Remaking Prototypical: Exploring the Shifts in High-School Girls' Engineering Identity

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In the years 2005 to 2019, the number of American women receiving a degree in engineering was below 20 percent. Furthermore, even after receiving a degree in engineering, 40% of those girls do not enter the profession. While the above graduation data is essential for understanding the problem at the end of the educational journey, it doesn't point to a girl's reasons to pursue or not pursue a degree in engineering. Nor does it express the societal impact a diverse engineering workforce could have on society. However, not only do we need more engineers, but we need more diversity in how we solve the ever-increasingly complex problems humanity will face. This proposed two-phase study will explore the shifts in high-school girls' engineering identity. Based on past research, my theory of improvement takes a blended approach that incorporates application, collaboration, and empathy-building in engineering design challenges. Phase one will take the form of a project-based unit plan that guides students in creating a solution to a societal problem. By transforming the traditional classroom format and fostering positive classroom interaction between students, the Engineering Design Unit increases a girls' understanding of the assigned problems and how to develop a solution to those problems. Finally, phase two will take the form of an open-ended essay to gather qualitative data on shifts in a girl's engineering identity after completing the Engineering Design Unit. The Engineering Design Unit ran over 30 school days in the fall of the year 2021 with three sections of the Introduction to STEM course and a total of 72 students. However, only data from the twenty-three students who identify

as a girl, female, or woman will be analyzed to understand the shifts in high-school girls' engineering identity.

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1.0 Section I: Naming & Framing the Problem of Practice

1.1 Broader Problem Area

Despite decades of increased attention around girls[1] in STEM, women and girls continue to be underrepresented in engineering. A 2019 report by the U.S. Bureau of Labor Statistics (B.L.S.) and the American Society for Engineering Education (A.S.E.E.) shows a median annual salary of $94,600 for engineers compared to all U.S. Occupations at $38,640. As for job growth over the next decade, the B.L.S. and the A.S.E.E. report a 13% increase in the engineering fields over the predicted 5.2% increase in available jobs for the entire U.S. workforce. So even with a positive growth outlook and a higher salary range, girls still only make up "13% of the engineering workforce" in the U.S. (Silbey, 2016).

In 2013, under 20 percent of American students receiving an engineering degree were women (Weis, 2017). U.S. Department of Education (2019) backs up this information, reporting that between the years 2005 to 2017, the number is below 20 percent. While the number of women receiving engineering degrees steadily rises to reach 20.6 percent in 2018 (US DEPT 2019), the number of girls who intended to pursue a degree in engineering but did not is concerning. The Society of Woman Engineers (2016) reports that in 2007, 2.6 percent of "female" college freshmen intended to major in engineering, but only 1.6 percent received an engineering degree. However,

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[1] In the case of this study the word “girls” or “high school age girls” will refer to any person who identifies as a female, woman, or girl.

even after receiving a degree in engineering, 40% of those girls do not enter the profession (Silbey, 2016). While the above graduation data is essential for understanding the problem at the end of the educational journey, it doesn't point to a girl's reasons to pursue or not pursue a degree in engineering. Nor does it express the societal impact a diverse engineering workforce could have on society.

In her research, Susan Silbey (2016) finds that "men and women" share common reasons for enrolling in engineering programs after high school. However, girls engage more with the social and environmental impacts of engineering (Cech, 2014). According to Fátima Monteiro, Carlinda Leiteb, and Cristina Rocha (2018), engineers have three roles in contemporary society. The third is the notion that engineers serve as an "agent of change committed to progressive social change and sustainable development" (p. 2). Even though research suggests girls engage more with the socially-conscious aspects of engineering and one of the main roles of engineers in society is as social servant. However, there are likely other factors at play to discourage or reject girls from the field. These factors could manifest in different stages of a girl's development or in different aspects of a girl's life. In her research, Susan Silbey (2016) found that these factors include an industry that does not address issues of "sexism and stereotypes" from the education side to the workplace. While research by Robnett (2013) suggests that a girl's peer group has an impact on a girl's interests, including interest in engineering or other STEM fields.

For the purposes of my project, engineering will refer to any field of study with "engineering" or "engineer" in the job or degree title. Examples of this can include but are not limited to, mechanical, electrical, computer, software, chemical, and robotics. In addition, another term utilized throughout this paper, S.T.E.M. (herein known only as S.T.E.M.), is used to incorporate all science, technology, engineering, and mathematics careers, skills, and classroom experiences in the kindergarten to the twelfth grade (K-12) levels of schooling. Finally, another term used throughout this paper is the word "girls," which will refer to high school-age girls of ages 14-18.

1.2 Organizational System

My current position is in Southwestern Pennsylvania High School (SPA High School or SPAHS), part of the Southwestern Pennsylvania School District (SPASD) in Washington County, Pennsylvania. Based on data from the 2017-2018 school year, this affluent district serves 4,049 students ("Common Core of Data," 2019) from kindergarten to twelfth grade. The median income of the community is $143,882 ("National Center for Education Statistics (N.C.E.S.)," 2017). This income level is double the median income of the county in which it exists, Washington county, as well as the state in which it exists, Pennsylvania (censusreporter.org). The community residents also have educational attainment of a bachelor's degree or higher of 73.1%.

The income and educational attainment statistics are essential to understanding my organizational system because it suggests the community values education and professional success. The school district's successes further demonstrate these communal values. For example, the district has some of the highest standardized test scores in the state, and for 2017-2018, 2018-2019, and 2019-2020 the best P.S.S.A., P.S.A.T., and Keystone state assessments scores. Also, the district has a 98% college acceptance rate to four-year postsecondary institutions.

As an elective teacher, students have the option to take my courses. I teach students in grades nine through twelve in a range of elective classes focused on the various fields of engineering. In this context, an elective class is any class not required by the state as a graduation requirement. Core classes include mathematics, sciences, English language arts, social studies, and physical education. Elective courses include technology education, computer science, business, social sciences, health sciences, media production, visual arts, and music education. Because my classes are considered an elective, students decide whether to take them and at which point in their high school career. Meaning, my classes usually have a mix of students in grades nine through twelve and allows for cross-age learning.

Courses available as electives to students in the technology education department include engineering (or what we call applied engineering), architecture, robotics, manufacturing, product development, computer-aided design (CAD). As a department with three full-time teachers who only teach technology education courses at the high school, we see very high enrollments in ten different engineering and traditional industrial arts-focused courses. High enrollment in engineering classes is no surprise when considering parents' income level, educational attainment, and careers. However, when you look at the gender ratio of the enrollment in these courses, a problem emerges. Nine of our courses have a 0%-20% female enrollment. An introductory course, Introduction to S.T.E.M., offered as an introduction to other courses in the technology education department, has an annual enrollment of 30%-40% girls. However, the Introduction to S.T.E.M. course is one of three technology electives students must take before graduating. Therefore, a student enrolling in Introduction S.T.E.M. does mean they are interested in engineering or any other S.T.E.M. field.

In my previous role as a community education manager at a local university, I worked with the district as an educational consultant to update their curriculum to reflect the changes made from industrial arts to engineering. I was subsequently offered a teaching job in the technology education department to implement these changes due to other faculty members ' reluctance to change. This reluctance to change reinforces the "shop class" and "boys only" stereotypes ingrained in modern society. Not only are these preconceived notions damaging to the changes that the department has undergone over the past five years, but they are also still reinforcing the "boys only" mentality. Through the Introduction to S.T.E.M. course, we have the opportunity to engage a girl's interest in engineering. However, the male-dominant culture plaguing the department often squanders this opportunity.

The "shop class" identity of high school technology education was part of technology education's industrial arts model. The technology education curriculum at the state and national levels has changed over the last 15 years from the traditional industrial arts curriculum to an engineering-focused curriculum. Some now refer to this curriculum at the state and national level as S.T.E.M., albeit incorrectly.

As a high school teacher, my interactions with students only allow anecdotal information of what could encourage or discourage girls toward or away from engineering. One of the most prominent examples of what might push them away is the lopsided enrollment numbers in my engineering-focused courses. In my experience, it can be intimidating for a girl to walk into a predominantly male class. This intimidation factor manifests in different ways, including minimal engagement in course discussions or just dropping out of the course altogether. A second example, which is also related to the lopsided enrollment numbers, is a girls' peer group not sharing the same interests. I rarely have girls enrolled in engineering-focused courses, which are friends outside of the course. Peer groups are crucial for adolescent students, and these groups ultimately form us into the person we become.

A third example is related to a student's home life. Typically, girls who enroll in higher-level engineering courses have a family member who has or had a career in a S.T.E.M. field, including engineering. Previous interactions and collaborations with parents in this school district have demonstrated a high number of engineers, scientists, doctors, and business owners. However, several girls do not take my courses and still pursue engineering degrees. This information comes from software that students in the SPASD use to apply, communicate, and enroll in post-secondary institutions. However, I do not have data on whether the girls who enroll in engineering as a major actually graduate with that degree. In contrast, I do not have data showing whether girls who graduate from SPASD switch their major to engineer later in their post-secondary education.

The final example of what I have noticed about girls who take my engineering courses is that they thrive. In my experience as a teacher, girls rarely get bad grades and are always willing to challenge themselves in the coursework. This success is not only in my classes but in the entire technology education department as well. Success could be attributed to the lack of a peer group to distract them. It could also be a manifestation of the intimidation discussed in my first example; in that they want to show the boys they are more capable.

1.3 Stakeholders

1.3.1 Teachers

The teachers are responsible for many different parts of the educational experience at Southwestern PA High School. These responsibilities include the development, evaluation, and execution of the curriculum. Teachers also serve as unofficial career counselors and mentors to students through general student interaction and serving as student club sponsors.

In the case of my problem of practice, teachers are organized into two groups. The first group consists of a group known hereafter as core teachers. This group includes all education disciplines commonly required by all students to take during their high school career but not part of the elective course offerings. These overall disciplines include but are not limited to English Language Arts (E.L.A.), Mathematics, Sciences, and Social Studies. These teachers have a close working relationship with the school administration and connect with the technology education teachers, students, and parents. In addition, they have power over students due to their position as a teacher.

The second group will consist of a group known hereafter as technology education teachers. Technology Education teachers hold Pennsylvania state teaching credentials for technology education. The technology education state curriculum has changed over the last 20 years to move away from traditional industrial arts for an engineering focus. Due to their connections and working relationships with all identified stakeholders, technology education teachers are central to the identified problem of practice. Concerning the other identified stakeholders, technology education teachers have power over the students who elect to enroll in their courses.

1.3.2 Students-High School Girls

High school-age girls, those who fall in 14-18 years of age, are the primary stakeholders for this problem of practice. These students decide which elective courses to enroll in, determined by their interests. The number of electives a student enrolls in is set by the school administration, school board, and the state of Pennsylvania's high school graduation requirements. Students are connected to all stakeholders due to the primary focus of the problem of practice. However, even with the primary focus, they have no power over any other stakeholder.

Findings from research suggest that the primary factors driving this problem of practice include gender stereotypes and the associated internal and external barriers ingrained in modern society, reinforcing ideas that girls are bad at and have no interest in engineering. This type of gender stereotyping is threatening educational performance for girls and can also negatively influence career aspirations. Another of the primary factors includes access to engineering experiences throughout their childhood development. The access factor manifests as barriers to necessary experiences or education that is important for aspiring engineers. For example, if a girl does not have a strong base in mathematical skills, they are hamstrung when progressing through advanced mathematics. A 2018 report by the U.S. Department of Education says that only 24% of public-school students take algebra in 8th grade. The report also says that only 59 percent of schools offer Algebra I in 8th grade. According to a literature review, strong mathematical skills are vital for engineers. The earlier girls are exposed to these skills, the better chance they could have of following this career path.

1.3.3 Parents

Parents of high school-age girls are essential stakeholders. In this context, parents have limited power and limited connections to other stakeholders except for the students. Findings from empathy interviews suggest that families are a significant driver for students pursuing degrees in engineering and other S.T.E.M. fields. Much of the research on why girls do not pursue degrees in S.T.E.M. fields suggests that peer groups, their K-12 education experiences, and family play an equal role in a girl's choice to pursue a degree in S.T.E.M. field study. For example, Anaya, Stafford, and Zamarro (2017) use data from the University of Michigan's Panel Study of Income Dynamics to study how a parent's occupation type could affect self-perceived math ability and math achievement. The study's findings suggest that girls who have a parent employed in a S.T.E.M. occupation benefit more than boys (Anaya et al., 2017).

The connection between this problem of practice and parental engagement can take three different forms. First, the interest parents demonstrate with their child's education. Second, an understanding of how a parent's professional career affects their child's interest in a future career. Third, in the support, a parent gives a child who shows interest in a potential career topic. Finally, it would be beneficial for this problem of practice to know the parents' careers and any preconceived notions of engineering that might skew a student's interest in engineering or other STEM-related careers.

1.3.4 School Administration

School administration includes building principles, the assistant superintendents, the superintendent, and the school board. This group focuses on the school's success in preparing students to be contributing members of society, keeping students safe, attracting and hiring high-performing teachers, and the district's financial responsibilities as a whole. Their ideal reality is on standardized tests, high student success, student acceptance to post-secondary schooling, and economic balance. The school administration is connected to the teachers directly but not as connected to any other stakeholders.

1.3.5 Post-secondary Schools

Post-secondary schools with engineering programs have an interest in the problem of practice due to their own recruiting practices. The ability to recruit a qualified, motivated, and diverse student body is of high interest and importance to colleges and universities. If students have an established plan to pursue engineering in their post-secondary schooling, they would also understand the importance of engineers' strong mathematical skills. These students would be ideal for recruitment into engineering programs because they would ideally have higher mathematical skills and a better chance of success in these programs. Post-secondary schools are connected to students and the engineering industry, but those connections may be tenuous at best. However, this problem of practice has the potential to demonstrate how a close relationship with teachers who teach engineering courses in a high school could be valuable for all stakeholders. However, these connections do not manifest in more power for the post-secondary school over any other stakeholder except for the students.

1.3.6 Engineering Industry

The engineering industry also has an interest in the problem of practice due to a need for a source to refill its workforce. Roberta M. Rincon explains in her 2017 article for the Global Policy Institute that we could see an "engineering job growth of about 30% through 2022" (Hogan & Roberts, 2015; Rincon, 2017). With this increasing demand, it is clear that we need more engineers to keep our economy competitive in the global market. Not only do we need more engineers, but we need more diversity in how we solve the ever-increasingly complex problems humanity will face. The engineering industry could engage with the other stakeholders in the form of mentors for teachers and students. The industry could also work closely with school administration and post-secondary schools to develop and update their engineering curriculum. However, the engineering industry would only have power over the post-secondary schools due to their hiring practices. If the industry does not hire from a particular post-secondary school due to engineering graduates' quality, it could negatively affect that schools' engineering program.

1.3.7 Positionality Statement

The lens of my problem of practice also needs proper consideration of my positionality and how it impacts my teaching. As a white lower-middle-class cisgender male raised in a lower-class family, I am unaware and unable to understand on a personal level the oppression and life experiences that girls in our society face. This inability to understanding on a personal level also extends to the professional realm, especially in the STEM industries. While my current socio-economic position allows me to understand those students who share that position, I cannot understand the life experiences of those considered low socio-economic status.

My position as a Pennsylvania certified Technology Education teacher and my positionality as a white lower-middle-class cisgender male puts me in a position of power. This position of power could impact the results of my surveys. As a teacher, students may answer survey questions asking about their experiences with what they think I would want to hear. My teaching philosophy also magnifies this position of power by relying on a constructivist and cross-curricular approach where the application of core class content to hands-on, real-world experiences is the focus. The fault in my teaching philosophy is that it does not take gender identity, ethnicity, or socio-economic status into account. I hope that the findings in this study and the experience overall will allow me to learn about girls' experiences in STEM through their developmental ages. Ultimately this will help me adjust my teaching philosophy and improve the STEM educational experiences for high school-age girls.

1.4 Statement of the Problem of Practice

The problem of practice that will guide my research is to explore shifts in a high-school age girls' engineering identity. National data has shown that the yearly number of students graduating with a degree in engineering is only, on average, 20% female. Even after receiving a degree in engineering, 40% of those female engineering graduates do not enter the engineering workforce. If 20% of engineering graduates are girls and only 60% actually enter the engineering workforce, then we have an increasingly homogenous workforce. While in the short term, this homogeneity can keep our economy competitive in the global market. The lack of diversity can only hinder our ability to solve the ever-increasingly complex problems humanity will face in the long term. A diverse engineering workforce could give us, our country and humanity in general, the edge in overcoming current and future challenges. As a high school technology education teacher, I do not have access to affect change at the post-secondary or industry level for girls entering the engineering workforce. However, my role allows me to foster a space for high school-age girls who may have been discouraged or not given the time to explore their interests in engineering. Likewise, help direct those students who may not even know they have an interest in the career due to lack of engagement throughout their education journey.

1.5 Review of Supporting Knowledge

1.5.1 Purpose of Review

In this review of supporting knowledge, I will seek to answer the following questions:

1. What are the key factors that explain a high school age girls' disinterest or tendency to avoid engineering as a potential post-secondary field of study?
2. What are effective ways of supporting a high school-age girls' interest in engineering?

This literature review will begin with a search using keywords in various combinations: engineering, girls, women, career, STEM, science, technology, mathematics, high-school, middle-school, and education. Empirical research will be an essential cornerstone of this review of the literature to link anecdotes and current practice standards to empirical data.

1.5.2 Roadmap

This review of literature examines previous research focused on strategies that have been shown to support adolescent girls' interest in engineering. First, I look at gender stereotypes and the associated internal and external barriers ingrained in modern society, which reinforces ideas that girls are bad at and have no interest in STEM. This type of gender stereotyping threatens performance in schooling for girls and can also negatively influence career aspirations. Second, I look at strategies to support a girl's interest in engineering. Using these areas of research, I plan to develop an action research study to address my problem of practice.

1.5.3 Review of Scholarship

What are the Key Factors that Explain a High School Age Girls' Disinterest or Tendency to Avoid Engineering as a Potential Post-Secondary Field of Study?

1.5.3.1 Stereotypes

Gender stereotyping could be one of the key factors to explain an adolescent girls' disinterest or tendency to avoid engineering as a potential post-secondary field of study. From an early age, girls are at a disadvantage due to gendered stereotypes in the STEM fields and the importance of strong mathematic skills required in the engineering field (Dasgupta & Stout, 2014;

Reilly et al., 2019). The stereotype is that mathematics and science are masculine, and reading and language are feminine (Reilly et al., 2019). Equally, these gender stereotypes can undermine the interest and performance of girls in the STEM domain, even when girls have positive math attitudes (Shapiro & Williams, 2012b). So even when a girl has a positive math attitude, they still have the ingrained internalization of these stereotypes that can challenge these positive attitudes. Dasgupta and Stout (2014) suggest that the internalization of these stereotypes happens before a measurable problem emerges in math education. Research on this topic agrees that by the time a girl could be found to have an issue or dislike in mathematics, it could be too late to combat the stereotype. It seems that the internalization happens so early in a girl's life that it is unavoidable due to the collective societal experience we all share.

