Empathy, Engineering and Girls (Fundamental)

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Women's participation in engineering remains consistently underrepresented. Mechanical engineering, the discipline with the highest percentage of engineering graduates, has approximately 25,000 graduates per year, with only 10.9% women in the discipline; civil engineering and electrical engineering, which tally the second and third highest numbers of engineering bachelors degrees, with approximately 12,500 graduates per year each, has 14.8% and 9.4% of all employment apportioned to women [1] [2]. The need for establishing a critical mass of women and the need to evolve engineering cultural norms are consistently reported as an antidote to the low participation of women in the engineering workforce [3] [4]. This study investigates a potential mechanism for shifting engineering cultural norms with the integration of empathy in engineering; this may also be a springboard for cultural change and the development of a critical mass of women in an engineering. This study employs a well-established informal engineering education program which has educated over 4000 young women over a continuous 20-year period. Program curriculum developers focus on methods which guide students to learn more about engineering, to creatively solve engineering design problems, to connect their personal interests to engineering and to guide learners to envision the potential that these skills have in their future careers. This study spotlights how the engineering experience is markedly different for these young women when empathy is the unifying cornerstone from which engineering design experiences flow.

Recent research findings on empathy and engineering points to the necessity of pairing empathy with engineering, including empathy needed for emotional intelligence in engineering design, the necessity of empathy for product design and the need for empathy as an essential skill in engineering project management. Additionally, the use of empathy in the school years is well established for success in multiple modes, including in an inclusive learning culture and as a basis for teamwork. Yet under explored is how different populations of students may more fully embrace engineering design as a problem-solving strategy and engineering as a potential career path when empathy and engineering are paired.

The research questions this study addresses are twofold: How might building an empathy-engineering connection influence student motivation? And how may an empathy-engineering connection impact career ambition? The research methodology is mixed methods and employs triangulation of data collection with pre and post survey data, observations and interviews. Data from this study points to the strong disposition towards empathy that participants hold. And qualitative thematic analysis is consistent across observations and interviews. Explored within the study is the degree to which empathy influenced learners' motivation in employing engineering design, learning more about engineering and potentially pursuing engineering. Additionally, innovations developed in this low-stakes environment may lead to teaching tools which may transfer into traditional classroom settings.

Why Empathy, Engineering and Girls?

The summer program in which this research takes place has been serving 6th and 8th grade girls for 20 years with the intent of providing girls unique inspiring engineering experiences. The

longevity of the program has allowed for the emergence of best practices, innovative engagement mechanisms, as well as, evidence of areas which could be enriched. The specific area of improvement which is of interest in this research is participant non-empathetic connections and participant behavior which negatively impacting the engineering experience. Just as importantly, in prior programs there were instances where participants failed to connect their preexisting interests, specifically interests with inherent empathetic underpinnings, with the problem-solving potential of engineering. The program developers sought to strengthen students understanding of and experience of empathy in engineering as an interconnected theme throughout the program based on previous research.

The pivot towards developing students understanding of empathy-engineering connections is bolstered by bn emerging body of evidence pointing to the benefits of linking empathy in engineering at multiple levels including engineering at the professional level, college level and K-12 level. Empathy in engineering involves the engineer's acknowledgement of the stakeholders for who they are designing and the coupling of appropriate communication skills. Engineering increasingly emphasizes the engineer's role in a project. Yet, traditional engineering education has been slow to acknowledge the importance of these connections. In a study completed at Purdue University, research participants indicated that empathy was important in their everyday lives but did not believe it was applicable to engineering and the work they were completing [5]. When an engineer recognizes the importance of their role in the project connected to another individual, it allows for the solution to viewed as something realistic, usable, and practical, resulting in greater overall success [6]. As an engineer, it is important to learn about those the project will impact to ensure that the product will meet their needs. By asking students to consider the needs of others and providing realistic environments to practice empathy in engineering design challenges, researchers hoped to achieve two outcomes: first, increased retention and initial registration in STEM-based classes after participating in the program, and second, greater overall success in designing and creating solutions.

The empathy connections made in the program drew heavily from education research, including Noddings' ethics of care and Dweck's growth mindset. These constructs emphasize the connection between the teacher and student, as well a connection between students and their peers [7] [8]. Yet these intentional connections, which are often emphasized in other parts of a student's day in K-12 education, may be lacking in many STEM-based programs and lessons. The importance of integrating empathy into engineering design challenges and lessons for middle school students is especially crucial, as problem-solving skills and abstract thinking begins to develop during the Formal Operational Stage of Development [9]. The integration of empathy into engineering design lessons, a predominant aspect of current curriculum, allows for a greater sense of belonging, and therefore, motivation to pursue the subject [10] [11].

