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Professional Development Program for High School Counselors on the Engineering Design Process (Evaluation)

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Shifting High School Counselor Perceptions of Engineering through Hands-On Professional Development (Evaluation)

Abstract: High school counselors play a pivotal role in students' educational pathways to STEM careers. Guidance provided by these school officials can be critical in student selection of elective courses, achievement, and fostering an environment through outreach activities. Each of these factors can influence students' career interests, college choice, and major selection, which can have a major impact on diversifying who pursues degrees in engineering. This research study details the development of a professional development (PD) program for high school guidance counselors to better understand how such an experience can impact counselor perception of engineering. Counselors participated in a series of engineering design activities to learn more about the engineering process, engineering stereotypes, stereotype threats, implicit biases, and different disciplines within engineering to better inform their students of future career options. Details are provided around the design of the engineering counselor PD as well as insights into how the PD impacted counselor perceptions of engineering. The study has implications toward broadening participation in engineering through school counselor professional development.

Background

The engineering education system across the world still struggles to be more inclusive despite numerous calls to increase representation of women and minorities. In 2016, women accounted for only 21% of students pursuing a bachelor's degree in engineering [1], while Hispanics accounted for approximately 10% of students studying engineering and African Americans accounted for just under 4% of all engineering undergraduate students [1]. According to Katehi, Pearson, and Feder (2009), the lack of diversity present in undergraduate engineering has its roots in the K-12 system where "access and participation will have to be expanded considerably" (p. 10) [2]. Many efforts have been undertaken to introduce engineering to pre-college students through curriculum, extracurricular programming, and university recruitment visits. Little has been done with school officials, particularly counselors, who play a key role in student selection of elective courses and student choice to pursue future educational and/or career pathways in Science, Technology, Engineering and Mathematics (STEM) [3–5]. Recognizing school counselors as an untapped resource and equipping them with the knowledge and resources they need to inform students about engineering has the potential to increase students' motivations and capacities to pursue careers in engineering, especially for historically underrepresented minorities. Such capacity building of school counselors will inherently improve the diversity of our nation's engineering workforce.

This study focused on high school guidance counselors as part of a larger ongoing project [PROJECT NAME]. The project is a new high school level engineering education initiative that aims to 'demystify' engineering for high school students, teachers, and counselors through an all-inclusive high school level engineering course. Three key components of the project include: 1) design and development of a new engineering course open to all high school students, 2) teacher and counselor PD, and 3) a learning community of teachers, counselors, engineering educators, and practicing engineers. The overarching goal of the PD and the learning community is to help teachers and counselors make positive changes in their practices to affect students' engineering pathways to higher education institutes.

The following paper details a professional development opportunity designed specifically for high school counselors. Data was collected and analyzed to demonstrate the impact of the PD on the following research question: What are counselors' perceptions of engineering before and after participating in a hands-on engineering professional development experience?

We describe our research methodology and present findings that provide details regarding shifts in counselor perceptions of engineering. We conclude with implications and future directions for this work. Particular emphasis is placed on the potential impact of this program on broadening participation in engineering.

Literature Review

Lack of Diversity in STEM

There has been a long persistent and significant educational gap for women and people of color in higher education. These disparities are further exacerbated in STEM fields. Men have historically and consistently greater levels of higher education attainment than women (Ryan & Bauman, 2016). This gap has narrowed considerably over time. As of 2015, there was no difference in attainment levels between men and women at the undergraduate level, though the level of representation varied considerably by discipline (McFarland et al., 2017). Women now account for over 30% of all STEM degrees, but the proportion of women is lowest in engineering. In 2016, women accounted for only 21% of students pursuing a bachelor's degree in engineering (NSF, 2019).

Representation of people of color is also low in engineering. Asian students account for 30% of all STEM degrees and are most likely to earn such a degree (Musu-Gillette et al., 2016). In 2016, Hispanics accounted for approximately 10% of students studying engineering (NSF, 2019). The proportion of African American students was particularly low in engineering with these students accounting for just under 4% of all engineering undergraduate students (NSF, 2019). The 2018 Status Report on *Engineering Education: A Snapshot of Diversity in Degrees Conferred in Engineering* reports that among bachelor's degrees conferred in major fields of study in 2016, engineering was the second-largest field of study for White and Asian American males. Hispanic and African American males conferred significantly less engineering degrees, ranking fourth and tenth largest, respectively for each race. Engineering was ranked significantly lower for female graduates across all races in the same report; it was the eighth largest field of study among Asian women while White, Hispanic, and African American females all saw the field of engineering ranked as the eighteenth largest.