This stereotyping becomes a part of a girl's view of the world, which follows them into post-secondary education and can ultimately affect their career choices. However, is an internalization of these stereotypes the only force that hinders a girl's interest in engineering? Or are their external barriers that reinforce the stereotype as well? Who or what is pushing these stereotypes, and where are they spawn? As discussed above, cultural stereotypes are one culprit and have a significant impact on a girl's interests from a young age. Related bodies of work focus on discovering who acts as an external barrier to a girl throughout their development, albeit unknowingly and without malice. Gunderson, Ramirez, Levine, and Beilock (2012) suggest that parents and teachers can view girls and boys differently as a result of their math-gender stereotypes and gender-biased perceptions. These findings are based on their investigation of existing research showing expectancies for children's math competencies are often gender-bias, and this bias could influence a child's math attitudes and performance (Gunderson et al., 2012). Overall, this treatment considers that girls' attitudes toward engineering and STEM in general form based on experiences with parents, teachers, and peers.

Shapiro and Williams (2012) review the research done by Gunderson et al. (2012) a step further from a conceptual standpoint and apply "the social psychological phenomenon of stereotype threat" (p.175) to further understand how stereotypes could undermine a girl's potential interest and performance in the STEM domains. The authors conclude that the transfer of gender-related stereotypes relating to the STEM domains, even something as simple as a generally negative attitude toward a STEM-related topic, can put a girl at risk for self-realization and manifestation of the stereotype. These stereotype threats could manifest in a self-fulfilling prophecy and confirm the stereotype is indeed true through hindering a girl's performance before it even begins.

Another barrier acting as an internal and external barrier is found in the research by Ehrlinger, Plant, Hartwig, Vossen, Columb, & Brewer (2018). The authors conducted a study with a group of undergraduate students, of which 68.2% were girls. The focus of this research was to understand a girl's perception of what an Engineering professional is, relating to gender and intellectual ability. The authors observed that girls perceived the academic traits of prototypic engineers to be more intense and stereotypical than male participants and showed less participation in potential engineering courses and professions. This perception demonstrates how a combination of stereotypes and the associated internal and external barriers can hinder a girl's interest in engineering. Could this mean that since girls do not see themselves in the prototypical societal version of an engineer, they cannot see themselves as engineers? The researchers even account for exposure to engineering and exposure to professional engineers, by way of family members, peer groups, and through past extracurricular activities, into their methodology. The results still show that girls do not see themselves as the prototypical CS&E professional and this misalignment of perceptions contributes to the lack of interest in CS&E for girls (Ehrlinger et al., 2018).

Do the internal and external barriers discussed above manifest in performance disparities? A 2015 report by the Organization for Economic Co-operation and Development (OECD) finds that differences in performance based on gender do not come from a difference in aptitude. The report suggests that low performance in math and science in high school-age females is partly because of girls' lack of confidence in their abilities. This lack of confidence leads to lower academic performance in the STEM fields of study, which could lead to a lack of interest in the career. Shapiro and Williams (2012) discuss another example of a lower performance attributed to gender stereotypes. In their article, they discuss data from an AP Calculus AB exam in which high school students were either required to comment about their identity before they began or after they completed the exam (Shapiro & Williams, 2012). Shapiro & Williams (2012) found that when girls were required to comment on their gender before taking the AP Calculus exam, "thereby making gender salient prior to the test," their performance was decreased by 33% compared to girls who report on their gender after the test. (p. 176) So, even we girls participate in advanced math assessments, the mention of their gender could affect their performance. This self-belief is a prominent theme throughout much of the research for this topic. Since gender stereotyping is threatening performance in schooling, it can also harm career aspirations.

The above literature suggests that girls and women are challenged with internal and external barriers that are reinforced throughout society and are still ingrained in modern thinking. Ideally, every girl would be interested in STEM, and in the case of this literature review, engineering. The situation would still be only slightly less-than-ideal if girls would be disinterested in engineering because of personal reasons. However, the reality of these barriers is that societal norms hinder a girl's interest in engineering throughout K-12 schooling.

1.5.3.2 Access

In addition to stereotypes as a barrier hindering a girl's interest in engineering, another prominent in the literature is a barrier of access. However, could the lower performance in STEM assessment be attributed to a lack of access to courses throughout their K-12 journey? If a girl does not have a strong base in mathematical skills, they are hamstrung when progressing through advanced mathematics. A 2018 report by the U.S. Department of Education says that only 24% of public-school students take algebra in 8th grade. The report also says that only 59 percent of schools offer Algebra I in 8th grade. Strong mathematical skills are vital for engineers, and the earlier girls are exposed to these skills better chance they could have of following this career path.

What about the availability of advanced mathematics and science classes at the secondary school level? A 2018 report by the U.S. Department of Education drawing on data from the Civil Rights Data Collection study shows that only 50% of high schools offer calculus, and only 63% offer physics nationwide. The data would suggest that girls are already at a disadvantage at a critical time in their development from a schooling perspective. Also, even if girls are interested in engineering or other STEM careers, some students may not even get the higher-level courses needed to exercise and nurture that interest.

Table 1 Science and Math Distribution of Students by Sex

	Male Enrollment	Female Enrollment
High School Enrollment	51%	49%
Algebra I	53%	47%

Geometry	51%	49%
Algebra II	49%	51%
Advanced Mathematics	48%	52%
Calculus	50%	50%
Biology	50%	50%
Chemistry	48%	52%
Physics	54%	46%

If girls have science and math courses available, how is their enrollment? Data released in 2018 based on the 2015-2016 Civil Rights Data Collection study shows (Table 1) that when girls do have access to advanced mathematics and science courses, their enrollment is close and sometimes more than that of males (U.S. Department of Education Office for Civil Rights, 2018). Even with the gender parity in high school courses, only 15% of high school-age girls concentrate on engineering and associated technologies (Milgram, 2011, p. 4). This research suggests that girls take courses that would support a career in engineering, but they do not follow that career path. Maybe girls do not even know what engineering is and thus do not follow it into college.

Even if they discover engineering in college and decide to change paths, it may be too late. Wang, Eccles, and Kenny (2013) back up this claim explaining the difficulty for students to initiate a STEM career trajectory after starting college due to the rigid and planned nature of the curricula. Their study, published in 2013, investigated whether 12th grade students with "high math and high verbal ability" were more or less likely to choose a STEM occupation than those demonstrating "high math and moderate verbal ability" (Wang, Eccles, & Kenny, p. 770). The national longitudinal study included 1,490 individuals surveyed as 12th graders and then again at the age of 33, with 49% being female and 51% male. (Wang, Eccles, & Kenny, 2013)

Most people would assume that students with high math and high verbal ability would follow a path to a STEM career. However, Wang, Eccles, and Kenny (2013) suggest that the opposite is true. Their findings demonstrate that individuals with high math and moderate verbal ability rely more on their math strengths and thus gravitate to those careers. As it relates to girls and engineering, they find that more girls demonstrate high math and high verbal abilities and, therefore, can consider a broader range of occupations. When you look at the 2015-2016 Civil Rights Data Collection study above and then consider Wang, Eccles, and Kenny's (2013) study, one could consider the notion that girls are just as capable as boys to be engineers. Still, they have a more comprehensive range of career options due to a broader range of skills.

The issue of access for girls into the field of engineering could stem from a peer group. If a girls' peer group is not interested in STEM, or more explicitly, engineering, as a collective, how does that affect the individual girls within the peer group? Robnett's (2013) work looks at peers' role in a girl's pursuit of a STEM career. Her work surveyed three different groups of girls: high school, undergraduate, and graduate. To determine the extent to which a girl's peer group motivates STEM identification and, in turn, how that identification predicts STEM career commitment and following through on that commitment (Robnett, 2013). Her findings, combined with previous research in the field, suggest that motivation and confidence play a significant role in girls' interest in STEM fields at the high school and college levels.

Motivation and confidence seem to be connected to a girl's social relationships and play a significant role in shaping a girl's identity. Robnett's (2013) findings are also backed up by another study that looked at adolescent girls' social and personal experiences in relation to their motivation in STEM versus non-STEM (English) subjects (Leaper et al., 2012). Like Robnett (2013), the results of Leaper, Farkas, and Brown's (2012) research suggest that peer support of math and science can be a positive motivation for a girl's interest in math and science. Leaper et al. (2013) base these findings on a study of 579 girls, ages 13-18, from across the U.S. and from different ethnic and socioeconomic backgrounds. Both studies suggest that a girl is affected by their peer group throughout their development, and this group can influence their career choices. These findings beg the question that if peer groups influence a girl's interests, then would teaching engineering skills in their day-to-day classrooms increase their interest in engineering as a career? Could it be as simple as concentrating on a group of girls rather than looking at the individual for understanding?

Many scholars come to their conclusions about how to solve the problem of increasing a girl's interest in engineering. Robnett (2013) and others, as discussed above, for example, look at a girl's relationship to peers as an essential role to drive interest in STEM. Naukkarinen and Bairoh (2020), however, conclude that the need for more girls in the engineering field will not be solved by building their collective interest in STEM. Meaning, the category of STEM courses should not be categorized together as one thing if you want to promote engineering as a potential career. So, a group of girls who show interest in STEM as a whole may be a disservice to individuals in that peer group who may show more interest in engineering over mathematics.

Naukkarinen and Barioh (2020) look at over 9,000 applicants to bachelor-level studies in Finland for the 2016 school year. Students pick between different majors when they apply to post-secondary schooling and rate their program choices on a numeric scale (first choice, second choice, etc…) (Naukkarinen & Barioh, 2020). The authors look at the gender of students who pick between engineering as their first program of choice and students who choose natural sciences or mathematics (SCIMA) as their first program of choice. The results of this investigation found that 70% of the female applicants who pick engineering as their first choice do not choose SCIMA as an alternative program for study (Naukkarinen & Barioh, 2020). Alternatively, 50% of girls who pick SCIMA as their first choice do not choose engineering as their subsequent choice. (Naukkarinen & Barioh, 2020). Ultimately, Naukkarinen and Bairoh (2020) find that to support a girl's interest in engineering do not consider STEM as engineering and vice-versa.

Research on the key factors that explain adolescent girls' disinterest or tendency to avoid engineering as a potential post-secondary field of the study suggests that gender stereotypes and access to engineering experiences are potent drivers of this issue. Parents, teachers, peers, and societal institutions build and reinforce a barrier that is found in gender norms prevailing in our collective society. This barrier is established early in a girl's life and continues to stand throughout her educational journey affecting her interests, and the way she makes decisions. Another barrier comes from access to engineering experiences and educational opportunities that would otherwise support a girl's interest in engineering as a potential post-secondary field of study.

1.5.3.3 Intervention Strategies

What are Effective Ways of Supporting a High School Age Girls' Interest in Engineering?

If **stereotypes**, serviced by internal and external barriers, and **access** to information throughout their K-12 journey are barriers to girls aspiring to follow a career in engineering, then what are the current strategies that could be utilized to disrupt these patterns? In this section, I examine three intervention strategies that, based on the literature, have shown to support an adolescent girl's interest in engineering.

Intervention strategy: exposure. Much of the literature suggests that a collaborative, real-world, and hands-on form of educational experience is beneficial to the effort of building a girl's interest in engineering as a career path. Dasgupta and Stout (2014) refer to this by explaining that engineering, and other STEM fields, are critical to solving real-world problems that hinder society and require strong collaborative skills to be successful. In their 2014 investigation into the obstacles that impede a girl's interest in STEM, Dasgupta and Stout find that "girls are more interested in math instruction taught from an applied perspective than boys." (p. 23) Although this is specific to math instruction, Dasgupta and Stout (2014) suggest similar findings around engineering and other STEM fields.

Similarly, Bystydzienski, Eisenhart, and Bruning (2015) back up this information with findings from their 2015 study where 82% of female participants had no idea what engineering was and never considered it as a career possibility. Bystydzienski, Eisenhart, and Bruning (2015) implemented a three-year intervention program, working primarily with low-income, Hispanic, and African American 10th-grade girls to "spark and sustain" their interest in engineering careers. After 18 months of enrolling in the Female Recruits Explore Engineering (FREE) project, 57% (75 of 131) of the original participants elected to continue participating in the program. Of the 75 continuing their participation in the FREE program, 51% "seriously considering a career in an engineering field" compared to the 18% claiming interest at the beginning of the project (Bystydzienski, Eisenhart, & Bruning, 2015, p.90). These studies suggest that just introducing the career of engineering at a base level and how it is applied to our world could build a girl's interest in the profession. However, offering continued opportunities for girls to participate in engineering experiences could be a powerful way to nurture and sustain a girl's interest in engineering.

What about the issues of gender stereotypes that, as discussed above, affect a girl's interest in engineering from an early age? Weinberg, Pettibone, and Thomas (2007) question whether exposure to robotic competitions impacts a girl's perception of their abilities in engineering and other STEM fields. The authors applied Wigfield and Eccle's (2000) expectancy-value theory to examine why girls may perceive their potential achievements in STEM as negative (Weinberg, Pettibone, & Thomas, 2007). The expectancy-value theory considers that individuals' choices are directly related to their "belief about how well they will do on an activity and the extent to which they value the activity" (Barnett, 2004, p. 68; Weinberg et al., 2007, p. 1; Wigfield & Eccles, 2000). In Weinberg, Pettibone, and Thomas's (2007) study, 7th-grade students were put into 12 all-girl teams and 24 mixed-gender teams for a total of 324 students (225 female and 99 male) from 13 different states in the United States. The authors found that girls participating in the robotic competition had an increase in positive attitudes toward engineering and decreased acceptance of "traditional gender roles" (Weinberg, Pettibone, & Thomas, 2007, p. 3). Also, an increase in self-concept and expectations of success in science and math was reported by girls in mixed-gender teams (Weinberg, Pettibone, & Thomas, 2007). These findings suggest that exposure to engineering and STEM challenges is beneficial to a girl's ability to shun the traditional gender roles that bombard them in our society from a young age. At the same time, girls respond positively when challenged with hands-on application-based engineering experiences.

Intervention strategy: role models. Another intervention strategy in practice for getting girls interested in engineering is through collaboration with role models. Shapiro and Williams (2012) back up this suggestion when they discuss intervention strategies in their research discussed above. Role models may reduce the stereotype threat that could hinder a girl's willingness to engage in STEM experiences (Shapiro & Williams, 2012). Interaction with successful female role models in the STEM fields could reduce the fear girls have of poorly representing their gender (Shapiro & Williams, 2012). In a best-case scenario, a girl would have a parent who followed a career in engineering, or other STEM fields, to serve as a role model.

Anaya, Stafford, and Zamarro (2017) use data from the University of Michigan's Panel Study of Income Dynamics to study how a parent's occupation type could affect self-perceived math ability and math achievement. The findings of the study suggest that girls who have a parent employed in a STEM occupation benefit more from the positive effects than boys (Anaya, Stafford, & Zamarro, 2017). Even if a girl has strong math skills, they are more likely to go into a STEM field if they have a parent in that field (Anaya, Stafford, & Zamarro, 2017). Parents who follow a career in a STEM field are more be well equipped to expose their children to STEM-related experiences. Suggesting the best way to defend against the seemingly unwavering specter of gender stereotypes pushing girls away from STEM is having a parent working in a STEM occupation. Ideally, the parental role model would entice a child to follow the same path, both from a career standpoint and an educational standpoint.

What about those girls who do not have a parent working in the STEM fields? Who or what serves as a role model for these girls? Maltese and Tai (2011) suggest that a majority of students in the United States who pursue a career in a STEM field of study decide while in high school. When teachers promote and support further interest in STEM, research suggests that this has a positive effect on students (Maltese and Tai, 2011). Could these findings suggest that teachers also serve as valuable role models for girls to pursue a degree in engineering? Does it matter if that teacher is a girl or boy? While Maltese and Tai (2011) do not look at gender as a factor, Stearns et al.'s (2016) research consider gender a determining factor in whether a girl pursues a STEM field study, including engineering. Stearns et al. (2016) draw on the theory of representative bureaucracy to investigate whether girls are more likely to follow a career in a STEM field if their middle school and high school had more female science and math teachers.

The authors define representative bureaucracy as "a bureaucracy that is representative of the people it serves will mirror the interests of its clients." (Stearns et al., 2016, p. 88) Their data set included 21,300 college-bound students in North Carolina and later those students who attended any of the 16 University of North Carolina colleges in 2004 (Stearns et al., 2016, p. 92). Stearns et al. (2016) find that the more female math and science teachers a girl has in high school, the more likely they will pursue a career in a STEM field. Based on the Maltese and Tai (2011) study and the Stearns et al. (2016) study, a majority of girls will decide to pursue a career in a STEM field while in high school and based on the science and math teachers they have during their high school years. So, if a girl has a parent working in a STEM field and a high school with impactful science and math teachers, would that raise the chances they will follow a career in STEM? Or could there be a missing piece connecting a girl's interests, parental influence, and societal experiences to provide a meaningful pathway into engineering, or other STEM careers?

Intervention strategy: integration. Another strategy that has been shown to increase the likelihood that girls develop an interest in engineering as a potential career is integration experiences. Two separate articles discuss the benefits of integrating engineering into other course disciplines. Dahle, Jockers, Scott, and Wilson (2017) and the Liu, Lou, and Shih (2014) articles find that a multidisciplinary integration of Engineering concepts into the curriculum has been shown to increase the interest of girls and women in the engineering fields. Liu et al. 's (2014) research surveyed 88 girls enrolled in a national high school in Taiwan to determine if enhancing gender-role beliefs and interactions with female engineering role-models could increase a girl's STEM self-efficacy.

In comparison, Dahle et al. (2017) study how recruitment and retention of girls at the State University of New York (SUNY) New Paltz engineering major with a minor in art program changed. The authors find that from the years 2014-2016, the number of girls enrolling in the new engineering and art program double. This double enrollment and the results of a female student suggest that girls engage more with the creative side of engineering. Both the Dahle et al. (2017) and Liu et al. 's (2014) studies indicate that girls respond positively to an application-based approach that relies on real-world issues.

Could the method of presenting engineering content as a real-world problem with no finite answers be key to building a girl's interest in engineering? A study by Knezek and Christensen (2019) found that girls respond positively to an inquiry-based and real-world focus on science as it relates to their science attitudes and long-term interest in science overall. In their National Science Foundation's (NSF) funded study Knezek and Christensen (2019) sought to explore middle school students' dispositions in STEM subjects and the impact of hands-on experiences. Pre and post-test surveys were taken before and after a three-week science lesson that had students track their electricity usage throughout their day. The results after two school years of data collection show a positive effect on a girl's STEM disposition, more so than boys, and that the hands-on nature of the experiences we received positively by girls more than boys.

Marcu et al. (2010) back up Knezek and Christensen's (2019) findings with their 2010 research. Marcu et al. (2010) designed four-week computing and engineering course for middle school girls of low-income families. In their program, they took the teaching and learning approach that supports "hands-on building of projects combining crafts with technology, engineering-focused roles structuring group work, and the frequent presence of an audience to motivate engagement." (Marcu et al., 2010, p. 238) The results of presenting engineering and computing with this approach allowed students to understand better the work or different engineers through hands-on and conceptual work. Findings from Marcu et al. (2010) and Knezek and Christensen

(2019) would support the open-ended, real-world approach to presenting engineering information to girls.