Infusing empathy and engineering allows learners to experience engineering as a powerful change agent in society rather than an abstract concept they learn in school. Infusing empathy into engineering lessons can give students an increased understanding of why engineering is important, when compared to lessons without the presence of empathy. Furthermore, teaching tolerance focuses on the impact of social justice and bias, and how to help people understand how to show respect and be aware of the needs of others. The online Teaching Tolerance

resources offer curriculum that develops and deepens students understanding of and practice of empathy for others [12].

Why Engineering, Empathy and Girls in this program?

The program goal throughout the twenty-year existence has been to inspire 6th and 8th grade girls who are making critical middle school and high school curriculum choices to choose rigorous mathematics and science courses with an eye towards a STEM related career. As a means of ensuring best program practices, research is consistently conducted on the program. Previous research has yielded innovative curriculum developments, demographic/gender informed engineering self-efficacy knowledge and findings on the inclusion of cross-cutting concepts in out-of-school activities.

Yet previous observations, surveys and interviews has also led to a pivot in considering the contextual thread that weaves the program's activities together. Observations, interviews and surveys pointed to a lack of participants understanding other points of view and a lack of connectedness with other participants. In prior years, this lack of connection led to students struggling with at least two components of the engineering design process: 1. students were reluctant to collaborate with their peers, as they were often "stuck" on using their own ideas and 2. students had difficulty defining the purpose for their designs, or in other words, difficulty explaining the problem(s) they were trying to solve [13]. These findings were a springboard for considering how to effectively integrate empathy and engineering as the thread which weaves the program together. Program designers intentionally wove empathy connections with people's real-life stories into the program's engineering activities. Specifically, intentional storytelling and human connections were incorporated into the engineering design challenges with the intent of developing student empathy.

How would we know these efforts were effective? Program research focused on two questions, how might building an empathy-engineering connection influence student motivation? And how may an empathy-engineering connection impact career ambition? The effectiveness of the content, academic language and active learning was measured using three different qualitative and quantitative methods: first, daily observations by the instructional team were conducted and analyzed. Second, students were interviewed at the end of the program to gauge an understanding of their empathetic growth. And third, students participated in a pre and post survey regarding the program and engineering in their lives.

Throughout the program, students are encouraged to work in pairs or teams with other students they may not have known before attending the program to allow them to practice problem solving skills in a team environment. Teamwork emphasizes the importance of considering different perspectives that may arise when reviewing a problem, because people are likely to have different perspectives and priorities regarding what "needs" to be done to solve the presented problem effectively [14]. When put into teams, students must work together and collaborate to effectively solve a problem [15]. One of the challenges, the boat float design challenge, presents students with the task of creating a flotation device to hold a 5lb bag of flour. In this challenge, students work in teams to determine the best way to keep their passenger above the water. This simulates how engineers respond when faced with a challenge and the need to think about who they are helping. The lesson that accompanied this challenge is paired with the

story of the Titanic, and students work as a whole group to brainstorm a passenger who may have been on the boat. This is person, or stakeholder, they are designing for.

Sketch of the Summer Engineering Program

Program recruitment is intentionally focused on girls who may not have engineering experiences or engineering role models. Several mechanisms are used to reach these students including providing information to teachers and administrators who then pass along programming information on to their students. Less affluent school administrators, as identified in the Statewide Data System and the state Department of Education Report Card, were contacted directly based on lower low-incomes student participation rate in college [15] [16]. Social media including Twitter, LinkedIn and regional STEM newsletters are also used to promote the free programming.

Demographics of the applicants and participants is more diverse than the state averages. The self-identified racial breakdown of applicants is shown in Figure 1. Of the 231 applicants, 125 were invited to attend the program and racial breakdown of participant group is shown in Figure 2. Students were randomly chosen to participate with a best practice allowance for underrepresented students attending with a friend in order to create a critical mass for comfort for the students [3].