Role of Counselors

According to Katehi, Pearson, and Feder (2009), the lack of diversity present in undergraduate engineering has its roots in the K-12 system where "access and participation will have to be expanded considerably" (p. 10). School officials can help influence student choices in future educational and career pathways, especially in the STEM pipeline (Jolly, Campbell, & Perlman, 2004). School environment and attitude towards engineering can either lead to or serve as a barrier to students pursuing engineering (Gillen, Carrico, & Matusovich, 2018). High school coursework can preclude students from pursuing an engineering degree before they even enter college, especially when engineering is perceived as steeped in math and science (Gillen et al., 2018; Nathan, Tran, Atwood, Prevost, & Phelps, 2010). School counselors play a key role in student selection of elective courses, achievement, and overall fostering of an environment through outreach activities that influence students' choices in college including major selection (Gillen, 2018; Lewis, 2013). It is important for students to begin planning and to have conversations around pursuing an engineering degree in high school with individuals who are knowledgeable about different possible careers.

School counselors can help foster an environment that supports development of high school

students as future engineers. Their role in schools tasks them with preparing students for future career choices (Lewis, 2013). Prior research has concluded that lack of time and basic knowledge about engineering is a barrier for school counselors when advising students about pursuing engineering careers (Beck, Diefes-Dux, & Reed-Rhoads, 2009; Falco, 2017; Gibbons et al., 2003). Falco (2017) advises that school counselors need to better understand STEM pathways and career development in order to better encourage students from historically underrepresented groups towards engineering. Professional development (PD) can serve as a means to educate counselors on engineering career paths, including preparation in high school, which could help foster greater participation in engineering (McCuen & Greenberg, 2009).

Program Details

The [PROGRAM NAME] PD program is situated within the context of a large, nationwide, NSF funded project. The [PROJECT] project aims to "demystify" engineering for high school students and teachers through creating an all-inclusive high school engineering curricula [6]. The larger [PROJECT] program provides: 1) ongoing professional development to high school teachers, and 2) an online learning community of teachers, school officials, engineering educators, and practicing engineers. This work explores the significant need to provide PD for counselors who play a major role in student choice to pursue future engineering education.

Recruitment

Recruitment followed a two-pronged approach using snowball sampling and local networks. Teachers who had already been selected to participate in the summer [PROJECT] PD program were asked to share contact information for the counseling staff at their school. We also invited counselors from local high schools known to the research team. A total of 76 counselors across the US were invited to participate in the summer counselor PD program via an initial interest survey. A subset of 20 counselors completed the initial interest survey and participated in the program; 15 successfully completed the program. Participants were incentivized with a $75 Amazon gift card at the end of the program.

PD Structure

The [PROGRAM NAME] counselor PD program was initially planned to be a two day in-person PD program accompanying the [PROJECT] teacher PD. Modifications were made and the program was redesigned to be fully online due to the COVID-19 pandemic. Counselors participated in a 5-week, online PD program in Summer 2020 consisting of synchronous sessions and asynchronous activities. The project used the learning management system, Canvas, as the primary hub/activity center for all PD information and activities.

The [PROGRAM NAME] counselor PD was split into three phases. Phase I sessions were designed to facilitate counselors' discovery of how engineering connects with a variety of

disciplines, while learning about inclusive practices and challenges associated with implicit biases, stereotypes, and stereotype threats.

Phase II engaged counselors in hands-on engineering design activities to help them "think like an engineer." All participants received a mail-kit with materials needed to complete this component of the PD program. The mail-kit included necessary items for completing all hands-on activities throughout the PD. Collaborative design activities undertaken by the counselors allowed them to practice key traits of engineers, including problem-solving, design thinking, creativity, innovation, and collaboration. Participants were prompted to build a tower out of spaghetti noodles (Figure 1a), construct a rain shelter from newspaper (Figure 1b), and construct a robotic arm (Figure 1c). Examples of participants' work are presented in figures below.