The open-ended, real-world integration approach to teaching and learning is in contrast to how math and science are currently taught in school, although the same could be said for all school subjects. Does the current method of the teacher seen as the giver of knowledge while the student takes on the role of an empty vessel waiting to be filled with knowledge hinder a girl's interest in engineering? Could the fear of presenting an incorrect answer to a teacher and receiving a bad grade be a hindrance as well? While it may be impossible to determine the answers to these questions, the research does suggest that integrating engineering into a girl's schooling as open-ended, real-world problems could support their interest in engineering as a career. The conclusion of Marcu et al. 's (2010) study supports this approach by suggesting schools shift focus to STEM curricula that utilize a hands-on exploration of STEM careers with a focus on how their work affects society could increase girls' interest in engineering and computing more broadly.

1.5.4 Synthesis

My review of the literature reveals the seemingly unending force pushing girls away from engineering as a career. Early in a girl's life, they are constantly bombarded with people and things indirectly telling them that engineering is for boys. Just trying to understand why an adolescent girl's disinterest or tendency to avoid engineering seems to be too simplistic a question given the deep and complicated nature of the findings presented. However, the research points to supporting approaches to building and supporting an adolescent girl's interest in engineering. These approaches range from just exposing a girl to simple engineering-themed experiences up to changing the current methods of teaching and learning common in K-12 education.

This literature review assisted in the understanding of my problem of practice in three significant ways. First, gender stereotypes, and associated internal and external barriers, hinder a girl's interest in engineering from a young age and are ingrained in our shared societal experience. Second, access to engineering experiences and essential educational prerequisites rely on a girl's peer group and the resources available to their school and family to support their potential interest in engineering. Third, while there are no metaphorical switches to flip that will make engineering exciting and available to girls, scholars have found several intervention strategies shown to engage and support a girl's interest in engineering as a potential career. These strategies can be categorized as exposure to engineering experiences, interaction with female role models who work in the engineering field, and integration of engineering into current teaching and learning methods. This information will help develop a study to address my problem of practice in a high school engineering classroom.

The initial understanding of this topic was around a lack of access to engineering education and experiences as the only driver for an adolescent female's disinterest in the field. However, surprisingly, the research has shown that both traditional gender stereotypes and access are to blame for this issue. While gender stereotypes and access are not the only drivers, they are two of the most systemic in our modern society. The depth of these two issues is the biggest challenge to my work. How can I affect an adolescent girl's interest in engineering if these barriers are so ingrained? Real change must start at an early age, where parents are supporting a girl's interest in the STEM fields and follow through schooling, where teachers are also supportive of a girl's potential interest in engineering and STEM overall. In that case, a girl's journey through education and society has a significant effect on my problem of practice.

1.5.5 Conclusion to the Review of Supporting Knowledge

Despite the findings that suggest much of the development of the barriers interfering with a girl who may show an interest in engineering occurs before they get to high school, intervention is essential early in a girl's high school career. This intervention could take the form of engaging with extracurricular engineering experiences as a teacher and offering these experiences directly to girls in my 9th-grade classes. Another would be in the way we, as a department, advertise our elective courses. Finally, another intervention strategy that could be beneficial to supporting a girl's interest in engineering at the high school level would be in creating a female peer mentoring group. This group could include girls in the advanced engineering courses that engage with middle school girls as a way of opening the door into the engineering courses we offer at the high school.

While these interventions may work as a method of overcoming the issue in the short term, they do not help me to understand the reasons why girls in my place of practice may or may not be interested in engineering. Understanding this issue requires an investigation of the girls early in their high school career and girls who elect to take the higher engineering courses. No girl's experience with gender stereotypes and access to engineering experiences are the same. What is evident in the research is that early engagement through exposure, role models, and integration, provide a support structure for girls who may be interested in engineering. Connecting these findings with my adolescent female students in a way that works in my place of practice will be crucial to set up that support structure

2.0 Section II: Theory of Improvement and Implementation Plan

2.1 Theory of Improvement

My problem of practice will explore the shifts in high-school girls' engineering identity. My theory of improvement is designed as a blended approach that incorporates application, collaboration, and empathy-building in engineering challenges. If improving their attitude towards engineering through classroom experiences, then high school-age girls' engineering identity will improve.

Change ideas come from breaking apart my theory of improvement. First, I examined the engineering design process in my course. This included application-based challenges that require students to engage in hands-on projects, collaboration to build peer groups and demonstrate how real engineers work in teams, and empathy-building to illustrate how engineers design and build solutions to help humanity. The second change idea explored how and to what extent this engineering design process supports a girl's ability to see themselves as an engineer.

Research shows that girls engage more with engineering when presented with a focus on empathy and understanding of why problems exist and how they affect humans on a personal level (Dasgupta & Stout, 2014; Bystydzienski, Eisenhart, and Bruning, 2015). So, by including relevant information, visuals, and even experiences that spotlight how an issue affects real people, I hope to positively shift a girl's engineering identity. As for including collaboration, researchers found peer groups play a significant role in shaping a girl's identity. So, by requiring girls to work together, I hope to build peer groups with engineering as a common bond. Finally, application required girls to apply skills to complete engineering challenges. Research shows that girls engage more with S.T.E.M. topics when taught from an applied perspective (Dasgupta & Stout, 2014; Bystydzienski, Eisenhart, and Bruning, 2015).

For my project, engineering will refer to any field of study with "engineering" or "engineer" in the job or degree title. Examples of this can include but are not limited to mechanical, electrical, computer, software, chemical, and robotics. Another term utilized throughout this paper, S.T.E.M. (herein known only as S.T.E.M.), is used to incorporate all science, technology, engineering, and mathematics careers, skills, and classroom experiences in the kindergarten to the twelfth grade (K-12) levels of schooling. Finally, another term used throughout this paper is the word "girls," which will refer to high school-age girls of ages 14-18.

2.1.1 Driver Diagram

My project aims to positively shift a girl's engineering identity by transforming the traditional classroom format and fostering positive classroom interaction between students. The pursuit of this aim requires an understanding of the research questions used to guide the review of literature for this project. These include acknowledging key factors that have to be found to push girls away from engineering and effective ways of supporting a girl's engineering identity.

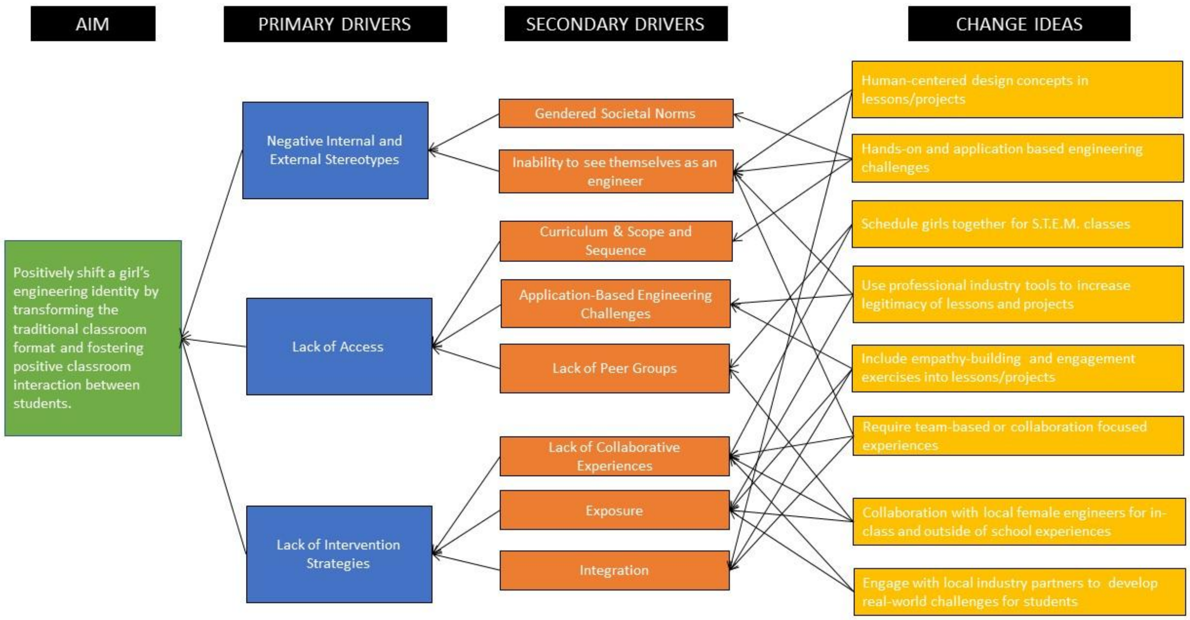


Figure 1 Driver Diagram

2.1.1.1 Primary Drivers

The first primary driver for this problem of practice takes the form of gender stereotypes reinforced by society and family. From a young age, girls are discouraged from showing interest in engineering or any S.T.E.M.-related field. A review of literature for this problem of practice shows that these stereotypes are found in everything from popular culture to a child's parents. Gunderson, Ramirez, Levine, and Beilock (2012) suggest that parents and teachers can view girls and boys differently due to their math-gender stereotypes and gender-biased perceptions. These external stereotypes manifest as internal barriers for girls who may demonstrate an interest in engineering. Further research into this topic finds that the internal barriers feed into a self-fulfilling prophecy and confirm the stereotypes true when a girl is unsuccessful in any engineering or S.T.E.M. related experience (Shapiro and Williams, 2012).

The second primary driver takes the form in a lack of access to engineering education and necessary S.T.E.M.-related educational skills. Engineers require a strong base in mathematics and physics but a 2018 report by the U.S. Department of Education shows that only 50% of high schools offer calculus, and only 63% offer physics nationwide. Even if girls have access to the base skills engineering requires, research shows that it is difficult to decide on following a career in engineering in high school or post-secondary school due to the rigid mathematics and science skill requirements (Wang, Eccles, and Kenny, 2013). By building these experiences early in a girl's high school career, they can start preparing for the critical math and science course throughout high school.

The third primary driver takes the form of a lack of intervention strategies to support a girl's interest in engineering as a career. Much of the literature suggests that a collaborative, real-world, and hands-on form of educational experience is beneficial to the effort of building a girl's engineering identity. For instance, research by Dasgupta and Stout (2014) finds "girls are more interested in math instruction taught from an applied perspective than boys" (p. 23). The authors have also found the same results in other STEM-related disciplines, including engineering. Further research backs up findings like Dasgupta and Stout (2014), although through different research goals.

Another example of the lack of intervention strategies that can support a girl's interest in engineering as a career is around the notion that girls may not know anything about the field of engineering. In their 2015 study, Bystydzienski, Eisenhart, and Bruning found that 82% of high school-age female participants had no idea what engineering was and never considered it a career possibility. The collection of research on the topic suggests that just introducing the career of engineering at a base level and how it is applied to our world could improve a girl's attitudes towards the profession.

When considering these three primary drivers and comparing them with the literature preceding this problem of practice, an aim emerged. Research shows that girls engage more with engineering when presented with a focus on empathy and understanding of why problems exist and how they affect humans on a personal level. These types of experiences can counteract the internal barriers and external stereotypes that girls must deal with in modern society. In that case, high school-age girls would benefit from a blended approach that incorporates real-world scenarios, relatable data, and empathy-building in hands-on solution-based engineering challenges. With this understanding, I aim to explore the shifts in high-school girls engineering identity.

2.1.1.2 Secondary Drivers

Secondary drivers for this theory of improvement will specify where in my study I can affect change. First, I look at the gendered societal norms fueling a girl's negative internal and external stereotypes. These stereotypes over time can manifest in a girls' inability to see themselves as an engineer. Research suggests that motivation and confidence play a significant role in girls' interest in the S.T.E.M. fields at the high school and college levels (Robnett, 2013).

The second set of secondary drivers focuses on the issues around a girl's lack of access to skills critical for engineers to learn throughout their years of schooling. Skills such as mathematics, physics, and other STEM-related disciplines are vital for entry into post-secondary engineering programs and building a girl's interest in the career. These secondary drivers take the form of a high school's curriculum and the scope and sequence.

Another secondary driver associated with the lack of access primary driver is built on the connection of a girl's peer group and interests. Three different studies suggest that a girl is affected by their peer group throughout their development, and this group can influence their career choices (Leaper, Farkas, and Brown's, 2012; Robnett, 2013; Naukkarinen and Bairoh, 2020). These findings beg the question that if peer groups influence a girl's interests, then would teaching engineering skills in their day-to-day classrooms increase their interest in engineering as a career? Could it be as simple as concentrating on a group of girls rather than looking at the individual for understanding?

The last set of secondary drivers is around the lack of intervention strategies to help build a girl's attitudes toward engineering. Research into these secondary drivers provides evidence to suggest collaborative, real-world, and hands-on form of educational experience is beneficial to building a girl's attitudes in engineering as a career path. (Dasgupta and Stout, 2014; Bystydzienski, Eisenhart, and Bruning, 2015) Research also indicates that collaborative experiences with professional female engineers (Shapiro & Williams, 2012; Anaya, Stafford, and Zamarro, 2017) and experiences that put girls in the engineering industry (Dahle, Jockers, Scott, and Wilson, 2017; Liu, Lou, and Shih, 2014) would help girls build an engineering identity.

2.1.2 Change Ideas

My intervention aimed to explore the shifts in high-school girls' engineering identity in Southwestern PA High School. Changes were relegated to my classroom and the classes I teach.

However, I still had to adhere to the approved curriculum for the courses I teach. My theory of improvement took a blended approach that incorporated application, collaboration, and empathy-building in hands-on engineering challenges into the courses I currently teach. The theory of improvement can be broken down into specific change ideas that guided my interventions. Each of the following change ideas was taken from the findings in the initial research outlined in my literature review.

First, I looked to incorporate real-world scenarios to promote the idea of where this content is applicable. Past research into girl's interest in engineering is affected by gender stereotypes and self-concept. However, girls participating in application-based engineering experiences had an increase in positive attitudes toward engineering and a decrease in acceptance of traditional gender roles. This method of including real-world scenarios served a girl's self-concept as an engineer due to their work's applicability. This application-based approach also required girls to step out of the theory-based realm of learning and apply the knowledge they have gained throughout their educational journey. Finally, this change idea also served as a confidence-building tool to expose them to a hands-on experience to create solutions to the challenges.

I relied on the Design Thinking Bootleg (Both & Baggereor, 2013) process modules developed by the d.school at Stanford University (Figure 2) and the Engineering Design Process (Figure 3) as guiding models for this approach and my unit plan. I aligned each of the five original Process Modules as a different step in the engineering design process (Table 2). Using these process modules and the engineering design process added further legitimacy to this approach due to adopting these skills in professional industries.

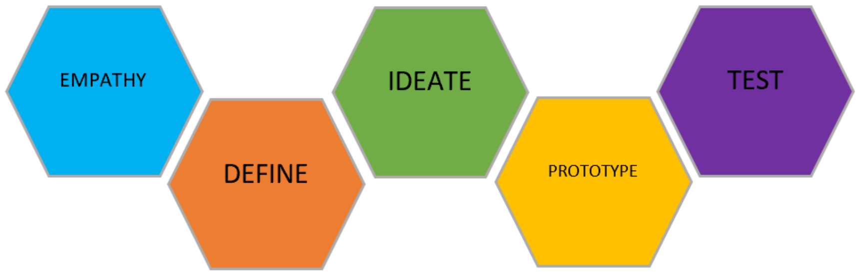


Figure 2 Process Modules

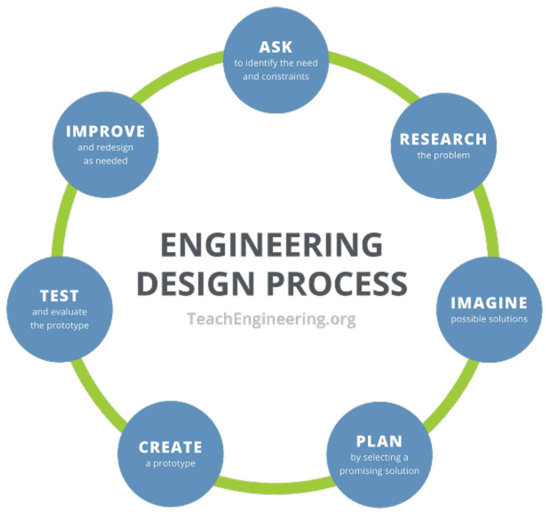


Figure 3 Engineering Design Process

Table 2 Process Module Alignment

Process Modules	Engineering Design Process
Empathy	Ask
Define	Research
Ideate	Imagine Plan
Prototype	Create
Test	Test Improve

Second, the collaboration served as a method of building peer groups. As research suggests, high motivation and confidence play a significant role in a girl's interest in engineering (Robnett, 2013). A girl's motivation and confidence seem to be connected to her social relationships and play a significant role in shaping her identity (Leaper et al., 2012). By requiring girls to work together in groups throughout the unit, a potential boost to motivation and confidence will accompany a peer group's development. The idea is that a peer group that engages with engineering will support each other's interest in either the different aspects of engineering or the career as a whole.

Third, empathy-building helped girls understand how the engineering challenges affect actual people. Research shows that girls engage with the human side of engineering over the more technical side. Empathy-building was done through the use of human-centered design techniques for empathy-building. The methods will come from the Design Thinking Bootleg (Both & Baggereor, 2013) developed by the d.school at Stanford University. Specifically, students followed the How to Empathize process module that utilizes a "observe, engage, and immerse" (p.3) approach to building empathy and the "What? How? Why?" tool (p.15) of observation (Figure 4). Additionally, students utilized the Prototype for Empathy tool (p.50) when designing and building their engineering solutions.

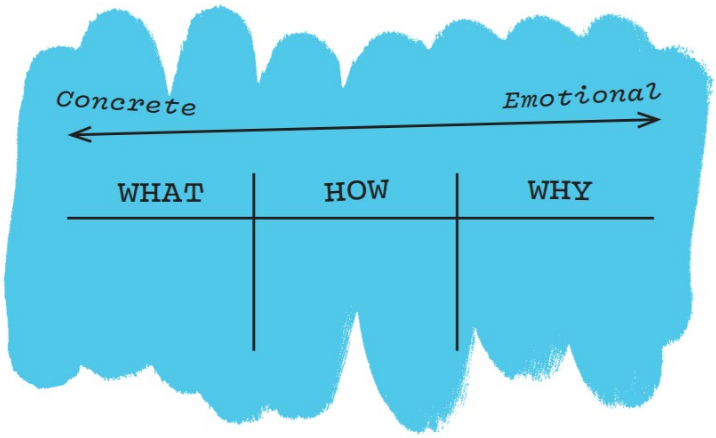


Figure 4 What? How? Why?

2.1.3 Intervention Description

By transforming the traditional classroom format and fostering positive classroom interaction between students, the engineering design unit increases a girls' understanding of the assigned problems and how to develop a solution to those problems. The Engineering Design Unit ran over 30 school days in the fall of the year 2021 with three sections of the Introduction to STEM course and a total of 72 students. However, only data from the twenty-three students who identify as a girl, female, or woman was analyzed to understand the shifts in high-school girls' engineering identity.

The qualitative data collection for this study comes from three sources: analysis of daily lesson plans (Appendices A-F), analysis of the Teacher Daily Reflective Journal (Appendix P), and analysis of student responses to the Open-Ended Essay (Appendix O).

