentation of proposals from the three groups at the end of the debate (last class) Other students will evaluate which proposal sounds the most feasible for the class to pursue, which really gets to the root of the problem and considers the audience who have the problem.
Explore	1	As a result of the proposals, students will explore how to create what is proposed. What materials would be needed and how do we know those materials will do what is needed? Testing occurs.
Explain	½	Individual student groups (of 3-4 students) will brainstorm unique solutions to the problem using the information already gathered and considering all of the criteria and constraints for the problem we outlined in a previous class period. Students will each brainstorm their own and then use a decision matrix to choose which solution should be created based on the criteria written in the decision matrix.
Elaborate	1	Students will create their solution and measure for specifications. Students will also create a title of the product and slogan for the product.
Evaluate	1	Students will evaluate the products effectiveness and write up their engineering design challenge.
Total	**4 class periods**	

Appendix B

Data Collection Tools

Tools used to collect data for this study including: survey used for pre and post, focus group questions and statements on participant reflections.

B.1 Survey

Taylor, P.C., Fraser, B.J. & Fisher, D.L. (1997)

Classroom Environment Questionnaire

Directions

1.Purpose of the Questionnaire
This questionnaire asks you to describe important aspects of your science classroom. There are no right or wrong answers. This is not a test and your answers will not affect your assessment. Your opinion is what is wanted. Your answers will enable us to improve future science classes.

2.How to Answer Each Question
On the next few pages, you will find 42 sentences. For each sentence, circle only one number corresponding to your answer. For example:

		Almost Always	Often	Sometimes	Seldom	Almost Never
In my science class . . .						
8	The teacher asks me questions.	5	4	3	2	1

- If you think your science teacher *almost always* asks you questions, circle the 5.
- If you think your science teacher *almost never* asks you questions, circle the 1.
- Or you can choose the number 2, 3 or 4 if one of these seems like a more accurate answer.

3.How to Change Your Answer

If you want to change your answer, cross it out and circle a new number, For example:

8	The teacher asks me questions.	3	2	1

4.Completing the Questionnaire

Now turn the page and please give an answer for every question.

Learning about the world	Almost Always	Often	Some-times	Seldom	Almost Never
In my science class . . .					
1 I learn about the world outside of school.	5	4	3	2	1
2 My learning starts with problems about the world outside of school.	5	4	3	2	1
3 I learn how science can be part of my out-of-school life.	5	4	3	2	1
In my science class . . .					
4 I get a better understanding of the world outside of school.	5	4	3	2	1
5 I learn interesting things about the world outside of school.	5	4	3	2	1
6 What I learn has nothing to do with my out-of-school life.	5	4	3	2	1

Learning about science	Almost Always	Often	Some-times	Seldom	Almost Never
In my science class . . .					

7	I learn that science cannot provide perfect answers to problems.	5	4	3	2	1
8	I learn that science has changed over time.	5	4	3	2	1
9	I learn that science is influenced by people's values and opinions.	5	4	3	2	1

In my science class . . .

10	I learn about the different sciences used by people in other cultures.	5	4	3	2	1
11	I learn that modern science is different from the science of long ago.	5	4	3	2	1
12	I learn that science is about inventing theories.	5	4	3	2	1

Learning to speak out		Almost Always	Often	Some-times	Seldom	Almost Never
In my science class . . .						
13	It's OK to ask the teacher "why do we have to learn this?"	5	4	3	2	1
14	It's OK to question the way I'm being taught.	5	4	3	2	1
15	It's OK to complain about activities that are confusing.	5	4	3	2	1

In my science class . . .

16	It's OK to complain about anything that prevents me from learning.	5	4	3	2	1

		Almost Always	Often	Some-times	Seldom	Almost Never
17	It's OK to express my opinion.	5	4	3	2	1
18	It's OK to speak up for my rights.	5	4	3	2	1

Learning to learn		Almost Always	Often	Some-times	Seldom	Almost Never
In my science class . . .						
19	I help the teacher to plan what I'm going to learn.	5	4	3	2	1
20	I help the teacher to decide how well I am learning.	5	4	3	2	1
21	I help the teacher to decide which activities are best for me.	5	4	3	2	1

Learning to learn (cont.)		Almost Always	Often	Some-times	Seldom	Almos t Never
In my science class . . .						
22	I help the teacher to decide how much time I spend on activities.	5	4	3	2	1
23	I help the teacher to decide which activities I do.	5	4	3	2	1
24	I help the teacher to assess my learning.	5	4	3	2	1

Learning to communicate		Almost Always	Often	Some-times	Seldom	Almost Never
In my science class . . .						
25	I get the chance to talk to other students.	5	4	3	2	1

26	I talk with other students about how to solve problems.	5	4	3	2	1
27	I explain my ideas to other students.	5	4	3	2	1
	In my science class . . .					
28	I ask other students to explain their ideas.	5	4	3	2	1
29	Other students ask me to explain my ideas.	5	4	3	2	1
30	Other students explain their ideas to me.	5	4	3	2	1

Interest in learning science		Almost Always	Often	Some-times	Seldom	Almost Never
	In my science class . . .					
31	I am interested in science lessons.	5	4	3	2	1
32	I am willing to learn.	5	4	3	2	1
33	What we do in science class is important to me.	5	4	3	2	1
	In my science class . . .					
34	I try my best.	5	4	3	2	1
35	I pay attention.	5	4	3	2	1
36	I enjoy science lessons.	5	4	3	2	1

Teacher support in	Almost Always	Often	Some-times	Seldom	Almost Never

learning science

In my science class . . .

37	The teacher is friendly to me.	5	4	3	2	1
38	The teacher helps me with the work.	5	4	3	2	1
39	The teacher is interested in my problems.	5	4	3	2	1

In my science class . . .

40	The teacher goes out of his/her way to help me.	5	4	3	2	1
41	The teacher moves around the class to talk to me.	5	4	3	2	1
42	The teacher considers my feelings.	5	4	3	2	1

The items in successive blocks of six assess, respectively, Personal Relevance, Critical Voice, Shared Control, Uncertainty, Student Negotiation, Commitment, and Teacher Support. The circled number is the score for every item except Item 6, which is scored in the reverse manner. Omitted or invalid responses are scored 3.

http://www.letus.northwestern.edu/msta/surveys/source-documents/cles.html 10/12/07

B.2 Focus Group Questions

Before Engineering Task Begins:

What class do you experience the most success in school and why?
How would you rate science class and why?
How do other students contribute to your learning in science this year?
How is STEM related to your life outside of school?

During Engineering Task (2):
How would you describe the difficulty of the engineering task?
What successes and challenges has your group had in completing it so far?
How does this task relate to your non-academic life?

At the end of the Engineering Task:
What class are you experiencing the most success in school and why?
How did you, in comparison to your group, contribute to the completion of your task?
How is STEM related to your life outside of school?

B.3 Participant Reflection Statements

Fraser, B. J. (1981).

Attitude to Scientific Inquiry
(3) I would prefer to find out why something happens by doing an experiment than by being told.
(52) It is better to ask the teacher the answer than to find it out by doing experiments.

Adoption of Scientific Attitudes
(53) I am unwilling to change my ideas when evidence shows that the ideas are poor.

Enjoyment of Science Lessons
(32) I like to listen to people whose opinion are different from mine.

Leisure Interest in Science
(41) Talking to friends about science after school would be boring.

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