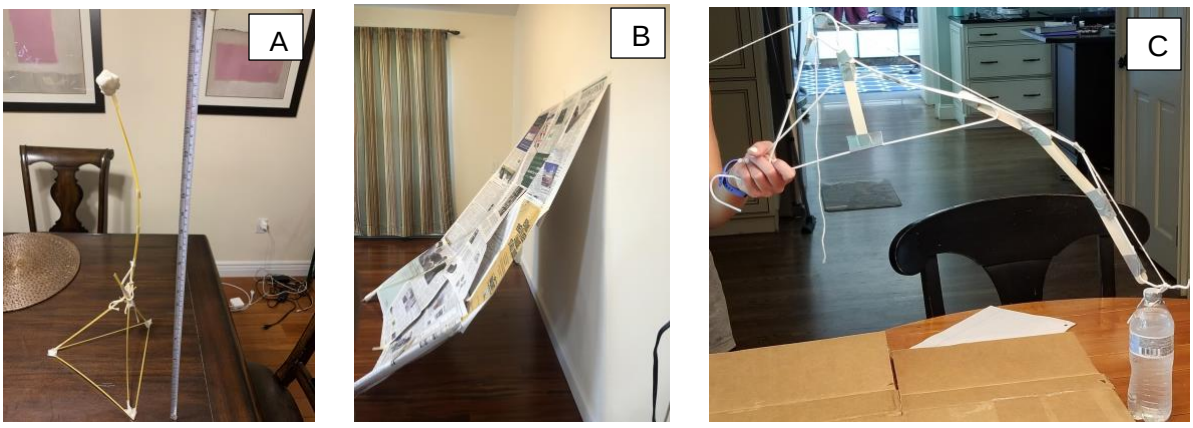

Figure 1. Sample projects from the PD program: a) spaghetti tower, b) newspaper shelter, and c) robotic arm

Phase III of the PD program involved sharing information about engineering careers and pathways. Phase I and II were done in collaboration with teachers participating in the teacher PD sessions, while Phase III entailed specific breakout sessions just for counselors. Participants attended at least one synchronous session (approximately three hours) per week, including an introductory kickoff meeting with the project team and collaborative sessions with teachers. Counselors were given opportunities in these sessions to undertake activities in teams. Discussions were held to share experiences and reflect on their learning of engineering. Asynchronous sessions afforded counselors with opportunities to work on engineering projects individually, read relevant literature, and construct mind maps demonstrating their understanding of engineering and the engineering design process (see example mind map in Figure 2).

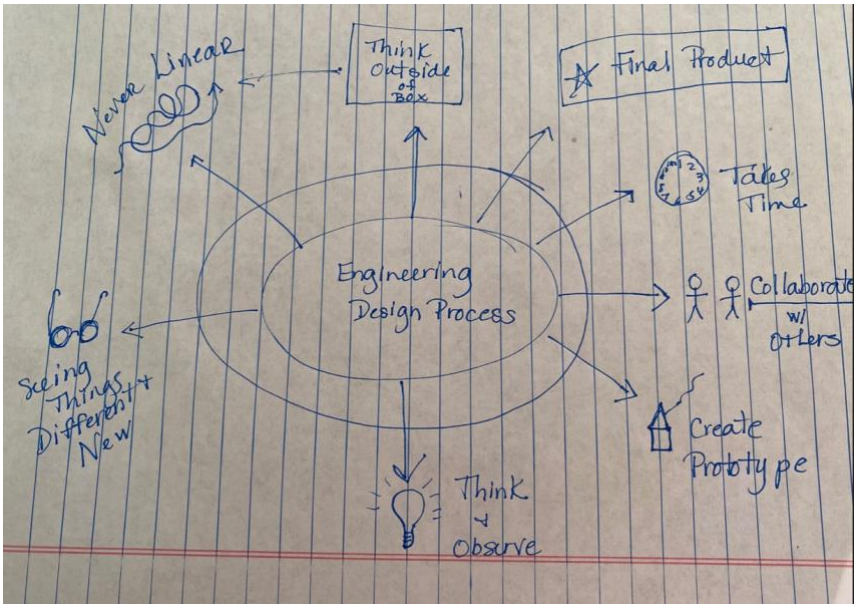

Figure 2. Sample Mind Map.

The final two weeks of the program were dedicated to wrapping up the project and discussing next steps as a group, including providing details regarding engineering majors and meeting with university partners. These activities were specifically created in response to counselor requests and provided greater tangible focus on practices that counselors can use to encourage students to pursue further engineering education and careers. Participants were also offered optional opportunities for engagement during the 2020-2021 academic school year. Multiple discussion prompts were posted for counselors to connect with the [PROJECT] learning community.

Methods

Data Sources

Multiple forms of data were collected throughout the summer PD program. This exploratory, concurrent mixed-methods study [7] included qualitative and supplementary quantitative data, including focus groups, counselor created artifacts, and a post-survey.