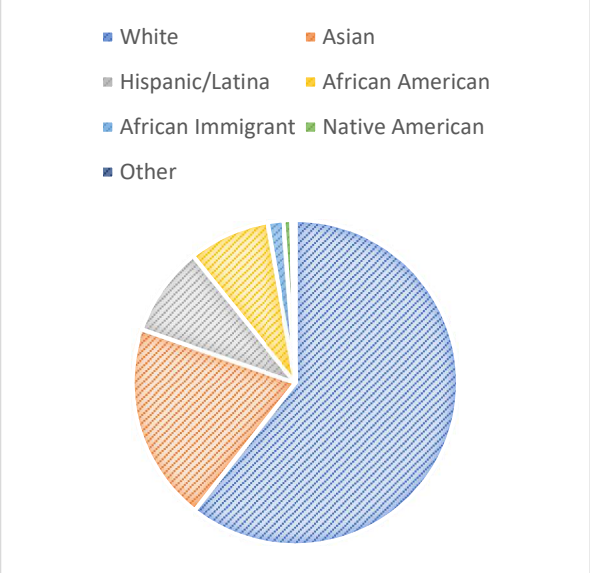

Figure 1 Applicant Demographics

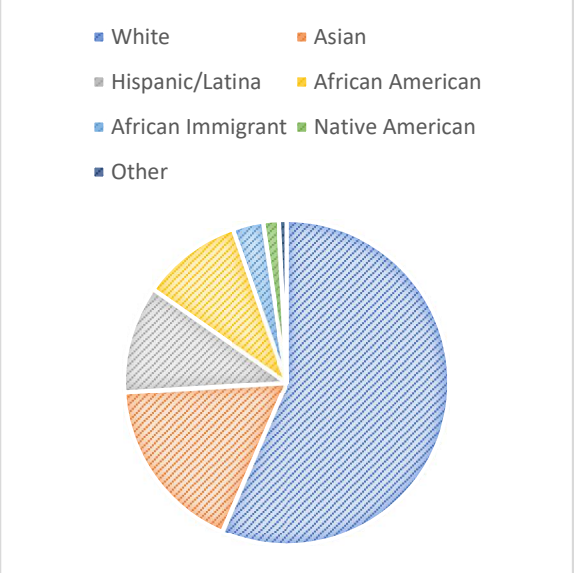

Figure 2 Participant Demographics

Engineering Design Lessons

Challenges and lessons for the engineering program evolved from previous years' lessons and are informed by the Teaching Tolerance curriculum, Association of American Colleges and University VALUE rubrics and the Stanford d-school design process [12] [18] [19]. Existing lesson plans were revised to allow for greater exploration of empathy in engineering disciplines and engineering design while maintaining the creative, innovative and cross cutting science

connections that were built into the lesson plans. The appropriateness of teamwork and collaboration is reinforced throughout the program as students are encouraged to work in groups or discuss their thought process in pairs. These pair-and-share and teamwork opportunities help students understand their own and others engineering design, prototyping, testing and improvement as they considered the people, stakeholders, who they were designing for. Overarching learning objectives are 1. students will understand engineering in terms of engineering disciplines, the engineering design process and the science and mathematics which support engineering design and 2. students will be able to make empathetic connections by understanding the persons they are designing for, their stakeholders, and understanding their peers, which includes communicating with peers, engaging peers with questions and deep listening.

Sixth-grade lesson plans include exploring electrical engineering connections with squishy circuits and art bots. Students are encouraged to make connections between different materials that they may have been exposed to in the past and understand how these elements work together to make electricity as they investigate how motors work. Squishy circuits are an electrical circuit anticipatory set. Opening questions include “where do you use electricity in your life?” and “what are some ways that your life would change without electricity?” Inquiry on the art bots allows for a deeper understanding on how electricity travels and how off-set motors function. An empathetic connection is focused on boy who had developed acute flaccid myelitis and needs assistance with coloring projects [20]. Engineering of the art bot then led to students naming and decorating their bots while keeping their stakeholder in mind. Returning the shared conversation to the boy allowed for learners to reconsider their purpose. Play included in the activity leads to students sharing joy in with one another and their engineering creations.

Both sixth and eighth grade groups experience working as civil engineers. The lesson hook is a 7-minute PBS Under Told Story Project story, How off-the-grid Navajo Residents are getting running water [21]. The video provides a compelling real-life connection to people with water challenges. The video models how engineers work with the stakeholders to solve their water problems. Student articulation of the engineering-empathy connection is rich and nuanced. Students use this shared story as the backdrop in the civil engineering lab lesson which includes engineering academic language, exploration of how hidden infrastructure intersects with their daily life, engineering materials introduction with mixing concrete, and steel gusset plate design/testing. The culminating component of this lesson is forensic engineering bridge inspection of the collapsed I-35 bridge components. The site visit bookends the engineering and empathy lesson with a discussion on the gusset plate engineering design and how families are impacted by use and failure of infrastructure.