The engineering design process (Figure 3) follows a specific set of steps that align with and are organized into the engineering design unit. Therefore, a classroom lesson plan was developed for each individual step in the engineering design unit. These lesson plans include activities and assignments for each step to engage students with the overall idea of each step in the unit (Table 3). The activities and assignments also follow Design Thinking Bootleg (Both & Baggereor, 2013) process modules developed by the d.school at Stanford University (Figure 2) as guiding models for each activity and assignment.

Table 3 Engineering Design Unit Lesson Outline

Engineering Design Unit	Activity	Assignment	Lesson Objective
Step 1: Empathy	Class Discussion	Daily Water Use Chart	Understand who is affected by dirty water around the world due to natural disasters and other issues
Step 2: Define & Understand	Problem-Tree Analysis	Clean Water in a Disaster Research	Define and understand the issues that lead to people being without access to clean drinking water
Step 3: Ideate	Affinity Cluster	Design Sketch and Material List	Develop ideas to solve the problem of not having access to clean water after a natural disaster
Step 4: Prototype	Prototype Build	Water Filter Prototype Documentation	Use the materials that your team has collected to build a prototype based on your design from the Ideation step
Step 5: Test & Improve	Water Filter Design Test	Water Filter Testing Data Record	Test water filter design based on the constraints and criteria of the project
Step 6: Presentation	Water Filter Design Presentation	Water Filter Design Presentation	Develop a presentation that explains how to assemble and use your water filter design

2.1.3.1 Step 1: Empathy

The objective for "Step 1: Empathy" (Appendix A) of the Engineering Design Unit is for students to understand who is affected by dirty water around the world due to natural disasters and other issues. Videos from different news outlets were used to show how various disasters affect people's access to clean water. Videos from news outlets typically focus on the people affected by a specific topic. Following the videos, the class engaged in a discussion about people's experiences in the videos and how they would deal with the same situations. Students also kept a chart of their daily water consumption (Appendix G) over three days.

The discussion activity and daily water use chart activities followed the Design Thinking Bootleg's (Both & Baggereor, 2013) Empathize Process Module (p.3). Watching these videos and discussing the connection between their experiences and the people in the videos followed the Observe technique (p.4) in the "How to Empathize" method. In this method, students are asked to watch how people interact with their environment, what they say about their situations, and listen to their needs. The assignment for this step also followed the Immerse technique (p.4) in the "How to Empathize" method of the Empathize Process Module (p.3). The Daily Water Use Chart (Appendix G) assignment required students to keep track of their water usage. This record helped them see just how much water they use throughout the day and how much they depend on easy access to clean water.

2.1.3.2 Step 2: Define & Understand

The objective of "Step 2: Define & Understand" (Appendix B) of the Engineering Design Unit was to define and understand the issues that lead to people being without access to clean drinking water. The lesson plan focused on research so that students build an understanding of what makes water dangerous in a disaster and the other scientific factors that contribute to the lack of access to clean water. The primary resource for this step is the Time article "Here's How Dirty Flood Water Really Is" (Sifferlin, 2017), which the teacher reads aloud. After reading the article on what makes water so bad for humans during a natural disaster, the class engaged in a discussion. After the discussion, students completed the Clean Water in a Disaster research assignment (Appendix I) in their teams. Finally, the teams finished a problem tree analysis activity (Appendix H). They presented and explained five causes and five effects of the problem of access to clean water in a disaster area.

The Clean Water in a Disaster research assignment (Appendix I) and the Problem-Tree Analysis activity (Appendix H) follow the Design Thinking Bootleg's (Both & Baggereor, 2013) Define Process Module (p.5) and the research phase of the Engineering Design Process (Figure 3). The Clean Water in a Disaster research assignment gave students questions that require research on the current issues plaguing parts of the world that have been hit with natural disasters and are now struggling with clean water availability. The teams took what they learned in the empathy step and combine it with this research on the political, scientific, and engineering challenges that people in their situation face to better understand the problems. Then, using the problem-tree analysis activity, teams demonstrated their understanding of these challenges from their research in the assignment.

2.1.3.3 Step 3: Ideate

The objective for "Step 3: Ideate" (Appendix C) of the Engineering Design Unit was to have the students develop ideas to solve the problem of not having access to clean water after a natural disaster. The lesson plan focused on students taking all of the information they have gained in the first two steps of the unit to develop a solution for overcoming the challenge. First, students are presented with a scenario (Appendix J) in the form of a narrative to build reasons for the challenge and design constraints of the overall project. The challenge (Appendix J) and design constraints serve as the requirements and directions for the teams to complete the project. Students are also presented with the evaluation criteria (Appendix J) that serve as the criteria for testing their solution. Ultimately, the scenario, challenge, design constraints, and evaluation criteria all focused student teams on developing their solution in the form of a physical product that they will design, build, and test. Evaluation of the Water Filter Project followed the Water Filter Project (Appendix K) and is discussed further below in the *Water Filter Evaluation* sub-section.

Student teams were required to design a reusable water filter with things you find at home that can quickly and efficiently filter water. A complete physical water filter was the ultimate goal of the Engineering Design Unit. However, for Step 3, teams were only required to complete the Affinity Cluster activity (Appendix C) and the Design Sketch and Material List assignment (Appendix C). One crucial part of the challenge is that students may only use everyday items found around a typical house after a natural disaster. Also, complete devices like pool filters, store-bought water filters, and anything that uses fire are not allowed. The design restrictions required them to use simple materials found around their house that do not cost much money and are readily available. Part of the challenge explains that they should design their filter so that the plans could be included in a disaster kit so that anyone could build their design in a disaster situation.

The ideation step in the Engineering Design Unit followed the Design Thinking Bootleg's (Both & Baggereor, 2013) Ideate Process Module (p.7). This step also followed the Imagine and Plan phases of the Engineering Design Process (Figure 3). The Design Thinking Bootleg authors explain that the Ideate process is all about convergent and divergent thinking in teams (p.7). The different techniques use these convergent and divergent thinking sessions to develop as many solutions as possible, and then the teams converge these ideas into workable solutions. Next, the teams engaged in the Affinity Cluster group activity (Appendix C), guiding them through convergent and divergent thinking processes. At the end of the activity, the teams had a few different solutions to the challenge. The solutions are used to complete the group assignment where students developed a design sketch of their water filter design and a material list (Appendix C).

2.1.3.4 Step 4: Prototype

"Step 4: Prototype" (Appendix D) of the Engineering Design Unit aimed to use the materials that the teams collected to build a prototype based on their design from the Ideation step. The lesson plan focused on the process of students using the design sketch and materials list from step 3 to develop a working prototype of their water filter design. The water filter must also follow the design constraints of the overall challenge (Appendix J) for this Engineering Design Unit. The activity for this step was the building of the prototype based on the design sketch assignment (Appendix C). After completing the water filter prototype, teams completed the Water Filter Prototype Documentation assignment (Appendix D). This assignment documented what their water filter looks like and who brought in what materials for the prototype.

The building of the water filter working prototype followed the Design Thinking Bootleg's (Both & Baggereor, 2013) Prototype Process Module (p.9) and the Create phase of the Engineering Design Process (Figure 3). The authors of the Design Thinking Bootleg explain that prototypes are more beneficial to the design team when they are usable (p.9). The student teams developed working prototypes that were tested in the next step of the Engineering Design Unit. The authors also mention how usable prototypes allow for empathy and understanding as part of the design process (p.10). Including empathy and understanding of the potential users of this design leads to more meaningful and successful solution designs. After students have constructed their first prototype, they were encouraged to consider the users who would be building and using this device in different environments and at varying stress levels. For instance, if water is poured into the water filter, does the filter fall over, or does it fall over after the water has been filtered? These questions may lead to teams adjusting their design before the next step in the unit.

2.1.3.5 Step 5: Test & Improve

The objective for "Step 5: Test and Improve" (Appendix E) of the Engineering Design Unit was to test the water filter design based on the design constraints and criteria of the project. The lesson plan focused on students testing their water filter design in four trials. Students poured 1.5 liters of water into their filter design in each trial. Three different data points were gathered and recorded on the Water Filter Testing Data Record assignment sheet (Appendix L). The first data point (Time) was the time it takes for the 1.5 liters of water to filter through up to five minutes max. The second data point was the amount of water lost (Water Loss) or not filtered during the five-minute allowable filter time. The last data point that students record was the clarity of the water (Clarity Test). A 0.95mW hard-seal helium-neon laser was shot through the reclaimed water and evaluated on three levels, not visible, scattered, or solid. The original design for the Clarity Test (Figure 5) was modified from the Measuring Density by Bending Light lesson from the UCAR Center for Science Education (Russell).

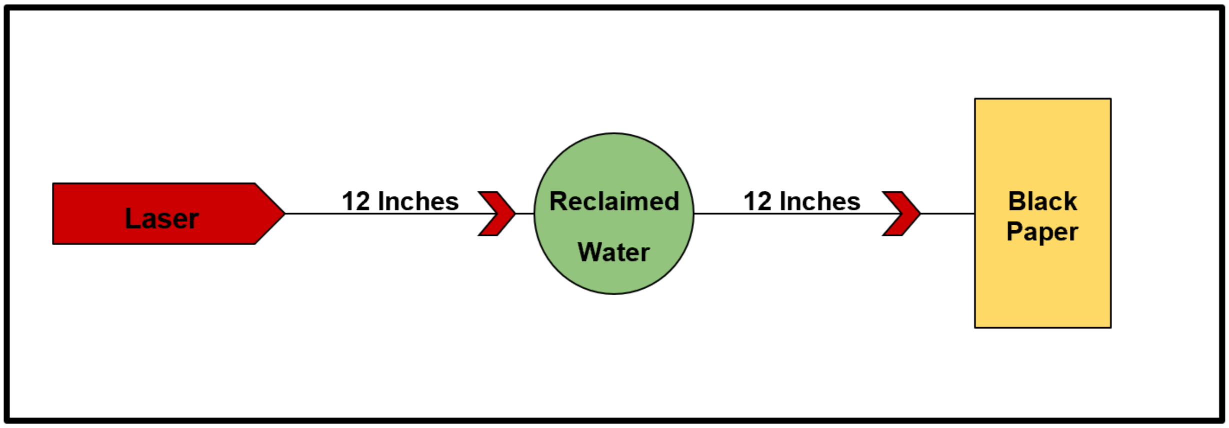


Figure 5 Clarity Test Diagram

An essential part of the Test and Improve step was evaluating and improving the water filter between the four trials. Students considered the performance of their water filter design after each trial and decided what they would change to improve the performance in the subsequent trial. The trial water used for this was a premixture of ingredients (Table 4) mixed before each class trial, and each period got its own five-gallon bucket. So, on trial one day, period one got a new mixture of ingredients, and period two got their own mixture of ingredients. On day two of the trials, all periods got their own new five-gallon mix. Once a team completed their trial run, their reclaimed water was returned to the class bucket.

Table 4 Premixed Trial Water Ingredients

Material	Amount
Water	4.5 Gallons
Potting Soil	6 Cups
Sand/Stone Mix	3 Cups
Vegetable Oil	1 Cup
Coffee Grounds	3 Cups
Dish Soap	1 Cup

The premixed trial water (Table 4) was a mixture of different materials, and each material challenged different filtering methods due to the size, weight, and consistency of the material. The potting soil broke apart in the water but floated while the sand and stones sank to the bottom of the bucket. The soil and sand served as base-level materials that are easy to filter. However, the sand could become difficult depending on the filter design because it can easily clog a filter if it builds up over multiple trials. The dish soap could cause bubbles when poured into a filter and lead to overflow due to students not being able to see their fill line. The vegetable oil could cause issues for teams on trials two through four because it was difficult to clean and reset the filter. The most difficult to filter material was the coffee grounds. The coffee dissolved into small particulates in the water and is difficult to filter out due to the size of these particulates.

2.1.3.6 Step 6: Presentation

The objective for "Step 6: Presentation" (Appendix F) of the Engineering Design Unit was to develop a presentation that explains how to assemble and use your water filter design. The lesson plan (Appendix F) focused on students creating a presentation that discussed their water filter design development and performance. Evaluation of team presentations was done using the Engineering Design Unit Presentation Rubric (Appendix N) that followed the assignment requirements in the Water Filter Presentation Requirements sheet (Appendix M).

Reflection was one major component of the presentation assignment. This requirement was for teams to discuss three problems they ran into while building and testing their design. Promoting the benefits of their design was another significant component of this assignment. The promotion requirement specifies that teams must explain how their design is better than other water filter designs available. Finally, the last major component of this assignment, teams had to clearly explain how to assemble and use their filter design. The explanation phase was essential because students had to develop concise visual directions on assembling and using their water filter design.

2.1.3.7 Water Filter Project Evaluation

Evaluation of the water filter project overall relied on using the Water Filter Project Rubric (Appendix K). The rubric is organized into three major sections, and each category (row) is evaluated using a five-point four-column scale. This evaluation tool is how student grades are calculated for this project.

The design section includes categories that evaluate the materials teams use in their design, the water retrieval system, and the overall user experience of the design. The operation section includes categories that assess if the team completed the four trials and if they recorded their data for all four trials. The other two categories in the operation section evaluate if the water filter can stand on its own throughout each trial and if the teams clean up after themselves throughout the project. The last section evaluates the performance of the water filter throughout the trials. The performance section includes the time, water loss, and clarity test categories, the same as the Water Filter Testing Data Record assignment sheet (Appendix L) students complete in their teams.

2.1.4 Inquiry Questions

The questions that will guide my inquiry include:

1. What does the engineering design process look like in my course?
2. How to what extent does the engineering design process support a girl's ability to see themselves as an engineer?

2.2 Methods & Measures

2.2.1 Sources and Collection Methods

My intervention aims to explore the shifts in high school-age girls' engineering identity in Southwestern PA High School. This intervention is guided by my theory of improvement that takes a blended approach that incorporates application, collaboration, and empathy-building in hands-on engineering design process challenges into courses I teach. The data collection of this research took a qualitative approach. I collected the data to assess students' attitudes toward engineering guided by my inquiry questions. All students enrolled in the Introduction to STEM course completed all steps of the Engineering Design Unit and the Open-ended Essay assignment (Appendix N). However, only data from students who identify as girl, female, or woman was used in the analysis. All students were allowed to opt-out of the data collection portion of this study and are able to choose not to specify their gender identity. All identifiable data was collected through Qualtrics and deidentified by a school administrator. To examine this theory, I proposed a two-phase approach of improvement.

2.2.1.1 Phase 1 (Intervention: Engineering Design Unit)

The first phase aligns with the change ideas and inquiry questions for this theory of improvement. This alignment guided the overall unit plan that students followed throughout the intervention. This unit plan, called the "Engineering Design Unit" followed a project-based classroom format familiar to high school students. The unit relied on the Design Thinking Bootleg (Both & Baggereor, 2013) process modules developed by the d.school at Stanford University

(Figure 2) and the Engineering Design Process (Figure 3) as guiding models for this approach. The five original Process Modules and the engineering design process alignment demonstrated in the Process Module Alignment table (Table 2) also aligned with the steps in the Engineering Design Unit (Table 3), with the addition of a presentation step. Using these process modules and the engineering design process will add further legitimacy to this approach due to adopting these skills in professional industries. Each step in the Engineering Design Unit (Table 5) was presented as a lesson that includes a team-based activity and assignment. The activity and assignment aided in the development of creating a solution to a societal problem. Further description of each step in the Engineering Design Unit, each activity, each assignment, and the Water Filter Project is found above in the Intervention Description section.

Table 5 Engineering Design Unit Alignment

Process Modules	Engineering Design Process	Engineering Design Unit
Empathy	Ask	Step 1: Empathy
Define	Research	Step 2: Define & Understand
Ideate	Imagine Plan	Step 3: Ideate
Prototype	Create	Step 4: Prototype
Test	Test Improve	Step 5: Test & Improve
		Step 6: Presentation

Another method of data collection that will occur throughout the first phase of this study is a form of reflective journaling (Appendix D). This form of journaling followed a modified version of Charlotte Danielson et al's (2009) Action Planning and Reflection teacher tool (p.392) and Lesson Reflection Questionnaire (p.383). The format and questions of these sources was modified to focus on student engagement and learning rather than the standard lesson mechanics present in their original forms. Journaling also occurred each day of the Engineering Design Unit and for each three class sections.

2.2.1.2 Phase 2 (Open-Ended Essay)

The second phase took the form of an open-ended essay (Appendix C) to help me understand more about a girl's attitude toward engineering as a potential career after completing the Engineering Design Unit. While semi-structured interviews may be more appropriate in this type of research, previous research that includes student interviews has not passed our school board due to past issues. In that case, all students were required to write an open-ended response essay about their experiences but data was only collected from the students who identify as girl, female, or woman.

2.2.2 Data analysis

The inquiry questions for this study focus on implementing the engineering design process in the classroom and then investigating how it supports a girl's ability to see themselves as an engineer. I describe how I analyzed the data by inquiry question below.

Inquiry Question #1: What was the design and implementation for the engineering design process for my course?

2.2.2.1 Engineering Design Unit Plan Data Analysis

I analyzed the Engineering Unit by reading over all the lesson plans, activities, and assignments. I utilized Saldaña's (2021) method of Descriptive Coding (p. 134) to code the Engineering Design Unit Plan. Saldaña's (2021) method of Descriptive Coding is useful in this situation because it "identifies and links comparable contents" (p. 134). Linking comparable contents in the Engineering Design Unit Plan analysis was important because I wanted to analyze how all parts of the unit plan aligned with my desired outcome and focus.

During multiple rounds of coding using the Descriptive Coding method of the Engineering Design Unit plan, I found that my lesson plans, activities, and assignments began to fall into specific categories. These categories included how students could understand the problems being discussed, how students would develop solutions to these problems, the format of the class, and how I would encourage student teamwork and interaction. So, the categories found during the Engineering Design Unit Plan analysis included problem understanding, solution design, class format, and classroom interaction.

To develop a better understanding of my categories, codes, and the qualitative data in general, I utilized Saldaña's (2021) method of theming the data, specifically categorically (p. 258-260). Saldaña (2021) says that a theme "identifies what a unit of data is about an/or what it means" (p. 258). Likewise, DeSantis and Ugarriza (2000) say that a theme "captures and unifies the nature or basis of the experience into a meaningful whole" (p. 362). Considering the categories and codes, one theme found in my analysis was understanding the design process, which included the solution design and problem understanding categories. The second theme, transforming the classroom environment, includes the classroom format and classroom interaction categories. Further explanation of these themes is found in the Results section (Section III) below.

2.2.2.2 Teacher Daily Reflective Journal

The teacher's daily reflective journal (Appendix P) was completed each day in the Engineering Design Unit. The format is modified from Charlotte Danielson et al.'s (2009) Action Planning and Reflection teacher tool (p.392) and Lesson Reflection Questionnaire (p.383). While observations and reflections were made throughout the class for both boys and girls, only data was recorded for the observed experiences of girls during the Engineering Design Unit. These experiences included interactions with teams of boys and girls and teams of girls only.