Pre and post-focus groups were conducted before and after the PD program to understand counselors' perceptions of engineering and to gain an understanding of their expectations (pre)/experiences (post) with the [PROGRAM NAME] PD. Counselors were divided into small groups (3-5 participants) for each focus group to discuss their thoughts and experiences around engineering and the PD program. Each focus group session lasted between 45 - 60 minutes. Questions were asked to assess: 1) perceptions of engineering education, 2) understanding of engineering as a discipline and career options, 3) beliefs around diversity, inclusion, and

belonging, as it relates to engineering, and 4) expectations of or experiences in the PD program. All focus groups were transcribed and reviewed for inconsistencies.

Many of the summer PD activities required participants to generate artifacts. For the purpose of this study, we analyzed "recruitment letters" written by the counselors that were designed to be shared with future counselor participants.

Additionally, a short survey was also sent to participants following the summer PD to evaluate their experience. The survey asked participants to report how many students they work with, major challenges they face in their role, program feedback, and next steps following the PD. The survey prompted participants to indicate their level of agreement to a series of statements on a 5-point Likert scale from *strongly disagree* to *strongly agree*. Sample items included: "I am satisfied with the E4USA professional development course" and "The program has prepared me to provide career guidance to students regarding engineering." Information was captured using fixed-item and open-ended questions.

Data Analysis

Pre/post focus groups and post-survey data were analyzed to discuss counselors' perceptions of the PD program and engineering as a discipline before and after the PD. Data analysis followed an interpretivist theoretical framework with a constructivist epistemology, which acknowledges contextualism [8]. The research team uncovered valuable interpretations garnered by the data provided by the participants' experiences shared in focus groups and on the post-survey [9].

Focus group data were analyzed using open-coding and the constant comparative method [10]. First, two research team members went through the focus group transcripts individually to conduct an initial round of coding. Next, four team members, including the original two coders, reviewed the emergent codes to discuss any inconsistencies or discrepancies. The two original coders then went back through the transcripts for a second round of coding. Those codes were gathered and reviewed again by the research team. A draft codebook was developed following consensus on all codes and example excerpts. An additional team member then used the draft codebook to conduct a final review.

Table 1: Codebook

Parent Code	**Sub-Codes**
Engineering is for everyone	Coming to understand engineering beyond math and science Diversity Motivation for professional development Broadening participation in engineering
Practices	Role of counselor Shift in Counseling Approach
Barriers in pursuing STEM	
PD program evaluation	Suggested improvements Things liked about the PD

Survey data were downloaded, cleaned, and translated (strongly disagree =1 to strongly agree = 5) in Excel. Analysis of data was conducted via SPSS [11]. Descriptive analysis was conducted on the five Likert-scale items regarding program effectiveness and evaluation. Open-ended questions were reviewed and categorized into program highlights and program suggestions. The same coding scheme developed for the focus group data was used to code these responses. The summation of the qualitative and quantitative findings are discussed under the broad headings of *'Initial' and 'Shifting' Perceptions of Engineering.*

Results & Discussion

Initial Perceptions of Engineering

Pre-focus group data revealed counselors had either limited or misconstrued perceptions of engineering prior to the summer PD. Numerous counselors either acknowledged their lack of understanding of engineering or admitted the faults in the previous associations they made with who would or wouldn't be interested in engineering. An underlying reason for counselors' misconception of engineering was tied to having never been given proper information. One counselor noted, "...my engineering knowledge was quite limited. In essence I thought that the 'math/science' students were the primary group that would be interested in the field." The counselor first admitted to having very little knowledge of engineering, and then divulged an incorrect assumption that most counselors shared prior to their participation in the [PROGRAM NAME].

The limited amount of information that the counselors did possess was mostly inaccurate. Another counselor stated, "yeah, you should have a good understanding of math and science, but you don't have to be a genius (like I always assumed you needed to be!)." Counselors confessing to the belief that engineering was solely for students who were proficient in math and science

highlights a concern that students who do not fall into that category are missing out on an opportunity to be introduced to engineering. This results in certain students never being encouraged to explore something they could have the potential to enjoy and potentially pursue as a career.

Shifts in Perceptions of Engineering

Post-focus groups, recruitment letters, and survey data were used to explore shifts in perceptions from the pre-focus groups. Overall, counselors learned what engineering is, what engineering entails, and that everyone can excel in engineering. One counselor explained:

> ...you will learn and experience for yourself what engineering is all about and have a lot of fun creating things you might not think you can create! You will also meet counselors from around the country and a great group of college professionals who are passionate about spreading the engineering message and breaking the stereotypes associated with it.