Eighth-grade students also take a deep dive into biomedical engineering. Students are introduced to biomedical case studies and then use limited materials (straws, paper, string, and tape) to create a prototyped hand which is focused on picking up something. The lesson discussion is focused on understanding the hand functions and not the aesthetics of the hand. The students understand that their goal includes diving into rich descriptions, brainstorming, prototyping and testing.

The final program lesson for both sixth and eighth grade is an engineering design challenge, the boat-float challenge, which fosters empathy of their floating person, which is simulated with a 5-

pound bag of flour. The engineering designers are exposed to boat design basics and encouraged to think about who the boat was is made for and what purpose it was serving. Small group engineering allows for teamwork, empathy for the person they are designing for and empathy for one another as students work together to design, test and improve their boat-float.

Research Structure

The research questions this study addresses are twofold: How might building an empathy-engineering connection influence student motivation? And how may an empathy-engineering connection impact career ambition? These research questions raised related questions including are participants able to describe empathy accurately? How do students answer and interpret the question "are you empathetic?" What impact does a person's story have on the learner's attitude toward a person or group? Does a person's story motivate a learner to solve problems for the person? Can students describe the connection with empathy for someone with the need for a solution? And how might learners communicate this need with one another? Are participants able to describe how empathy and engineering are linked? What is the interplay between solving problems and vocation aspirations? Can learners describe what they must do to become an engineer and how empathy might play into their training?

In order to answer these questions, data was collected with three independent measures: surveys, observations and interviews. Pre-program and post program surveys appraised student self-reports of how the program activities impacted students' connection of engineering and empathy, as well as, their feelings towards engineering as a career. Observation data consisted of two main approaches, written staff observation on observation sheets and student notebook notes and sketches. Researchers completed time-stamped observation sheets with prompts on participants actions and language, including how participants empathized with each other, and teachers' actions and language. Observations also include student notebooks which have lesson reflection questions as prompts for connecting lessons, empathy and real-world connections. The third means of data collection is interviews with students. Participants are asked interview questions at the end of the program reflecting on the lessons and how they connected empathy and engineering. The interviews consist of questions such as: was there a time during the day when you connected with a peer or teacher and learned about how they felt about their project or the topic at the time? If so, how did this connection affect you? and think back to a time today when you were faced with a challenge. What did you do to try and tackle that challenge? These questions, and others, were meant to prompt the participants to think about ways they might have used empathy and engineering throughout the day.

Survey data, observational data and interview data were first reviewed independently as three discrete data sources. Quantitative survey data was statistically and graphically analyzed. Qualitative data reduction by thematic analysis was completed for the survey qualitative data, observational data and interview data. As themes were revealed for each data source, it was clear that these sources triangulated thematic findings. Major assessment findings are shared by survey, observation and interview categories, with appropriate supporting data from related categories. Culminating thematic findings and applications are shared at the end.

Survey Data

Data describing student motivation and an empathy-engineering connection held some interesting results including evidence that the program population is already strongly motivated by empathy. Of the 113 participants 73% strongly agree with the pre-program survey statement "I want to do something in the future to help others" 25% agree and only 2% were neutral. The theme of "helping others" appeared consistently in interviews as well. While nearly 100% of participants report a desire to "help others," less than 50% of students initially reported that they "strongly" agree that engineers solve problems. With such a strong inclination towards empathy already, what growth does this data show? After completing the program, students showed a shift in believing that "engineering is a job that lets you help others." Both pre and post surveys had no votes in disagreement with the statement, but the 11% of neutral students dropped to 5%, while the number of students who chose that they "strongly agree" with the statement rose by 20%. Additionally, engineering related content knowledge grew, as more students indicated in their post surveys that they could demonstrate to a friend how a simple circuit works and how to use the engineering design process. These self-report growths in student content-related knowledge and an understanding that engineering may be used to help others is strengthening new connections and perceptions of what an engineering career might hold.

The predisposition to helping others is supported directly in the presurvey results when students were asked if solving problems for others (versus just helping) is an important part of what they want to do with pre-survey results indicating that 80% of students reported solving problems is an important part of what they want to do, 18% reported they were not sure, and less than 2% said no. Connecting to this, many students in the interviews described engineering as related to "solving problems." It seems that participants did not come to the program with language developed around engineering-empathy connections, for when asked the open-ended question, "What kind of problems do you want to work on?" 79% listed real world problems with environmental concerns leading the way, however less than 17% of students directly mentioned ideas to "help people" or create/improve things that people use. At the time of the pre-survey, students were already thinking of career fields that benefit others with a medical-based career mentioned the most often, yet less than 18% of students listed a career in engineering. This is consistent with data regarding women in STEM careers; in 2013, women held 53% of careers in biomedical sciences, and only 13% of careers in engineering [22].