Analysis of the journaling data followed the same analysis model as the lesson plans and individual steps of the Engineering Design Unit. To analyze the data, I read through journal entries and coded it utilizing Saldaña's (2021) method of Descriptive Coding (p. 134). Like with the Engineering Design Unit plan, I wanted to link comparable contents in the Teacher Daily Reflective Journal analysis. This method also allowed me to link comparable contents between the unit plan and what was recorded in the Teacher Daily Reflective Journal. While the coding of the Teacher Daily Reflective Journal was separate from the Engineering Design Unit Plan, the categorizing and themeing were done together. This resulted in the categories and themes being developed with the codes from both data sources. So, the categories found during the Teacher Daily Reflective Journal and the Engineering Design Unit Plan analysis included problem understanding, solution design, class format, and classroom interaction. Likewise, one theme found in my analysis was understanding the design process, which included the solution design and problem understanding categories. The second theme, transforming the classroom environment, includes the classroom format and classroom interaction categories. Further explanation of these themes is found in the Results section (Section III) below.

Inquiry Question #2: How and to what extent does the engineering design process support a girl's ability to see themselves as an engineer?

To answer this research question, I coded the open student response essays, which was a qualitative data source.

2.2.2.3 Open-Ended Essay

The Open-Ended Essay (Appendix O) was completed at the end of the Engineering Design Unit. All 72 students were assigned the essay assignment, but data was only collected from twenty-three students who identified as girls, female, or women. Before data analysis, a school administrator de-identified all names from the open response essay submissions. The administrator only reports the names of students who did not submit an essay response so that those students would not receive course credit for the assignment.

I read and coded the data using Saldaña's (2021) In Vivo coding method. The In Vivo method is "particularly useful in education ethnographies with youth" and "appropriate" for beginners in qualitative research who are "learning how to code" (Saldaña, 2021, p. 138). Saldaña (2021) further explains that the In Vivo method is useful for coding youth because "adolescent voices are often marginalized, and coding with their actual words enhances and deepens an adult's understanding of their discourse, cultures, and worldviews" (p.138). Since the Open-Ended Essay data source was the only data directly from the students, it was important that their actual words are not lost in translation and throughout the multiple cycles of coding, categorizing, and themeing.

The Open-Ended Essay (Appendix O) helped me understand the shifts in a high-school girls' engineering identity. Each essay response was written as an individual assignment and in each respondent's own words. These responses helped me understand the reaction to and experiences of girls throughout the different steps of the unit as it relates to a future career in engineering. While semi-structured interviews may be more appropriate in this type of research, previous research that includes student interviews has not passed our school board due to past incidents.

During the multiple rounds of coding using Saldaña's (2021) In Vivo coding method, I found that student responses fell into categories based on what specific responses they gave to the writing prompt. The essays helped me understand the students' associations with engineering, from how they see an engineer's place in society to their internal association with engineering as a career. Most notably, I was interested in a girl's self-identity as an engineer and if they could or do see themselves as one. These types of identity issues were discussed in my review of supporting knowledge and found most notably in the research by Dasgupta and Stout (2014), Shapiro & Williams (2012b), and Reilly et al. (2019). Other categories found during my analysis of the Open-Ended Essays are more focused on the classroom experiences and the act of developing solutions to the engineering challenges throughout the Engineering Design Unit. So, the categories found during the Open-Ended Essay analysis included extrinsic association with engineering, personal or intrinsic association with engineering, future implications, physical creations, solution development, and classroom experiences.

Just like in my effort to better understand my categories, codes, and the qualitative data in general for the Engineering Design Unit Plan analysis and Daily Teacher Journal analysis, I utilized Saldaña's (2021) method of theming the data. The themes were being and engineer and becoming an engineer. Categories found in the being an engineering theme included extrinsic association with engineering, personal or intrinsic association with engineering, and future implications. Categories found in the becoming an engineer theme included physical creations, solution development, and classroom experiences.

3.0 Section III: Results

3.1 Results of Inquiry Question #1

What does the engineering design process look like in my course?

Based on coding the data from the lesson plans (Appendices A-F) and teacher's daily reflective journal, I discovered two themes that align with the first inquiry question: What does the engineering design process look like in my course? The themes are *understanding the design process* and *transforming the classroom environment.* The themes, supporting categories, and codes are summarized in Table 6. Below, I describe these codes, categories, and themes in details providing examples of each level.

Table 6 Inquiry Question 1 Theme Alignment Table

Themes	Categories	Codes	Code Definition
Understanding The Design Process	Solution Design	Iteration	Tasks that include evaluating and changing their design/plan based on internal or external feedback or the results of testing their design
		Problem Solving	Students engage with looking at a problem and develop a solution based on the information they are given
		Assemble	Tasks that include assembling their product or project solution
Understanding The Design Process	Problem Understanding	Connection	Students discuss or develop questions based on personal experiences
		Empathy	Classroom tasks include a focus on empathy as a method of connecting real people to the assigned challenge
		Inquiry	Students ask questions to gain more insight on the information being presented or discussed
Transforming The Classroom Environment	Classroom Format	Choice	An open model for the class format that allows students the ability to solve problems or engage in the class tasks in any way they want.
		Opportunity	Creating time for students to think; creating opportunities for deep engagement
Transforming The Classroom Environment	Classroom Interaction	Discussion	Discussion is used in a class or small group to promote connections and understanding of the classroom topic
		Teamwork	Students engage with teamwork or collaborative skills to complete classroom tasks
		Presentation	Tasks include creating or presenting their work to their peers

3.1.1 Understanding the Design Process Theme

The first theme is understanding the design process and is supported by the categories of solution design and problem understanding. The codes in this theme are iteration, problem-solving, assemble, connection, empathy, and inquiry. The understanding the design process theme was defined by the grouping of the codes and categories. The codes found in this theme follow the Engineering Design Process (Figure 3) in the way students understand and design a solution to the presented problem. Students completed tasks that required them to learn about the problem, design a solution, build the solution, and test the solution.

Analysis of lesson plans (Appendices A-F) and teacher's daily reflective journal found classroom experiences that engage students in the process of developing solutions to a problem. For example, student groups used iteration to build, test, and improve their water filter design in the Prototype (Step 4) and Test & Improve (Step5) steps of the Engineering Design Unit. Other examples were found in the Ideate (Step 3) step of the Engineering Design Unit. Student groups developed designs for their water filters based on design constraints, their conceptional design and the material availability. Therefore, the *solution design* category describes how students' complete tasks or participate in experiences developing solutions to the assigned challenge.

The first code to appear in the *understanding the design process* theme is the *iteration* code. This code is part of the *solution design* category. The *iteration* code is defined as tasks that include evaluating and changing their design/plan based on internal or external feedback or the results of testing the student's design. One example of using the *iteration* code is found in the Prototype Build activity (Appendix D) in the Prototype step of the Engineering Design Unit. Student teams iterate on their design while building a working prototype prior to the start of the Test & Improve step. Another example I observed during student work is the Ideation step. One student group asked, "how would the water be used after being collected from the filter?" The team was trying to figure out how to filter the water into a separate container to limit water loss and not have to disassemble their filter to collect the water.

Another code in the *solution design* category is *problem-solving.* The definition of the *problem-solving* code is that students engage by looking at a problem and developing a solution based on their given information. One example of using the *problem-solving* code is when student teams work on the Problem Tree Analysis activity (Appendix H). The Problem Tree Analysis activity has students develop a broad understanding of the cause and effects of lack of access to clean water during the Research and Define step of the Engineering Design Unit.

A second example of the *problem-solving* code I found during the Prototype step was around engagement in the classroom task. Based on the observations, girls demonstrated more engagement and excitement while working on assembling their prototype as opposed to the research and understanding tasks. These observations included discussions between students during their prototyping building sessions that were nearly all on task. Topics of the discussions included how, when, and why to use certain materials. For example, I overheard Stephanie G ask her group, "well, how are they going to get the clean water out of the filter without spilling the whole thing?" While another student in a girls-only group, Melissa B asked her team, "What types of materials do you think you could find at your house after a disaster, like the one in Puerto Rico?" These responses demonstrate that the students were connecting different aspects of the problem to develop usable solutions, which is the definition of the *problem-solving* code mentioned above.

The *assemble* code is also found in the solution design category of the *understanding the design process* theme. A definition of the *assemble* code is tasks that include students physically assembling their product or project solution. One example of the *assemble* code is found in assembling and disassembling their prototype water filter in between each trial in the Test and Improve step of the unit. Another example of the *assemble* code is an outcome that I did not expect during the Prototype step. I expected most student teams to just quickly build a filter without much attention paid to the criteria and restrictions. However, many groups worked more thoughtfully on their design as a fully working product. I noticed that girls, whether in mixed-gender or girls-only teams, demonstrate more interest in how people would use the device rather than how it is actually assembled. This noticing follows along with research that shows girls engage more with engineering when presented with a focus on empathy and understanding of why problems exist and how they affect humans on a personal level (Dasgupta & Stout, 2014; Bystydzienski, Eisenhart, and Bruning, 2015).

Problem understanding is the second category of the *understanding the design process* theme. Analysis of lesson plans (Appendices A-F) and teacher's daily reflective journal found that students engage with different experiences to help them understand the problem being presented. Much of the supporting knowledge for this research points to the importance of understanding as a method of engaging girls with engineering as a potential career. For example, separate studies by Marcu et al. (2010) and Knezek and Christensen (2019) support that an open-ended, real-world approach to presenting engineering information to girls can increase their interest in STEM careers. Meaning that simply helping girls understand problems that real people are facing in the world and connecting how engineers can solve those problems can increase their interest in the career. The three codes found in the *Problem understanding* category include connection, empathy, and inquiry all of which help in the understanding of a problem. Therefore, the *problem understanding* category describes the tasks or experiences that students completed to better understand the assigned problem.

The *connection* code is found in the *problem understanding* category. The *connection* code is defined as the action of students discussing or developing questions based on personal experiences. One example of this code is found in the Empathy step of the Engineering Design Unit. For example, students build personal connections when they witness the struggles of people in our country that deal with the lack of access to clean drinking water in the present day through video news stories about their experiences. I noted in the Daily Reflective Journal that girl students brought up questions about our area and their access to clean water in an emergency.

Another example of the *connections* code is found in the Daily Water Use Chart assignment (Appendix G). Students record their water usage for three days, marking every time they use water in any way. After the three days, we as a class analyzed the results through a small group discussion. Then we move to a more extensive class discussion focusing on building an understanding of how much water each of us relies on daily. For example, one specific mixed-gender team was overheard discussing the location of their houses as it relates to in a valley or on a hill and if a flood would affect them.

Empathy is another code found in the *problem understanding* category of the *understanding the design process* theme. The *empathy* code is defined as tasks that focus on empathy as a method of connecting real people to the assigned challenge. One example is found in the Define and Understand step of the Engineering Design Unit. Students complete the Clean Water in a Disaster Research assignment (Appendix I) to build empathy for people dealing with a lack of access to clean water. The assignment requires them to investigate the political, environmental, and infrastructure challenges of getting access to clean water in places with recent severe natural disasters like Puerto Rico and Haiti. Student engagement was observed by the conversations between mix-gendered teams of students. These conversations were about the people and how students would feel or deal with the same conditions.

Another example of the *empathy* code is found in the Ideate step, where students complete the Affinity Cluster activity (Appendix C). The Affinity Cluster activity requires student teams to develop ideas to solve the challenge of the Water Filter Project (Appendix J). The focus up to this point in the Engineering Design Unit has been on the people who experience a lack of access to clean water. Ideally, developing a connection between these people and the requirements of the Water Filter Project will lead to student solutions being influenced by those who experience this hardship.

The *inquiry* code is also found in the *problem understanding* category. The *inquiry* code is defined as the act of students asking questions to gain more insight into the information being presented or discussed. One example of the *inquiry* code is found in the Define and Understand step of the Engineering Design Unit. For example, in the Problem Tree Analysis activity (Appendix H), students investigate the issues exacerbating a lack of access to clean water after recent natural disasters in Puerto Rico and Haiti. The activity requires students to develop five causes and effects found in the Clean Water in a Disaster Research assignment (Appendix I). An outcome that I did not expect from this assignment was student questions about the news coming out of Puerto Rico related to corruption and why the government does not help the island's people. Another example of the *inquiry* code is in the Test and Improve step of the Engineering Design Unit. Students must improve their water filter design after each trial by asking how and what can change to increase the success of their water filter design.

3.1.2 Transforming the Classroom Environment Theme

The second theme found in the analysis of the first inquiry question is *transforming the classroom environment*. The first inquiry question is: What does the engineering design process look like in my course? The *transforming the classroom environment* theme is supported by the *classroom format* and *classroom interaction* categories. The codes found in this theme are *choice, opportunity, discussion, teamwork,* and *presentation.* The groupings of categories and codes define this theme. These codes and categories all relate to the changes that I made to the traditional classroom paradigm to support my theory of improvement and the focus of the Engineering Design Unit.

Analysis of lesson plans (Appendices A-F) and teacher's daily reflective journal found that changes to the format of a traditional classroom can be beneficial for students but may be challenging to plan for and implement. Changing from a traditional teacher-centric classroom format may be difficult for some teachers to engage with and may not fit into core classes, those being not considered an elective course (science, math, ELA, etc.). Especially considering curriculum and time constraints due to state and federal standardized testing requirements and local district curriculum requirements.

Changes to a traditional format in the Engineering Design unit allow for situations that the teacher did not plan for and cannot direct. Examples of these type of changes to my classroom format are found in the Ideation step, the Prototype step, and the Test and Improve step of the unit. These steps are where students designed, built and tested their water filters. The overall plan for the water filter project did not give students any actual guidance or correct answers on how to solve the problem other than the design constraints. So, I cannot predict how a team will solve the challenge, such as the materials they will use or construction methods. However, one outcome that I did not predict was that a few mixed-gendered and girls-only teams were looking up online about the causes and effects during the Problem Tree Analysis activity. Two mix-gender teams were constructively arguing over the causes and effects and using the internet to prove or disprove each other. Therefore, the *classroom format* category describes any changes to the traditional classroom format from the teacher planning point-of-view.

The first code that supports this theme is *choice* and is found in the *classroom format* category. The *choice* code is defined as an open model for the class format that allows students to solve problems or engage in the class tasks in any way they want. One example of the *choice* code is found in the Affinity Cluster activity (Appendix C) of the Ideation step. Students choose how they approach designing and building their water filter prototype. Another example of the *choice* code is found in the Test and Improve step of the Engineering Design Unit. Students choose how they improve their water filter design based on the results of each trial. However, their improvements comply with the design constraints and the overall challenge requirements of the project. The success of the open class format was backed up by all mixed-gender and all-girl teams working together to complete the activity and assignment. I did not see any groups where one person did all the work while the other members did nothing.

The *opportunity* code is also found in the *classroom format* category of the *transforming the classroom environment* theme. The *opportunity* code is defined as creating time for students to think; creating opportunities for deep engagement. One example of the *opportunity* code is found in the Define and Understand step of the Engineering Design Unit. Teams will complete the Problem Tree Analysis activity (Appendix H) at different speeds, and the lesson plan allows for this fact. Students are not penalized for taking longer to complete the activity. Taking away time as a factor will allow students to build a deeper engagement with the content matter. Another example of the *opportunity* code is found in the Affinity Cluster activity (Appendix C) of the Ideation step. The exact time guidelines apply to the Affinity Cluster activity as the Problem Tree Analysis activity and for the same reasons.

The second category of the *transforming the classroom environment* theme is *classroom interaction*. The review of supporting knowledge suggests that peer groups (Robnett, 2013) and an exposure (Dasgupta and Stout, 2014; Bystydzienski, Eisenhart, and Bruning, 2015; Weinberg, Pettibone, and Thomas 2007) are powerful methods of building a girl's interest in engineering as a potential career. Analysis of lesson plans (Appendices A-F) and teacher's daily reflective journal found that students engaged with each other in a collaborative, open, but guided classroom experiences. The Engineering Design Unit relied on exposing students to engineering experiences through solving problems in groups without interference from the teacher on how to solve the water filter project. For example, the Presentation step (Step 6) of the Engineering Design Unit required students explain their designs in the form of a presentation to their peers. The purpose of this presentation assignment was to help students learn the different ways to solve the problem, successfully or not. Therefore, the *classroom interaction* category describes any student's interactions with each other, whether in their teams or with the entire class.

Discussion is the first code found in the *classroom interaction* category. The *discussion* code is defined as a discussion is used in a class or small group to promote connections and understanding of the classroom topics. One example of the *discussion* code is found in the Empathy step of the Engineering Design Unit. I heard a few groups in each class discussing the issues mentioned in the articles about Puerto Rico. Specifically, students discussed the corruption issues that plague Puerto Rico's rebuilding as it relates to water processing, testing, and distribution. Another example is found in the Ideation step of the unit, where students will discuss how they will solve the water project challenge. I heard many students coming up with outlandish ideas of what they could do while their teammates would discuss how these ideas could or could not work.

Another code found in the *classroom interaction* category of the *transforming the classroom environment* theme is *teamwork*. The *teamwork* code is defined as students engaging with teamwork or collaborative skills to complete classroom tasks. Examples of this code are found throughout the Engineering Design Unit. Such as, in the Define and Understand step, students complete the Problem Tree Analysis activity (Appendix H) and the research assignment (Appendix I). Using the information that the students learn from both of these tasks, teams work together to understand better how the lack of access to clean water happens and how it affects real people today.

Another example of the *teamwork* code is found in the Ideation step, where students complete the Affinity Cluster activity (Appendix C) to develop a prototype to solve the challenge based on the team's collective knowledge. During the Affinity Cluster activity work sessions, I noticed positive and constructive interactions with all of my all-girl teams. These interactions were universally common between the mixed-gender teams.

The last code in the *classroom interaction* category is *presentation*. The *presentation* code is defined as tasks that include creating a presentation about their work and then presenting it to their peers. One example is something I noticed about student interaction during the Water Filter Design Presentation assignment (Appendix M-N). Students were all very supportive of each other, boys and girls, and there were no issues with students being bullied when up in front of the class presenting. A second example follows the last example when considering how students would engage with the presentation task. Most high school students do not like public speaking, but nearly all teams showed interest in explaining their solutions to their peers.

3.2 Results of Inquiry Question #2

How and to what extent does the engineering design process support a girl's ability to see themselves as an engineer?

Through the data collection analysis, I found two themes that align with the second inquiry question: How and to what extent does the engineering design process support a girl's ability to see themselves as an engineer? The themes of *becoming an engineer* and *being an engineer* are found by analyzing the codes and categories. These themes and supporting categories and codes are summarized in Table 7 below. The data for analysis of this inquiry question came from the student open response essays (Appendix O). Students reflect on the Engineering Design Unit and then explain three specific things they did throughout the unit that would make them want to or not want to follow a career in engineering. The data for analysis comes from twenty-three student responses whom all self-identify as girl, woman, or female.