There is abundant data, including pre-program survey data, that describes the program population as already seeing themselves as empathetic. Of the students who completed the pre-survey, 96% reported they were empathetic in areas such as often thinking about others' feelings, trying to understand another point of view, and listening to others. This theme was consistent across the interviews as well. While 96% self-report empathic pre-disposition, at the time of the pre-survey, only 80% of the students believed that they were able to make a difference, despite their self-acclaimed empathetic values. This leads us to the questions of "why." If up to 96% of students believed that they embody empathy and want to make a difference, why do only 80% of students have confidence that they can? Post-survey data holds some interesting findings related to the program's effectiveness of making empathy-engineering connections and raising confidence levels in students' abilities to combine problem solving skills with empathy.

The post-survey data shows a shift in learners' attitudes towards empathy-engineering connections, engineering and career ambitions. The statement that "engineering is a job that lets you make a difference in the world" was agreed to strongly by 59% (up from 38% in pre-surveys) and the combination of agreed and strongly agreed statements rose to 94% (up from 89% to in pre-surveys). Respondents confidence increased to 96% (from 80%) in the statement "Problem solving for others is an important part of what I want to do". When reviewing these numbers in conjunction with the increase of students who agreed or strongly agreed with the statement "engineering is a job that lets you help others," it may be suggested that when empathy is infused into engineering instruction for middle school girls, their confidence in their ability to make a difference in the world increases more than it does after exposure to instruction that doesn't explicitly call out empathy. Similar responses were shared in interviews, when students indicated that they believed after completion of the program that engineers made a difference in the world and solved problems. This was also the most common theme stated consistently across interviews and open-ended survey questions regarded helping others, with 38% of participants mentioning the theme within their responses. Additionally, a reoccurring theme in both interviews and open-ended survey questions alluded to student enjoyment in working in teams and connecting with others.

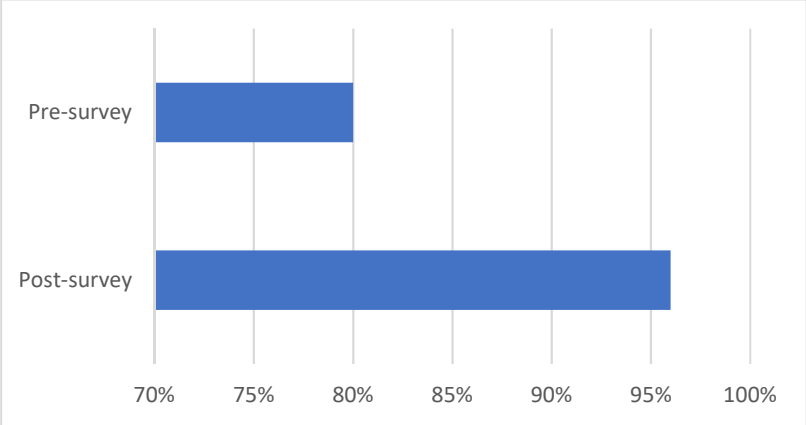

Figure 3 Pre-survey and Post survey responses to "Solving problems for others is an important part of what I want to do"

In addition to infusing empathy into engineering lessons and increasing confidence in students to make a difference in the world, researchers noticed an increase in the number of girls who were interested in pursuing a career in engineering after completing the program. When survey data for the same question regarding careers in engineering was reviewed for the post surveys, 54% (up from 18%) of participants now saw themselves pursuing an engineering career. Interview recordings and responses support this data from surveys regarding a growth in interest in pursuing a career in an engineering field. Additionally, the number of students who responded that "solving problems for others is an important part of what I want to do" also increased following the program. This leads to an interesting question, was it the students who were previously interested in pursuing a career in engineering who changed their answers to this question, perhaps in not recognizing the "helping" aspect of a career in engineering?

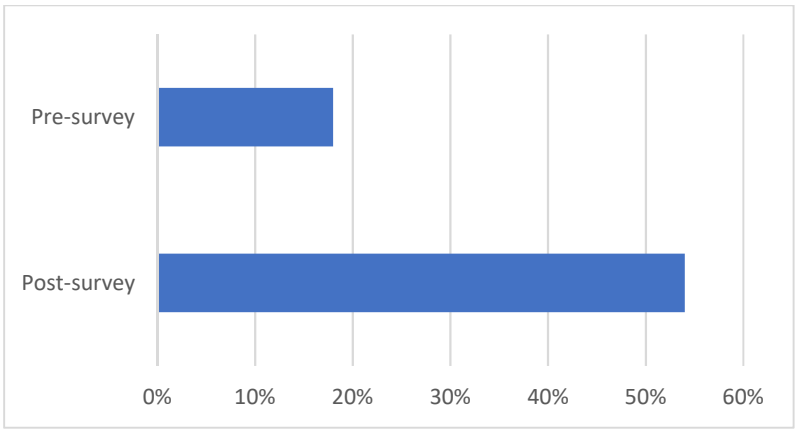

Figure 4 Pre-survey and Post survey responses to "I am interested in pursuing an engineering career"

This data seems to suggest that the engineering design challenge activities tied to empathy and story-telling increased students desire to pursue a career in engineering, while simultaneously increasing the number of students interested in "helping others." Additionally, most students who were interested in helping others prior to attending the engineering program were more likely to pursue a career in engineering. The process of teaching engineering with intentional integration of empathy allows for students to connect engineering in ways they previously have not and may encourage girls to potentially pursue careers in engineering.

Specific aspects of the lessons and engineering design components which students self-reported as the most influential in interviews and open-ended survey questions was "*helping others*" (38%). A second reoccurring theme in both interviews and open-ended survey questions was students' affinity to working in teams and connecting with others. For example, students described working together as being a key component to their enjoyment of the activities, using phrases like "*overcoming our problems together*" and "*sharing our different designs and just sharing our ideas*" when asked to explain why they liked activities. The ideas of "*solving problems together*" and "*building human connection*" were critical in advancing interests in engineering. There was a rise from 26 to 43% in pre and post survey respondents able to explain how knowing and caring for the *who* in the engineering design process is a key engineering design step. One student replied, *"I learned how engineers use empathy, I never really connected those two but I learned that engineers need to be able to empathize with the people they are working with, and working to solve the problem for."* While growth over this short program is modest, data seems to point to most of the participants being motivated by empathy for others. The implication may be that highlighting real world engineering tasks where solutions help people and facilitating positive small group engineering teams to solve related challenges in a hands-on way may engage young female learners in a new way and encourage them to see themselves as future engineers.

Observational Data

Review of observational data clearly points to teacher impact in student motivation related to an empathy-engineering connection and student motivation. Depending on the activity, teachers led

lessons by asking students questions anywhere from 33%-100% of the time when speaking. These questions are open-ended, guided inquiry. For example, some of the questions teachers ask include, "*What questions would you ask someone you are designing for?, How can we use engineering to help people who might have disabilities such as not having arms?",* and "*How can you connect this to empathy?"* These questions allowed teachers to structure student learning on intentional empathy-engineering connections.

Furthermore, teachers used guiding questions and comments to navigate participants to think creatively and utilize a variety of brainstorming methods as they worked through the engineering design process. This occurred between 0% and 57% of the observations, depending on the activity. Some of teachers' comments and questions included, *"what you think matters... your idea might be the one to solve the problem, you all have your own ideas but you can put all the ideas together to make a design that works*", and *"it's not cheating to watch other tests and see how their results can make your design more successful"* These quotes show the ways that teachers emphasized the value of each participant's ideas and how they can learn from each other, fostering a sense of community and connection as participants learned new and creative ways to think through problems.

These comments and questions effectively led participants build off the ideas of their peers and think about activities and solutions in a different way. This creative thinking was exhibited by participants between 0% and 50% of the observed categories, depending on the activity. For example, one participant stated, *"I'm going to try and modify [another student's] idea."* Another student said, *"I think we can put all our ideas into one bigger, better thing."* A third asked her teammates*, "based on the supplies given, how do we need to change our design?"* These quotes demonstrate that students implemented the engineering design process throughout the day and did so while connecting and collaborating with their peers.