Table 7 Inquiry Question 2 Theme Alignment Table

Themes	Categories	Codes	Code Definition
Becoming an Engineer	Extrinsic Association with Engineering	Empathy	Do they mention solving a problem for society or other people? Do they mention how problems affect others?
		Real-World	Do they connect what they are doing in class to a real-world experience?
		Application	Did they make a connection between school subjects and the act of engineering?
		Collaboration	Do they mention working as a team in anyway?
Becoming an Engineer	Personal or Intrinsic Association with Engineering	Connection	Connecting what a student has done in their life with the Engineering Design Unit or the engineering design process
		Understanding	Do they understand what an engineer does or how engineering is used to improve society?
		Identity	Do they connect their gender identity with engineering in any way?
Becoming an Engineer	Future Implications	Interest	Do they mention that this unit/classroom experience interests them in engineering or in the problem being presented?
		Career	Do they mention engineering as a career in any way?
Being an Engineer	Physical Creations	Iteration	Iteration is the process of creating different solutions based on tests of previous versions
		Building	Does the student mention the act of building something and/or the building of their prototype
Being an Engineer	Solution Development	Ideation	The process of coming up with ideas to solve the problem but does not include the act of physically building the device
		Solution	Do they mention developing a solution to a problem or the act of problem solving?
		Reflection	Do they reflect on their team's failures and successes in the development of their water filter device?

3.2.1 Becoming an Engineering Theme

The first theme is *becoming an engineer*, which is supported by the *extrinsic association with engineering*, *personal or intrinsic association with engineering,* and *future implications* categories. The codes found in this theme are *empathy, real-world, application, collaboration, connection, understanding, identity, family, interest,* and *career.* The *becoming an engineer* theme means that the tasks, activities, assignments, and experiences all focused on understanding a girl's ability to see themselves as an engineer based on their responses to the Engineering Design Unit.

Extrinsic association with engineering is the first category of the *becoming an engineer theme.* As discussed in my review of literature, extrinsic forces that are out of a girl's control can push them away from engineering as a potential career. These extrinsic forces can include gendered stereotypes driven by societal norms (Dasgupta & Stout, 2014; Reilly et al., 2019; Shapiro & Williams, 2012b), lack of access or understanding of engineering-focused experiences or opportunities (Ehrlinger et al., 2018; Milgram, 2011; Wang, Eccles, & Kenny, 2013), and an absence of peer support (Leaper et al., 2012; Robnett, 2013). Analysis of students' Open-Ended Essay responses found that the Engineering Design Unit presented engineering in a way that participants understood the purpose of the career. This unit also helped girls combat the different extrinsic barriers that may have or did drive them away from the field. Therefore, the *extrinsic association with engineering* category is described as a girl's ability to understand an engineer's place in society is to solve problems to make society better.

The first code found in the *becoming an engineering* theme is the *empathy* code and is part of the *extrinsic association with engineering* category. The *empathy* code will be defined as any student's responses that mention solving a problem for society or mention how problems affect others. One example of the empathy code is from Jessica T, who says she likes brainstorming and generating multiple ideas. Jessica explains that these tasks helped her "realize just how privileged I am to be able to have running water in my house because it is not as common as I thought it was." Another example of the empathy code is from Tara H, who says, "I enjoy using my ideas to make something that could potentially change someone's everyday life." Of the eighteen students that mention an interest in engineering as a career (Figure 8), ten explained that they are considering a career in engineering because they want to help people (Figure 6).

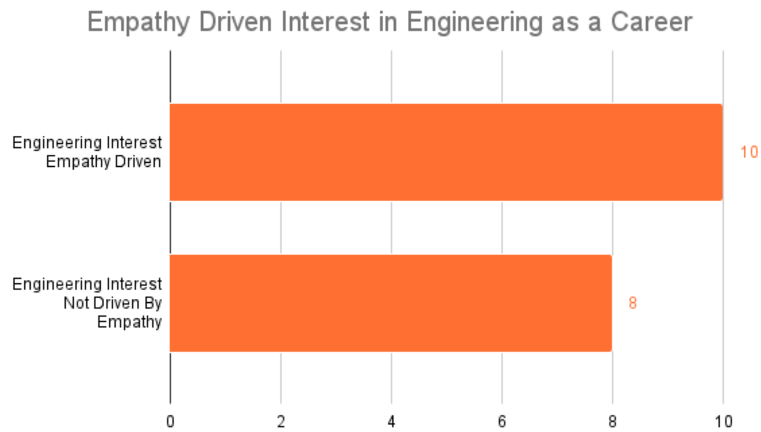


Figure 6 Empathy Driven Interest in Engineering as a Career

Another code found in the *extrinsic association with engineering* category is the *real-world* code. *Real-world* code is defined as instances where students connect what they are doing in class to a real-world experience. For example, Sarah W expresses her realization that "there are several regions of the world that do not have access to clean water, so it made me want to try to solve the problem." Another example of the *real-world* code is found in Melissa B's response, who explains how the Engineering Design Unit helped her to understand how lucky she is in her life. She says, "It was very eye opening to see how mindless we are when it comes to water as we would just go to the tap, fridge, or a water fountain." She continues by discussing how something as simple as clean water in our house is a "tremendous engineering feat in modern society that we all take for granted."

The *application* code is also found in the *extrinsic association with engineering* category of the *becoming an engineer* theme. This code is defined as the action of students making a connection between school subjects and the act of engineering. One example is found in a student's response about teamwork and the Engineering Design Unit. Ashley J explains that "teamwork is a vital concept in the real world," and school experiences that require teamwork "will help in their future careers." Another student, Yunjoe W, explains how the Engineering Design Unit has made her want to follow a career in engineering. She says, "I enjoyed testing the water filter" because testing "showed me what errors we made in the construction" and "what adjustments my team needed to make" for the subsequent trial.

The last code in the *extrinsic association with engineering* category is the *collaboration* code. The *collaboration* code is defined as any mention of working as a team. One example of the *collaboration* code is found in Yunjoe W's essay response when she explains how the water filter project made her want to become an engineer. She says, "One reason this water filtering project made me want to follow a career in engineering is because I enjoyed constructing the water filter with my team." Another student, Eva K, explains that "Combining ideas and working together is, in my opinion, the most engaging part of pursuing a career in engineering." Before this unit, she did not think engineering was such a career, but the Engineering Design Unit has changed her view of the career. In all, thirteen out of twenty-three respondents mentioned that working as a team made them interested in engineering as a potential career (Figure 7).

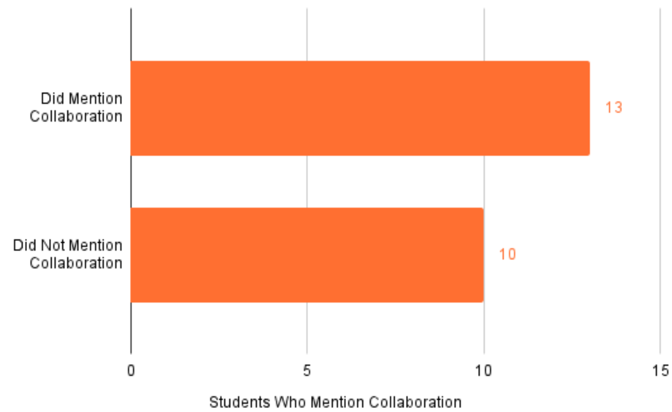


Figure 7 Students Who Mention Collaboration

The second category of the *becoming and engineer* theme is a *personal or intrinsic association with engineering*. While the extrinsic forces are pushing against a girl's interest in engineering as a potential career from the outside, these forces can have negative consequences on the inside. Research suggests the extrinsic forces can manifest in different ways that can influence a girl's interest, attitude, and performance in engineering and STEM related careers (Gunderson, Ramirez, Levine, and Beilock, 2012; Shapiro and Williams, 2012; Ehrlinger et al., 2018; Weinberg, Pettibone, & Thomas, 2007). Even a girl's confidence can be negatively affected by the extrinsic forces discussed above and can lead to lower achievement in the STEM-related fields (Shapiro and Williams, 2012; OECD, 2015). However, some research has found that these internal and external barriers can be positively impacted in the way engineering is presented or experienced by girls (Dasgupta and Stout, 2014; Bystydzienski, Eisenhart, & Bruning, 2015).

Analysis of students' Open-Ended Essay responses found that the Engineering Design Unit was successful in presenting engineering in ways that could help girls overcome potential internal barriers. The Engineering Design Unit employed techniques that were backed up by the research presented in my review of literature. These techniques include real-world application of engineering skills, peer collaboration, and exposure to engineering-based challenges. Therefore, the *personal or intrinsic association with engineering* category describes how a girl connects her personal world with engineering and how engineers work to improve society.

The first code in the *personal or intrinsic association with engineering* category is the *connection* code. The *connection* code is defined as connecting what a student has done in their life with the Engineering Design Unit or the engineering design process. One example of the connection code is expressed by Jessica T. She discusses how the Empathy step and the Define and Understand step showed her "how privileged I am to be able to have running water in my house because it is not as common as I thought it was" in the world. Another example from Taylor D explains how her "cousins, who live barely two hours away from here, can't drink water from their school due to there being lead in the pipes." This is a common notion seen in at least half of the female student responses. The notion is that many of the modern conveniences that we rely on every day are designed, built, and maintained by engineers.

Another code in the *personal or intrinsic association with engineering* category is the *understanding* code. This code is defined as understanding what an engineer does or how engineering is used to improve society. One example is found in Sidney V's response, who explains how she never realized that after a natural disaster, "people aren't able to get clean water to clean or drink, which can lead to serious illnesses." Understanding these ideas has made her interested in a career in engineering because she wants to help people suffering from these issues. Another reason Sidney explains is that "knowing that there are many different possible solutions to fix the issue or problem makes me want to pursue an engineering career." Another example comes from Riley K, who says she liked when we "watched videos of real people going through hardships to inspire us." She goes on to say the "videos showed us that engineering can help with real-world problems," and the videos were "more relatable, which is easier to connect with the teenage audience." Finally, Riley says that "the Engineering Design lesson made me want to follow a career in engineering."

The *identity* code is also found in the *personal or intrinsic association with engineering* category of the *becoming and engineer* theme. This code is defined as instances when a student connects their gender identity with engineering. For example, Allison R explains that the Engineering Design Unit has been the "most inclusive" she has ever done. She further says that the "inclusivity of the lesson has made it more enjoyable and engaging than others she has done in the past." Another example is expressed by Tara H, who discusses how a rewarding career is "very important to her and a career that is welcoming to women." She further explains how this unit has helped her understand that "becoming an engineer is a job that not only helps others but is also fun and very interesting." She says that even if the "career is not welcoming to women, the ability to serve society would be a driving force to persevere."

The third category of the *becoming an engineer* theme is *future implications*, supported by the *interest* and career codes. Analysis of the Open-Ended Essay's found that eighteen out of the twenty-three respondents mention an interest in engineering as a career (Figure 8). As discussed throughout the Results section of this study, there are different reasons why these girls are interested in engineering as a career. Also, there is no way to know from these results whether the girls had an interest prior to the start of the Engineering Design Unit. However, it is important to know if a girl mentions an interest in engineering as a career as it relates to the questions being asked in the Open-Ended Essay assignment that was completed after the water filter project had finished. Therefore, the *future implications* category describes a girl's interest in engineering as a potential career.

The first code in the *future implications* category is the *interest* code. The *interest* code is defined as any instance when a student mentions that the unit or classroom experience interests them in engineering. One example was explained by Kelly C, who says, "making a functional water filter is not easy." However, she goes on to say that "the challenge was part of her fun" and increased her interest in engineering as a potential career. Sarah W explicitly mentions "brainstorming" and "teamwork" to solve the problem as experiences that interest her in the career of engineering. A third student, Abby O, discusses how she "found it interesting to try to think of ideas for how to solve a problem that seemed so difficult." She goes on to say that the presentation step (Step 6) made her "most consider a career in engineering because it was exciting to share my product with others."

Not all students had positive experiences as it relates to the *interest* code. Negative examples of the *interest* code are found in three responses from three different students. Felicity P explains that while she "enjoyed the Engineering Design Unit," it did not push her toward a career in engineering. She does not want to follow a career in engineering due to the teamwork aspect, and she prefers "to be more independent in my work, and that is not ideal in the engineering field." Amy J explains that she has no interest in the career because she "could not imagine having to solve the problems every day and be expected to have an answer for it just to keep my job." Finally, Keri R says that she is not interested in engineering because of the "frustration you gain when you have to destroy and then rebuild a structure if it does not go right."

The last code for the *future implications* category and the *becoming an engineer* theme is the *career* code. The *career* code is defined as any mention of engineering as a career in their open response essay. For example, Cheri M explains her desire to become an engineer "because I like to build things and I also like working in groups." Sanah H says that "this project has shown me several ways the Engineering Design Process can have an impact on society, which increased my interest in pursuing a career in engineering." These two examples follow a common trend among students who mention careers in their responses. The three common examples of why they want to pursue a career in engineering are working in groups, solving a problem for society, and physically building something.

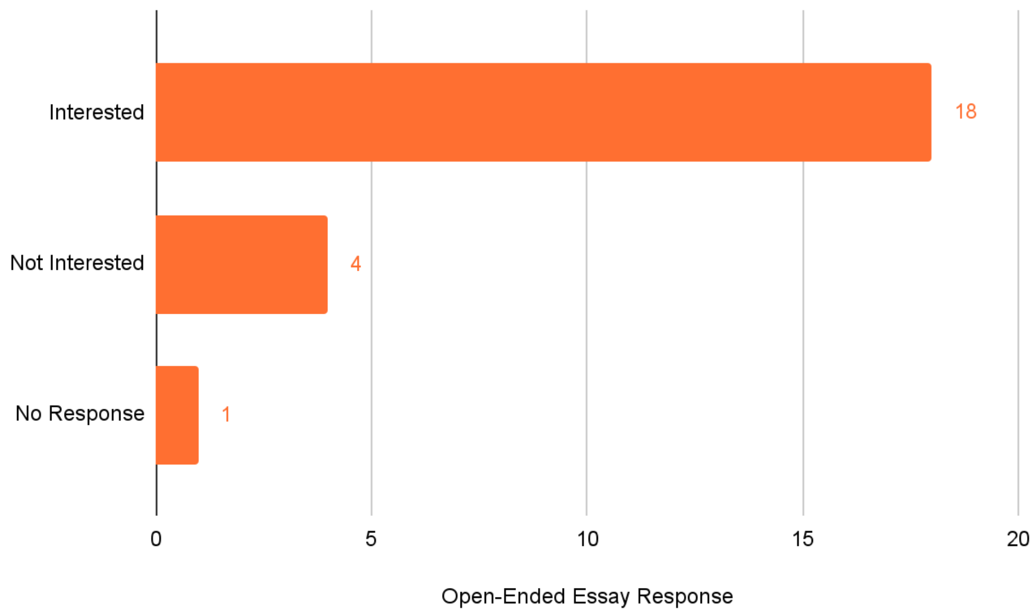


Figure 8 Mention of Engineering as a Career

Of the twenty-three respondents, eighteen students mention an interest in engineering as a career, while four explicitly say they are not interested, and one does not specify either way (Figure 8). One example of a student who is not interested is Keri R, who says, "I would not like to be an engineer because of the building." Another, from Lena O, says that she "does want to be part of that career because it is not creative enough and it is not as free as I would like." Amy J says that "Working as a team could be stressful in the way of people not liking the way you are trying to solve the problem." However, Amy J does say that engineering "can be fun but is not a job I would want to pursue in the future."

3.2.2 Being an Engineer Theme

The second theme of the second inquiry question is *being an engineer*, which is supported by the *physical creations and solution development* categories. The codes found in this theme are *iteration, building, ideation, solution, and reflection.* The *being an engineer* theme includes girls' responses to the Engineering Design Unit's activities, assignments, and experiences that sought to mimic the engineering design process in developing a solution to the assigned challenge.

The first category of the *being an engineer* theme is *physical creations* and is supported by the *iteration* and *building* codes. Confidence-building and motivation are key to supporting a girl's interest in STEM-related careers, including engineering (Robnett, 2013). My review of literature found that past studies were successful in increasing a girl's confidence and self-concept in engineering through hands-on experiences (Dasgupta and Stout, 2014; Weinberg, Pettibone, & Thomas, 2007). Specifically, the Weinberg, Pettibone, and Thomas (2007) findings suggest that exposure to engineering and STEM challenges is beneficial to a girl's ability to shun the traditional gender roles that bombard them in our society from a young age. At the same time, girls respond positively when challenged with hands-on application-based engineering experiences. Likewise, the Engineering Design Unit employs hands-on application-based experiences to aim for the same results. Therefore, the *physical creations* category describes the act of creating physical solutions to the assigned challenge of the Engineering Design Unit.

The first code found in the *being an engineer* theme is the *iteration* code which is part of the *physical creations* category. *Iteration* is defined as the process of creating different solutions based on tests of previous versions. One example of the *iteration* code comes from Allison R, who talks about the importance of creativity in the engineering design process. She explains that "building a prototype is also an outlet for creativity in the engineering process" and that being creative is crucial to her and her future plans. Allison R compares the action of being creative when she creates art and the creativity needed to develop a prototype for a product as she did in the water filter project. Another example comes from Sarah W, who says, "It was fun to see how the product that we built was different from our original design, and I enjoyed making changes to the design along the way." Eight of the twenty-three respondents mention that the problem-solving method of building and testing their water filter designs has increased their interest in engineering as a career.

Not all students had a positive experience in the iteration process. Three negative examples found in the iteration code come from three different students. Keri R says, "I wouldn't want to be an engineer because of the frustration you gain when you have to destroy and then rebuild a structure if it doesn't go right." She goes on to say, "this is frustrating because when you mess up a build, you have to go through and see what went wrong, and then you have to go back and fix it, delaying the finish time farther back." Lena P says, "we had to revisit our project over and over again, which was overall pretty frustrating." Lena P explains that "even though we changed our project plenty of times, it still wasn't good enough, which wasn't very rewarding in the end."

The last code in the *physical creations* category is the *building* code. The *building* code is defined as any time a student mentions the act of building something or the building of their prototype. One example of the *building* code is from Jessica T when she remembers the different problems her team ran into throughout the Engineering Design Unit. She explains the "fun in building and changing their design after each trial and how physically building the device made the experience more realistic." Another example from Sarah W says, "It was exciting to see how we could use household items to build a water filtration system that was effective and could easily be produced by almost anyone." Besides these two examples, around a quarter of the respondents mentioned positive experiences with physically building their water filter device.

The second category of the *being an engineer* theme is *solution development*, which is supported by the *ideation* and *reflection* codes. The *solution development* and *physical creations* categories share the same focus. Both categories rely on the use of hands-on application-based experiences to motivate and build a girl's confidence with engineering. However, the *solution development* category looks at the more creative and abstract side of engineering. Past research has found that girls respond positively to engineering when presented with a focus on the creative side of problem-solving real-world problems (Knezek and Christensen, 2019; Dahle et al., 2017; Liu et al. 's, 2014). Therefore, the *solution development* category describes the action of coming up ideas as a team and reflecting on those ideas in the effort to solve the assigned challenge.

The first code in the *solution development* category is the *ideation* code. The *ideation* code is defined as the process of coming up with ideas to solve the problem but does not include the act of physically building the device. In one example, Tara H says, "I think using my own ideas to create something is interesting." She says, "I enjoy using my ideas to make something that could potentially change someone's everyday life." Another example came from Jessica T when she said, "I liked brainstorming and generating multiple ideas because it helped me realize just how privileged I am to be able to have running water in my house." Finally, Lena P says, "In the water filter project I liked thinking of ideas with my partners." She goes on, "This collaboration of ideas and her team's support really made her consider engineering as a major in college."