When reviewing these quotes and observations surrounding empathy, helping others, and teamwork in engineering, alongside the survey data regarding the same themes, the researchers are able to make a strong connection between the importance of motivation, teamwork and the empathy-engineering connection when considering the research inquiry on how might building an empathy-engineering connection influence student motivation. Observational data also informs how an empathy-engineering connection may impact career ambitions. Teachers addressed this research question primarily through modeling empathy by telling stories about others, regarding others' feelings, and asking participants guiding questions to elicit student experiences. This was recorded on 0% to 73% of the observations, depending on the activity. Teachers used language such as, "*the person is the center [of the engineering design process]*" and *"sometimes we make a mistake and we have to be empathetic with each other and ourselves".* This led participants to think through the impact certain actions would have on others and to make connections between the activities and the real world. This theme of considering others' feelings was recorded on 0% to 45% of the observed categories, depending on the activity. For example, after watching a video about the lack of plumbing infrastructure in rural New Mexico, one participant commented, *"but it's so hot there, how do they not have water?*" During the prosthetic hand activity, another participant remarked, *"it can be hard to do things when you don't have full use of your body and we don't always think about that".* During

the boat challenge, a third stated, *"this is an engineering thing; we can figure out how to help people"*.

This indicates that participants used the principles of empathy as they talked with their peers and worked through the engineering design process. This triangulates with the evidence found in interviews, where 100% of those interviewed stated that they believed engineers can make a difference in the world or describe a way in which engineers positively affect the world.

Interviews

Participants are invited to participate in short interviews at the end of the program. These semi-structured conversations perhaps provide some of the most compelling data since participants are sharing their pre-reflective experience. Interviews allow for researchers to explore how building an empathy-engineering connection influences student motivation by collecting participants responses directly. In 25% of the interviews, participants shared that they were able to learn what others were thinking and see their point of view. For example, one student stated, *"when I got to meet new people, I got to know their perspectives about each topic or project."* Another shared a comment about the float design challenge, saying *"when their boats sank I kind of felt bad because they worked hard on their boats."* This may be evidence that students were using principles of empathy as they worked with their peers on various activities.

A theme of sharing ideas also emerged in the interview responses, with 29% of responses, indicating that participants exchanged ideas with their peers during the engineering design process. One participant commented, "*we got to hear others' ideas and then you kind of put all your ideas together to make the best product you could*." Several participants, 11%, specifically mentioned the theme of taking ideas from two or more people and merging them into one idea for a final project, but some participants took this idea a step further and made the connection to empathy. One stated, "*others had different ideas, but I still empathized with them, including theirs into the final boat that we did."* Another said*, "it made me feel like I had someone I could trust and a friend who would take my ideas into consideration and improve them."* These quotes indicate that participants incorporated principles of empathy into the engineering design process lessons and found an empathy-engineering connection.

Interview responses also illustrated that participants had the opportunity to get to know their peers and collaborated with them throughout the day, something 38% of them stated was their favorite part about the program. One participant shared that the activities of the day *"really helped us bond and really helped us get to know each other."* Another stated that "*the challenges always make you get closer with the people you work with and think about others' feelings,"* which demonstrates an affinity to empathy. These responses underscore the importance of creating space for students to make interpersonal connections and strength the argument that the empathy-engineering connection is important for building internal motivation.

Interesting data surfaced on empathy-engineering connections in relation to engineering career ambitions. Of the participants who were interviewed, 100% either stated that they believed engineers can make a difference in the world or described a way in which engineers can positively affect the world, showing that participants made a strong connection between

engineering and real-life impact. Participants stated that they believe engineers bring about this positive impact by helping people and improving the lives of others (37%), solving technical and societal problems (42%), and building, designing, or inventing things (59%). One participant shared, "*if they lost a limb for some reason, engineers are able to 3D print or program or think of some solution to fix something that will change someone's life entirely*." Another stated, "*without engineers we wouldn't have new or innovative technology. Engineers really push us forward into, like, the future*." A third commented that the job of an engineer "*is to solve other people's problems and make the world a better place for the people after them."* These statements show that participants made a strong connection between engineering and the ability to help other people.

What's more, given that 73% of participants indicated on the pre-program survey that they strongly agreed with the statement "*I want to do something in the future to help others,"* and the data gathered on student understanding of empathy-engineering connections, it seems that after the program participants have an increased awareness of how engineering can help them fulfill the desire to help others and may orient some of their career ambitions toward engineering. This data also triangulates with the evidence of participants considering others' feelings found in the observations (recorded on 0% to 73% of the observations, depending on the activity).

What have we learned?