Not all students had a positive experience in the ideation process. One negative example found in the *ideation* code responses is Keri R, who discusses how this step pushed her away from engineering. She says that “coming up with creative thoughts for a build or project” pushed her away from engineering as a career. She continues, “it’s hard to come up with what to build and how to build it.” Another example comes from a student who explicitly mentions boys as a stressor in this part of the project. While this is a piece of interesting information, most respondents do not mention if they are part of a mixed-gender group or a girls-only team. So it is unclear if other girls had the same experience with boy teammates.

Another code found in the *solution development* category is the *solution* code. The *solution* code is defined as any time a student mentions developing a solution to a problem or the act of problem-solving. For example, Sarah W said, "I enjoyed using problem-solving skills to solve problems that we faced." Then, as she says, "the real fun" was seeing how her idea is combined with all of her teammate's ideas to create an even better solution. Taylor D said that the "filter from the group I worked in was not that effective, but at the same time, it did work: further proving that a filter can be created using just everyday items." She goes on to say that "this process of solution development, as she says, is what most interests her about engineering as a career."

The last code in the *solution development* category is the *reflection* code. This code is defined as reflecting on one's team's failures and successes in developing their water filter device. One example comes from Grace N, who said, "What I liked most about this project was how we could all use our own ideas and try to build them to see if they passed or crashed." While Melissa B said that the Engineering Design Unit "has shown me you do not need to be the smartest person to be an engineer." She continues that she is encouraged to think about a career in engineering because there is no one answer to solve a problem. This type of response comes from at least five other students. The common theme is that any idea could solve a problem, and it does not have to come from the "smartest" person.

4.0 Section IV: Learning & Actions

4.1 Discussion

My problem of practice explores the shifts in high-school girls' engineering identity. Using a blended approach that incorporates application, collaboration, and empathy-building in engineering challenges, I sought to improve a girl's attitude towards engineering through classroom experiences. My improvement took the form of the Engineering Design Unit, which included each part of my blended approach.

During the Engineering Design Unit, learners were exposed to application-based challenges to allow girls to apply their knowledge to solve real-world problems. Second, girls worked in mixed-gender and girls-only groups while participating in application-based challenges. Finally, empathy-building experiences were utilized to build interest in solving engineering challenges.

Key findings relating to the shifts in high-school girls' engineering identity after completing the Engineering Design Unit demonstrated positive results in the intended focus of my improvement plan. Furthermore, these findings show that through application-based challenges, collaboration, and empathy-building, a positive shift in a girl's engineering identity is possible.

4.1.1 Application

This study integrated application-based challenges into the classroom as demonstrated by analyzing the classroom lesson plans (Appendices A-F) and Teacher Daily Reflective Journal (Appendix D). Application served as a method of exposure to real-world experiences with the hope of building a girl's interest in engineering as a career path. Application was achieved throughout the Engineering Design Unit in the form of assignments and activities. Such as the prototype build (Engineering Design Unit Step 4) activity where the students built a prototype water filter. Another example was the Water Filter Design Test activity and subsequent iteration after each trial (Engineering Design Unit Step 5).

Exposing girls to engineering challenges through the Engineering Design Unit with application-based experiences may combat the internal and external barriers that push girls away from an engineering identity. The literature review found that gender stereotypes are a key factor in a negative engineering identity in girls. From an early age, girls are at a disadvantage due to gendered stereotypes in the STEM fields (Dasgupta & Stout, 2014; Reilly et al., 2019). These gender stereotypes happen early in a girl's life due to our collective culture. Negative STEM stereotypes can undermine the interest and performance of girls in the STEM domain and even topple positive attitudes toward these fields of study (Shapiro & Williams, 2012b).

Results found throughout the Engineering Design Unit show how girls applied their own knowledge to solve challenges. The opportunity to apply their own knowledge builds their interest and attitudes toward engineering. At least half of the twenty-three Open-Ended Essay respondents specifically mention that this unit has led them to consider engineering as a potential career. Eight of those respondents mention that the problem-solving method of building and testing their water filter designs has increased their interest in engineering as a career.

Another example of how the Engineering Design Unit combats the internal and external barriers that push girls away from an engineering identity with application-based experiences relates to a girl's perception of a prototypical engineer. Ehrlinger, Plant, Hartwig, Vossen, Columb, & Brewer (2018) conduct a study to understand a girl's perception of what an Engineering professional is, relating to gender and intellectual ability. The authors observed that girls perceived the academic traits of prototypical engineers to be more intense and stereotypical than male participants and showed less participation in potential engineering courses and professions. This perception demonstrates how a combination of stereotypes and the associated internal and external barriers can hinder a girl's interest in engineering.

When comparing the research of Ehrlinger, Plant, Hartwig, Vossen, Columb, & Brewer (2018) to the results of the Engineering Design Unit, you can find examples of girls who can see themselves as following a career in engineering. Such as a student who says this unit helped her realize you do not have to be the "smartest person in the world" to become an engineer. While another student explains, she is grateful for the "inclusiveness" of the Engineering Design Unit because she felt welcomed in a place that she had previously felt was just for boys. However, these results do not suggest that the Engineering Design Unit changes a girl's view of the prototypical engineer. Instead, they demonstrate that the application-based experiences promote the idea that they can be engineers.

4.1.2 Collaboration

Another core component of my blended approach to improving a girl's attitude towards engineering through classroom experiences is collaboration. Collaboration was a necessary form of interaction throughout the entire Engineering Design Unit. All lesson plans were written with teamwork in mind. All assignments and activities were designed to be completed by teams of students, such as the prototype build (Engineering Design Unit Step 4) activity. Students had to bring in different materials from home to build their water filter prototype.

Collaboration serves as a method of building peer groups to increase a girl's confidence, motivation, and interest in engineering as a potential career. Findings from the review of scholarship suggest that high motivation and confidence play a significant role in a girl's interest in engineering (Robnett, 2013). Furthermore, a girl's motivation and confidence seem to be connected to her social relationships and play a significant role in shaping her identity (Leaper et al., 2012). By requiring girls to work together in groups throughout the Engineering Design Unit, a potential boost to motivation and confidence will accompany a peer group's development. The idea is that a peer group that engages with engineering will support each other's interest in either the different aspects of engineering or the career as a whole. Even if a girl does not have an interest in engineering as a career after this unit, the hope is that the experiences help their motivation and confidence in doing other things.

Findings from student responses in the Open-Ended Essay (Appendix C) demonstrate a connection between a peer group and engineering as a career. Thirteen out of the twenty-three respondents mentioned that working as a team made them interested in engineering as a potential career. While each of the thirteen respondents mentioned collaboration as a driving force, they all have different examples of where the engaging part of teamwork fits into their experiences. Also, none of the female respondents who mentioned collaboration specified if they were on a mixed-gender or girls-only team. Cheri M said, "Personally, I may want to pursue a career in engineering because I like to build things and I also like working in groups." Eva K said, "Combining ideas and working together is, in my opinion, the most significant part of pursuing a career in Engineering." A third, Lena P, said, "In the water filter project, I liked thinking of ideas with my partners and being able to use communication as part of the process." While these are only three examples, other student responses relate to similar collaboration variations. These findings also demonstrate collaboration throughout all steps in the Engineering Design Unit.

Observations from the Teacher Daily Reflective Journal (Appendix D) saw the importance of using collaboration to help positively shift a girl's interest in engineering. Such as the observations of students in both mixed-gender and girls-only teams using discussion to complete tasks as a team. Another example of collaboration was observed throughout the Ideation step, where students were developing designs and material lists for their water filter design.

A clear focus on engineering in this unit was intentional so that it does not get wrapped into the blanket term "STEM." The term "STEM" is used interchangeably in the educational and political world to bring attention and funding to a cause that needs both. Researchers Naukkarinen and Bairoh (2020) conclude that the need for more girls in the engineering field will not be solved by building their collective interest in STEM. Meaning, that the category of STEM courses should not be categorized together as one thing if you want to promote engineering as a potential career. So, a group of girls who show interest in STEM as a whole may be a disservice to individuals in that peer group who may show more interest in engineering over mathematics. While the Engineering Design Unit incorporated STEM concepts and practices into its overall plan, the unit uses engineering as the focus throughout its entirety. The unit does not include or point out experiences done explicitly by mathematicians or scientists in an application-based approach.

4.1.3 Empathy-building

Results of the data analysis suggest that empathy can play an important role in shifting a girl's attitude toward engineering as a career. Therefore, empathy-building was another key focus of the unit, especially in the first two steps and the Water Filter Project challenge (Appendix J). Empathy-building served to demonstrate how engineers develop solutions to help humanity. Research shows that girls engage more with engineering when presented with a focus on empathy and understanding of why problems exist and how they affect humans on a personal level (Dasgupta & Stout, 2014; Bystydzienski, Eisenhart, and Bruning, 2015). So, by including relevant information, visuals, and experiences that spotlight how an issue affects real people, I hoped to shift a girl's engineering identity positively.

Students engaged in assignments and activities where empathy-building was used to build interest. Such as the Daily Water Usage Chart assignment (Appendix G) to help students understand how much water they use in three days. The idea for my assignment came from research done by Knezek and Christensen (2019). The authors found that girls respond positively to an inquiry-based and real-world focus on science related to their science attitudes and long-term interest in science overall. In their National Science Foundation's (NSF) funded study, Knezek and Christensen (2019) sought to explore middle school students' dispositions in STEM subjects and the impact of hands-on experiences. Pre and post-test surveys were taken before and after a three-week science lesson that had students track their electricity usage throughout their day, just as the Engineering Design Unit did with the Daily Water Usage Chart assignment.

After analyzing the results from students tracking their electricity usage throughout their day, Knezek and Christensen (2019) found a positive effect on a girl's STEM disposition. This positive effect on girls was more so than on boys, and the hands-on nature of the experiences we received positively by girls more than on boys. In my study, three out of the twenty-three respondents made specific references to the Water Usage Chart assignment in their Open-Ended Essay. Directly referencing the Water Usage Chart, Melissa B says, "It was very eye-opening to see how mindless we are when it comes to water as we would just go to the tap, fridge, or a water fountain." While Sarah W mentions that she "never thinks about how easy it is for us to get clean water without any effort until you see how others live without this luxury."

Another assignment that intended to build empathy is the Clean Water in a Disaster Research and the Problem-Tree Analysis activity. These tasks pushed students to understand how people in the modern world still lack access to clean water. Also, it is difficult to repair that infrastructure after a natural disaster due to political and economic issues. After reading the articles about Puerto Rico, I observed six different groups discussing the issues mentioned in the articles throughout the day. Specifically, the corruption issues that plague Puerto Rico's rebuilding related to the water processing, testing, and distribution after the recent natural disasters. These group discussions morphed into whole-class talks in all three of my classes. In all three classes, students wanted to know how this corruption is allowed and why the government of Puerto Rico doesn't help the people of the island.

Overall, at least eight out of the twenty-three respondents mentioned that this unit made them understand how access to clean water is not as common as they previously thought and vital for life. These responses align with my intended goal for an empathy-building approach. However, now the question is if a girl was able to connect empathy and a positive shift in engineering identity. Based on the Open-Ended Essay (Appendix O) responses, ten of the twenty-three students explained that they are considering a career in engineering because they want to help people. For example, Sidney V says, "Knowing that creating a good and sufficient water system that will help someone in their everyday life makes me want to follow a career in engineering." I was looking for this type of response in an outcome for the Engineering Design Unit.

4.2 Next steps & Implication

The outcome of this study demonstrates a positive shift in a girl's engineering identity when engineering experiences are presented through a blended approach of application, collaboration, and empathy-building in engineering challenges. These experiences can counteract the internal barriers and external stereotypes that girls must deal with in modern society. My role as a high school technology education teacher allows me to foster a space for high school-age girls who may have been discouraged or not given the time to explore their interests in engineering. Likewise, help direct those students who may not even know they are interested in the career due to a lack of engagement throughout their education journey.

My classes will continue to focus on engineering as a career and the critical skills of problem-solving, teamwork, creativity, and perseverance. After taking my class, it is naive to think that every girl needs to be interested in engineering. However, these skills are transferable to any career path or educational endeavor. For example, take the research by Dahle et al. (2017) that looks at how the recruitment and retention of girls at the State University of New York (SUNY) New Paltz engineering major with a minor in art program changed. The authors find that from 2014 to 2016, the number of girls enrolling in the new engineering and art program doubled. This double enrollment and the results of a female student suggest that girls engage more with the creative side of engineering. While this example demonstrates how to increase girls' interest in engineering, it also shows that the engineers rely on a wide range of skill sets to thrive. Also, not every engineer needs to be a carbon copy of the next.

The results of the Engineering Design Unit will help me convince my colleagues and administrators of a way forward for our curriculum to combat the lopsided gender ratio of enrollment. As mentioned in the Organization System sub-section above, nine technology education courses have 0%-20% female enrollment. Unfortunately, a reluctance to change has led to the department carrying the "boys only" and "shop class" labels given to these classes anecdotally by students. Rewriting the curriculums of these classes to include application, collaboration, and empathy-building experiences could help change these labels and build a more inviting classroom.

Future iterations of the Engineering Design Unit would benefit from more scenarios other than the Water Filter Project. Other challenges from different sectors of our economy could also fit in the Engineering Design Unit model. I developed the Water Filter Project challenge after watching the videos used in the Empathy step (Engineering Design Unit Step 1) and reading the articles from the Define and Understand step (Engineering Design Unit Step 2). So I devised the engineering challenge after building empathy for the lack of access to clean water myself. Any teacher can develop an engineering challenge if they are passionate about the topic.

In that case, other challenges from different sectors of our economy could also fit in the Engineering Design Unit model. For example, a challenge to combat the housing crisis could have students design cheaper and more efficient buildings using different manufacturing or construction techniques. Another example with a computer science focus could have students design better and more cost-efficient educational learning management systems. In addition, previous research and my findings demonstrate that girls respond well to a blended approach of application, collaboration, and empathy-building in engineering challenges. So more options from different sectors of our economy could engage more girls in the different engineering specialties.

5.0 Section V: Reflections

5.1 Reflections

Popular culture would like us all to think that there is one moment in our lives that sends us down a path to economic success and academic excellence or, conversely, academic ruin and economic failure. However, the truth is more complicated and tangled in a web of biological, personal, and social incidences that we all pass through on a path through life. We are all made up of experiences from our families, peers, interests, goals, personal tragedies, and personal triumphs. It is naive for me to think that anyone would base their post-secondary schooling and their entire professional life on something they did in my classroom. Although Perry, Zambo, and Crow (2020) disagree by saying, "EdD programs should prepare their students to change the world through the transformation of practice" (p.132). However, all I can hope for is that I provide an experience for a student that makes them question their decisions while walking down that path.

My effort to improve my classroom, department, teaching practice, and provide a more inclusive technology education classroom has taught me an essential lesson about improvement science. Improvement on the level of changing a high school department's curriculum and focus, as I am trying to do, cannot be done by yourself, and it does not happen overnight. This is especially true when the outcome could bring pressure from the top to change, but other shareholders may be reluctant to change.

The research by Marcu et al. (2010) and Knezek and Christensen (2019) suggests that an open-ended, real-world integration approach to teaching and learning contrasts how math and science are currently taught in school. However, the same could be said for all school subjects.

The current schooling model of the teacher is the giver of knowledge while the student takes on the role of an empty vessel waiting to be filled with knowledge may not be beneficial to students, not all of our modern society. While I cannot solve the faults in the larger vision of schooling in America, I can provide engaging, inclusive, collaborative, and empathy-based lessons for my students to help them understand the future a little better.

Appendix A

Step 1-Empathy Building Lesson Plan
Engineering Design Unit

Objective: Understand who is affected by dirty water around the world due to natural disasters and other issues

1. Teacher Lead Instruction & Discussion
    - Dirty Water: Danger from the Tap-CNN Digital Documentary
        - (https://www.youtube.com/watch?v=1SrzQWvSEuw)
    - Securing Water in Your Home After Disaster
        - (https://www.youtube.com/watch?v=G8GFPnYtri4)
    - Millions Still Without Water After Texas Weather Disaster - NBC Nightly News
        - (https://www.youtube.com/watch?v=otQDnzKqcr8)
    - When is water safe to drink?
        - (https://www.youtube.com/watch?v=G244Q4AGJ7U)
2. Student Lead - Read and Discuss
    - Here's How Dirty Flood Water Really Is
        - (https://time.com/4919355/can-flood-water-make-you-sick/)
    - Guardian Water Article
        - (https://www.theguardian.com/business/2006/nov/10/water.environment?scrlybrkr=c28ef80d)
3. Activity
    - Class Discussion
        - What did you notice in the videos?
        - Who is affected by these problems?
4. Assignment
    - Daily Water Use Chart

Appendix B

Step 2-Define and Understand Lesson Plan
Engineering Design Unit

Objective: Define and understand the issues that lead to people being without access to clean drinking water

1. Teacher Lead Instruction
    a. Read this article as a class
        i. https://time.com/4919355/can-flood-water-make-you-sick/
    b. Class Discussion
        i. What makes water in a flood so bad for you while at the same time people need clean water to drink?
2. Student Lead – Use these resources to complete the Clean Water in a Disaster Research Assignment
    a. Guidance and Regulations
        i. https://www.cdc.gov/disasters/foodwater/safe-water.html
        ii. https://texashelp.tamu.edu/browse/disaster-recovery-information/disinfecting-water-after-a-disaster/
        iii. https://www.who.int/news-room/fact-sheets/detail/drinking-water
        iv. https://www.epa.gov/dwreginfo/drinking-water-regulations
    b. Disasters
        i. https://www.pbs.org/newshour/health/water-quality-in-puerto-rico-remains-unclear-months-after-hurricane-maria
        ii. https://www.nbcnews.com/storyline/puerto-rico-crisis/half-hurricane-ravaged-puerto-rico-faces-lack-fresh-water-n805346
        iii. https://www.aquasana.com/info/natural-disasters-affect-drinking-water-pd.html
        iv. https://htt.io/how-natural-disasters-affect-our-water-supply/
3. Activity
    a. Problem-Tree Analysis
4. Assignment
    a. Clean Water in a Disaster Research

Appendix C

Step 3-Ideate Lesson Plan
Engineering Design Unit

Objective: Develop ideas to solve the problem of no having access to clean water after a natural disaster

1. Teacher Lead Instruction
    a. Water Filter Project – Introduce the Water Filter Project using the Water Filter Project Overview Sheet
        i. Scenario
        ii. Problem
        iii. Challenge
        iv. Design Constraints
        v. Evaluation Criteria
    b. Premixed Trial Water Ingredients
        i. Discuss the water to be used in the Water Filter Project and show the water ingredients
    c. Videos – Show videos of different water filter solutions
        i. https://www.youtube.com/watch?v=fG13cf379Gw
        ii. https://www.youtube.com/watch?v=6qZWMNW7GmE
        iii. https://www.youtube.com/watch?v=MnTgx11eQ74
2. Activity- Demonstrate how to do an Affinity Cluster
    a. Affinity Cluster Activity
        i. Directions: Answer the questions below in an Affinity Cluster
            1. What are some ways to overcome the problem discussed in the Water Filter Project?
            2. What kind of household items can you use to overcome this problem?
3. Assignment
    a. Design Sketch
        i. Directions: Develop a rough sketch of what your water filter could look like based on the materials you have at home. Label each material on your drawing.
    b. Material List
        i. Directions: Make note of who is bringing in what materials

Appendix D

Step 4-Prototype Lesson Plan
Engineering Design Unit

Objective: Use the materials that your team has collected to build a prototype based on your design from the Ideation step

1. Teacher Lead Instruction
    a. Review the Water Filter Project using the Water Filter Project Overview Sheet
        i. Scenario
        ii. Problem
        iii. Challenge
        iv. Design Constraints
        v. Evaluation Criteria
    b. Premixed Trial Water Ingredients
        i. Discuss the water to be used in the Water Filter Project and show the water ingredients
2. Activity
    a. Prototype Build
        i. Directions: Using the materials the team has collected from home, build water filter prototype based on the challenge, design constraints, and evaluation criteria for the Water Filter Project. Use the Water Filter Project Overview and the Water Filter Project Rubric to review project requirements.
3. Assignment
    a. Water Filter Prototype Documentation Assignment
        i. Directions: Take a picture of your water filter then create a list of all materials used and who supplied them.

Appendix E

Step 5-Test and Improve Lesson Plan
Engineering Design Unit

Objective: Test water filter design based on the constraints and criteria of the project

1. Teacher Lead Instruction
    a. Explain the Water Filter Design Test Activity
    b. Explain how to use the Water Filter Testing Data Record
    c. Demonstrate and discuss the Evaluation Criteria of the Water Filter Project
    d. Discuss and demonstrate the use and safety of the classroom, testing areas, testing devices, and tools.
    e. Clarity Test
        i. Demonstrate how the Clarity Test will be performed in each trial
2. Activity
    a. Water Filter Design Test
        i. Students complete the 4 trials of their water filter based on the Water Filter Project Overview and Water Filter Project Rubric
        ii. Students may improve their water filter design based on the performance in each trial
3. Assignment
    a. Water Filter Testing Data Record Assignment Sheet

Appendix F

Step 6 - Presentation Lesson Plan
Engineering Design Unit

Objective: Develop a presentation the explains how to assemble and use your water filter design

1. Teacher Lead Instruction
    a. Overview of the Water Filter Presentation
    b. Scenario - Develop a pitch for your water filter design to present to potential
    c. Your presentation must answer these questions:
        i. Explanation
            1. What are the required materials to assemble your water filter design?
            2. What are the steps for assembling your water filter using these required materials?
            3. What are the steps for using the water filter design, be specific?
        ii. Promotion
            1. Explain 3 benefits of your design (or 3 ways your design is better) over other designs, be specific?
        iii. Reflection
            1. What are 3 problems your team ran into with your design and how did you solve each one?
2. Activity
    a. Develop a pitch for your water filter design to present to potential customers and investors.
    b. Find all requirements on the Water Filter Presentation Requirements sheet
    c. Evaluation criteria is found on the Water Filter Presentation Rubric sheet
3. Assignment
    a. Present you water filter design pitch presentation to the class
    b. Find all requirements on the Water Filter Presentation Requirements sheet
    c. Evaluation criteria is found on the Water Filter Presentation Rubric sheet

Appendix G

Personal Water Use Chart Assignment
Engineering Design Unit

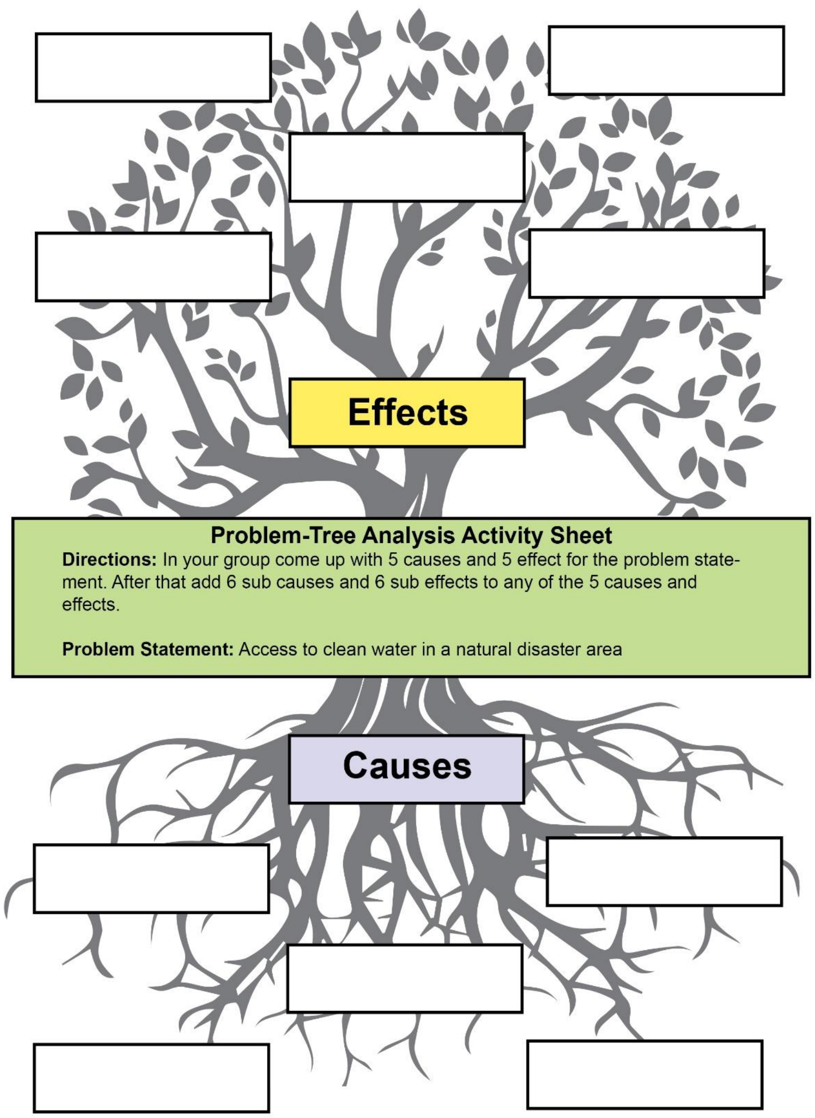
Name: ____ Dates: ___________ to __________

Directions: Keep track of how many times you complete the activities listed below throughout the day. Add at least 3, or more, other activities you do that uses water

Activity	Day 1	Day 2	Day 3	Total number
Washing face or hands				
Taking a shower/bath				
Brushing teeth				
Flushing the toilet				
Drinking water				
Cooking a meal				
Washing dishes				
Washing a load of laundry				

Appendix H

Problem-Tree Analysis Activity Sheet
Engineering Design Unit



Appendix I

Clean Water in a Disaster Research Assignment
Engineering Design Unit

Directions: In your team, answer each questions using the resource link.

Team Members:

Half of Hurricane-Ravaged Puerto Rico Faces Lack of Drinking Water https://www.nbcnews.com/storyline/puerto-rico-crisis/half-hurricane-ravaged-puerto-rico-faces-lack-fresh-water-n805346
Even if residents have running water why should they not drink it? Why is this an issue even with running water?
What is compounding the issue of access to cleaning drinking water? Why is this an issue for those who do not have access to clean water?

Water quality in Puerto Rico remains unclear months after Hurricane Maria https://www.pbs.org/newshour/health/water-quality-in-puerto-rico-remains-unclear-months-after-hurricane-maria
Why were residents being diagnosed with leptospirosis after the storm? What are the symptoms and how can it be contracted?
What are the issues affecting residents and their ability to get clean water? Who is responsible and what have they done?

Use Safe Water After a Natural Disaster or Emergency https://www.cdc.gov/disasters/foodwater/safe-water.html
Based on the information found on this web page, what are some potential water sources around your home that can be used in an emergency when clean water is needed? Why are these sources better than other sources?
Based on your personal homes, what ways can you save water when a potential natural disaster is imminent?

Natural Disasters Affect Drinking Water https://www.aquasana.com/info/natural-disasters-affect-drinking-water-pd.html
Why is loss of electricity bad for water quality? How can your family protect themselves as it relates to clean water in an disaster where the town or region is without power for a long period of time?

Facts Sheet: Drinking-water https://www.who.int/news-room/fact-sheets/detail/drinking-water
What diseases does the WHO say are transmitted by contaminated water and poor sanitation?
Pick two of the diseases above and research their symptoms and other facts about these diseases. What are the symptoms? Who is affected most by these diseases and in what regions of the world? What are the causes of these diseases in those specific regions?

Explain why easy access to clean water can improve economic and social situations.

Appendix J

Water Filter Project Overview
Engineering Design Unit

- **Scenario**
  - a major natural disaster has hit your town and region knocking out the access to major infrastructure. These services include cell service, power, water, and the ability to travel on most roads. Your house has been badly damaged in the disaster and you do not have much in the way of supplies. Stores are not open because there is no one who is able or willing to come into work, plus there is no power to process payments. You and your family have no idea when help will arrive but you need to plan for a lengthy delay in rescue services.
- **Problem**
  - Access to clean water after a disaster
- **Challenge**
  - While you have chlorine tablets that will clean water of disease-causing microbes and bacteria, you still need a way of filtering other stuff out of the water. Design a reusable water filter with things you find at home that can quickly and efficiently filter water that you will find in your environment. The materials you include in your design should be those that most people would have around their house. Plans for your design could be included in disaster kits, along with a chlorine tablet, so that people can create this simple filter if they are in this situation.
- **Design Constraints**
  - 1.5 liters of water must be processed in each trial
  - 4 trials over 2 days
  - You may modify your filter in between trials
  - You may not use more than 1 of any material except for granular materials (limit 1/2 cup total)
  - No complete filter systems such as a pool filter or completed device like a grill
  - No fire
- **Evaluation Criteria (for full explanation of each criteria see the Water Filter Project Rubric)**
  - Design Criteria
    - Materials
    - User Experience
    - Retrieval Design
    - Overall Design
  - Operation Criteria
    - Trials
    - Structure
    - Trial Data

        - Clean Up
    - Performance Criteria
        - Water Clarity Test
        - Time
        - Water Loss

Appendix K

Water Filter Project Rubric
Engineering Design Unit

	Advanced (5 pts.)	Proficient (4-2 pts.)	Below Average (1 pts.)	Incomplete (0 pts.)
		Design		
Materials	The filter is constructed with no more than 1of any eligible materials or no more than ½ cup of granular materials	The filter is constructed with no more than 1 of any eligible materials or no more than ½ cup of granular materials eligible materials but 1 or more materials may not work for the intended purpose	The filter is constructed with only a few materials and it is clear that no effort was made as it relates to material selection or collecting materials from home by all team members	No materials were collected, brought in from home, or the device was never built
User Experience	The design considers user experience as it relates to efficiency and safety of the device including how users will pour water into the filter and retrieve the filtered water	The design considers user experience as it relates to efficiency and safety of the device but the design did not work as intended during the testing phase as it relates to how users will pour water into the filter and retrieve the filtered water	User experience was not a focus of this design as it relates to efficiency and safety of the device including how users will pour water into the filter and retrieve the filtered water	The device has no user experience due to a major design flaw or the device was never built
Retrieval Design	The design takes water retrieval into consideration so that the filtered water is able to be easily retrieved for evaluation after each trial with no need to disassemble the filter without recontamination of the water	Only 1 part of the complete filter had to be removed to easily retrieve the water without recontamination	Team had to disassemble or remove more than 1 part of the filter to retrieve the water and/or the water was contaminated when the team tried to retrieve the water	The team was unable to retrieve any filtered water from their device or did not test/build their device
Overall Design	The filter design has a multilayered approach that demonstrates the teams understanding of the constraints and criteria including	The filter design demonstrates the teams understanding of the constraints and criteria but is inconsistent in	The filter operates at a base level but the design does not demonstrate the teams understanding of the	The design does not consider any of the project constraints or criteria, does not function at all, or was not submitted

	water retrieval, structural requirements, material requirements, testing requirements	operation and/or may have a design flaw that affects water retrieval, structural requirements, material requirements, testing requirements	constraints and criteria in multiple ways	
Operation				
Trials	Team completed all 4 trials within the allotted project timeframe	Team did not complete all 4 trials within the allotted project timeframe		
Structure	Device is able to stand and operate safely under its own weight throughout all trials without any need to be repaired from the first trial to the last trial	Device is able to stand and operate safely under its own weight throughout all trials with minimal repairs (fix tape, adjust materials, reattach a string/rubber band) in between trials	Device was is not able to stand or operate safely under its own weight throughout all trials but was able to complete at least 1 trial or requires major repairs (complete rebuild of filter or structure) in between trials	Device was able to stand or operate safely to complete at least 1 trial or was not built
Trial Data	The team records all data for each trial of the testing of their device including: Time Water Loss Clarity	The team records nearly (missing 1 data point) all data for each trial of the testing of their device including: Time Water Loss Clarity	The team is missing more than 1 data point from the testing of their device	The team did not record any data from the testing phase of their device or they did not test their device
Clean Up	The Team cleans up their work area at the end of each class period without being asked and they clean up the water trial area after each trial run	The team had at least 1 but no more than 2 instances where they did not clean up their work area and/or the water trial area	The team had multiple (more than 2) instances of not cleaning up their work area at the end of class or the trial area after their trial run	The team did not build their water filter and/or did not run a trial in the water trial area
Performance				
Time	Time for water to filter completely is within 1 minute or less of each other in each trial	Time for water to filter completely is within 2 minutes or less of each other in each trial	Time for water to filter completely is within 3-5 minutes of other in each trial	Time for water to filter completely is over 20 seconds of each other in each trial or did not complete the time test
Water Loss	The amount of water loss during each trial is only plus or minus 100mL of the of the amount filtered on the first trial	The amount of water loss during each trial is between 101mL and 500mL of the amount filtered on the first trial	The amount of water loss during each trial is more than 500 mL of the of the amount filtered on the first trial	Team did not test their device

Clarity Test Clarity Scale: Solid>Scatter>No Clarity	The clarity of the laser does not change throughout all trials or improves through the clarity scale	The clarity of the laser drops no more than one level on the clarity scale from the first trial to the last	The clarity of the laser drops two levels from the first trial to the last	Team did not complete the clarity test
			Total Points	

Appendix L

Water Filter Testing Data Record
Engineering Design Unit

Team Members: ____

Directions: Record all data during the testing of your water filter design in the "Trial Data" table and complete the "Change Log" after each trial.

Trial Data

Trial 1	Trial 2	Trial 3	Trial 4
Time: Record the amount of time it takes for your device to filter the 1.5L of contaminated water			
Water Loss: Record the amount of water filtered during each trial			
Clarity Test: Clarity Scale: Solid > Scatter > No Clarity			

Device Change Log

Trial 1: Attach a picture of the device

Trial 2: What changes were made after the previous trial and before the start of this trial? Why? Attach a photograph of the device prior to the start of this trial to show any changes.
Trial 3: What changes were made after the previous trial and before the start of this trial? Why? Attach a photograph of the device prior to the start of this trial to show any changes
Trial 4: What changes were made after the previous trial and before the start of this trial? Why? Attach a photograph of the device prior to the start of this trial to show any changes

Appendix M

Water Filter Presentation Requirements
Engineering Design Unit

1. Scenario - Develop a pitch for your water filter design to present to potential customers and investors.
2. Assignment - Create a presentation based on your water filter project following the requirements below:
    a. Your presentation must answer these questions:
        i. Explanation
            1. What are the required materials to assemble your water filter design?
            2. What are the steps for assembling your water filter using these required materials?
            3. What are the steps for using the water filter design, be specific?
        ii. Promotion
            1. Explain 3 benefits of your design (or 3 ways your design is better) over other designs, be specific?
        iii. Reflection
            1. What are 3 problems your team ran into with your design and how did you solve each one?
    b. Other Requirements:
        i. No complete sentences
        ii. Every slide must have a relevant image
        iii. Title slide
            1. must have the name of each team member
            2. must have the name of your water filter

Appendix N

Water Filter Presentation Rubric
Engineering Design Unit

	Advanced (5 pts.)	Proficient (4-2 pts.)	Below Average (1 pts.)	Incomplete (0 pts.)
Design	Presentation file has a constant cohesive design with a relevant image on each slide, no complete sentences, title slide, team member names on title slide, and name of the water filter on the title slide.	Presentation file has a constant cohesive design but missing1-2 of the following: a relevant image on each slide, no complete sentences, title slide, team member names on title slide, and name of the water filter on the title slide.	Presentation file does not have a constant cohesive design and is missing 2 or more of the following: a relevant image on each slide, no complete sentences, title slide, team member names on title slide, and name of the water filter on the title slide.	Presentation file was not submitted
Materials	List of required materials to build the water filter is clearly presented and explained using images	List of required materials to build the water filter is presented but not explained or presented well	List of required materials to build the water was not presented in the presentation but mentioned	Presentation file was not submitted
Benefits	The team was specific when explaining 3 benefits of their water filter over other designs	The team explained at least 3 benefits of their water filter over other designs but could have been clearer on specifics	The team vaguely explained 1-2 benefits of their water filter design over others	Presentation file was not submitted
Problems	The team clearly explained 3 problems they experienced when design and testing their water filter using images and how they solved these problems	The team mentions 3 problems they experience when designing and testing their water filter but could have been more specific, did not show any evidence, or did not explain how they solved these problems	The team did not discuss any problems, show evidence of, or/and did not explain how they solved any problems.	Presentation file was not submitted

Assembly Explanation	Assembly instructions were clearly presented with images and descriptive information	Assembly instructions were presented but needed more information, more images, or more description	The team did not explain assembly instructions, did not use any images, and/or did not describe how to assemble their device	Presentation file was not submitted
Usage Explanation	The steps for using the water filter were clearly presented using images and descriptive information	Usage explanation was presented but needed more information, more images, or more discerption	The team did not explain usage of their device, did not use any images, and/or did not describe in a step-by-step fashion	Presentation file was not submitted
Total				

Appendix O

Open-Ended Essay

1	To which gender identity do you most identify?
2	Reflect on the Engineering Design Unit, name and explain three specific things you did throughout the project that would make you want to or not want to follow a career in engineering.

Appendix P

Teacher Daily Reflective Journal

Modified from Charlotte Danielson et al's (2009) Action Planning and Reflection teacher tool (p.392) and Lesson Reflection Questionnaire (p.383)

1	Date
2	What step of the Engineering Design Unit plan are students working on today?
	Prior
3	What are your expectations of the students for this day of the unit?
4	How do you think students will react or engage with the tasks for today?
5	Did or Do I need to modify today's task based on yesterday's student interactions?
	During
6	What are the observed student reactions to the day's tasks?
7	What are some specific examples of the student's engagement for today?
8	What do you notice about how the students are interacting with each other?
9	Did any teams need redirection or direct help with the assigned task?
	After
10	What did I notice in the classroom today?
11	What were the similarities and difference to what you expect and what you observed?
12	Where there any outcomes from today that I didn't expect?

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