The quest to understand issues around women's low participation rate in engineering is complex and involves innumerable variables. This study grows out of twenty years of work in just one sliver of these complex variables. Yet there is evidence that developing and strengthening 6th and 8th grade girls understanding of empathy-engineering connections strengthens participants motivation around using engineering and may orient students future engineering career interests. This program provided participants opportunities to connect and share ideas with one another and then use those shared ideas to think about topics and activities in new ways. In multiple learning activities, participants reinforced connections between the work that engineers do and the positive impact this work has on the world, evidence of building empathy towards others. Evidence gathered points to participants increased motivation to use engineering after making empathy-engineering connections through the program, and possibly leading to increased interest in an engineering career.

When summarizing the data collected from three research data collection methods, there are specific themes that reoccur and connect. Specifically, students came to the program with an orientation to empathy, the empathy-engineering connection seems to increase student motivation, and an understanding of the empathy-engineering connection may increase interest in an engineering career. Without the identifying the existing empathy of the students in the program, it would not have been tailored to fit the needs and demographics of the students. Throughout the program, lesson language was changed slightly as educators became more aware of this, weaving in real-world stories and asking open-ended questions. In connection to this, students developed a strong sense of self and confidence in engineering through working in teams, likely rooted in their existing empathy, as most students didn't know one another prior to the morning of the program.

Another common theme identified in the research data is the connection of empathy and engineering. When empathy is integrated into hands-on STEM/engineering challenges, students are more engaged, and confidence levels in one's ability to make a difference through engineering increases. In addition to learning what their peers were thinking and feeling, the participants' interview responses also showed a theme of considering the perspectives of those whom engineering has the potential to benefit. One participant commented that she learned "*a lot about how some parts of not only the world but the USA is going through a lot of drought*." Another stated, "*part of understanding how people think is understanding obstacles that people with disabilities go through."* This shows that the obstacles faced by people the participants had never met were real to them and worthy of comment and consideration. The ability to connect engineering to the people it benefits shows that participants made the connection between engineering and empathy.

Finally, the increase in motivation to complete engineering design challenges due to the integration of empathy into lessons seems to lead to an increase in the number of middle school girls interested in possibly pursuing engineering careers. Therefore, integrating empathy through language, storytelling, and intentional integrated challenges involving teamwork may result in greater motivation to complete engineering challenges, work with others, and possibly pursue careers in engineering.

Implications of this small study data leads into the question of how might these preliminary findings inform engineering education? What are the most effective methods for integrating empathy into STEM education in an out-of-school program and/or classroom setting? One of the themes that the girls spoke most highly of throughout the program was getting to know their peers and collaborating with them on group projects. Giving students opportunities to work with partners or teams is a simple teaching method that STEM educators can employ to increase the motivation of girls in their classes. This may potentially lead to increased enjoyment and satisfaction for girls, counteracting the leaky pipeline of women in STEM. Working in pairs or teams is also an effective way that educators can implement Gardner's Theory of Multiple Intelligences into their lessons, since groupwork taps into the natural abilities of students with strong interpersonal and/or linguistic-verbal intelligences.

Another theme that emerged throughout our research was the importance of emphasizing the real-world connections between engineering and the people it helps. Given that the majority of the girls stated in surveys that they want to help others, intentionally drawing attention to instances where engineering helps other people is one way that STEM educators can remind girls that engineering and altruism are not mutually exclusive. This may lead girls to have increased understanding of the empathy-engineering connections and increase motivation to pursue a career in this field.

The final theme prevalent in our research pertains to teacher language. The methods of facilitating groupwork and highlighting real-world connections were enhanced by teachers' use of guiding questions. Whenever possible, the teachers used questions to guide the girls to draw their own conclusions or find answers for themselves instead of simply informing the girls of the conclusions they should reach. For example, when highlighting real-world connections, teachers

created space for students to consider how engineering could be used to solve problems and/or help others instead of providing that information outright. This allowed the girls to make connections that were more personal and fit into the context of their lives. This is a strategy that not only STEM educators, but educators in a variety of disciplines, can use to help students identify why something is personally relevant to them, allowing them to better solidify new information in their minds.

This program enters the 21st year of operation this year. Program directors, teachers and researchers will continue the work of understanding both what benefits the population which participates in this program and the potential to integrate this populations contribution in engineering problem solving by continuing the work of understanding the role of empathy-engineering connections.

As a last word, this program, STEPS is a free-for-participant program which allows the full range of diverse learners to participant in this unique program. We would like to thank our sponsors including Pentair, Ecolab Foundation, Xcel Energy Foundation, Opus Foundation, 3M Foundation and personal donations of individual contributors. Thank you for your support!

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