Participants indicated via the survey that the program helped them prepare to provide career guidance to students regarding engineering ($M= 3.11$, $SD = 0.96$). Many counselors remarked that they have a much greater understanding of engineering and they now understand the ways that "engineering applies to various disciplines." Since the course provided the "opportunity to share, learn and participate in the engineering design process," one counselor commented that they have "more concrete examples and experiences that make me more relatable to the students." Another counselor mentioned, "It's important that counselors have a full understanding of the field, so that they can effectively portray what engineering is truly about to their students."

Post-focus group data revealed dramatic shifts in counselors' perceptions of engineering following the PD, particularly their preconceived ideas about the skills needed for engineering. Many had pivotal realizations in their thinking about engineering as a profession and engineering as an option for students. Counselors learned to have a more open idea about engineering as a discipline. As one counselor stated, "what I really learned is that I have to have a broader, more open-minded approach to recommending this class/program to students." Many counselors had the preconceived notion that engineering is solely for students who excel in STEM courses and know that they want to pursue engineering. The PD helped them understand that engineering is a broad and diverse field that can be an option for a diverse group of students and should be presented to all students. One counselor stated how "it is equally as important to encourage females, minorities, and students of all backgrounds to explore engineering…" This approach allows students to decide for themselves whether engineering interests them.

Counselors realized that engineering is more than math and science aptitude; it is about creativity, teamwork, problem solving, and so much more. Skills required to be successful in

engineering are skills that can be possessed and used by anyone. It is vital that counselors have an accurate understanding of engineering so that they can effectively portray correct information to students, which will potentially broaden the participation in engineering to those who wouldn't have otherwise been presented with the opportunity or who would've been misinformed. A counselor remarked on their survey that they will now be able to do a lot more to encourage students towards engineering, outside of just saying "are you good at math and science?"

It is pivotal to spread awareness and understanding that engineering is much more inclusive than what many believe it to be. When recommending the PD to fellow counselors, one counselor encouraged, "not an engineer you say...that is what I thought a counselor would say...be prepared to learn that everyone can benefit from engineering training." The counselor alludes to the fact that other counselors most likely don't see themselves as engineers or as having an engineering mindset. It is necessary for counselors to understand that anyone, including themselves, has engineering potential. A counselor stated in their recruitment letter that the activities from the program require basic engineering skills, which "could be a great conversation starter when encouraging and advising one of your future engineers." They will then be more likely to broaden participation in engineering by spreading the opportunity to students who they may not have otherwise seen as potential engineers prior to the PD.

The general consensus from counselors was that the [PROGRAM NAME] PD effectively engaged them in the engineering design process, which facilitated a deeper understanding of engineering. The overall realizations made during the PD are best summarized by a statement made in one of the counselor recruitment letters:

> I learned what engineering really is. It's about looking at a problem and being excited to solve it. It's about collaborating and brainstorming, working as part of a team to accomplish a worthwhile goal. It's about asking why and how something works, not simply being glad that it does work. It's about discovering creative solutions to everyday or complex problems. It's about being part of a team and communicating your solution. It's about failing and succeeding and then redoing to make it better. Yeah, you should have a good understanding of math and science, but you don't have to be a genius. [recruitment letter]

The overarching belief of participants was that the knowledge gained will now allow participants to better advise and share information about engineering with a larger, and more diverse group of students than they had previously.

Conclusion, Implications, and Future Work

An important way to help broaden participation in engineering is through widespread education of counselors. Most counselors are unable to adequately convey the true meaning of engineering to students because they do not have a good understanding of it themselves. Professional development programs for counselors typically focus on social and emotional needs of students and/or communication skills [12]. The program was successful because it intentionally engaged counselors in the engineering design process, which expanded counselors' notions of engineering. Shifting realizations allowed counselors to be able to think about how to work with students differently when it comes to engineering-specific guidance. Participants indicated that they would be more intentional in recommending and talking about engineering with all students, not just the "brainiacs." This was a critical realization for counselors in thinking about how they will adjust future practices to intentionally expand access and participation in engineering.

This program revealed a major gap in the overall system designed to recruit, encourage, and retain students into engineering careers. Much can be accomplished through in-class and extracurricular activities designed to provide students with engineering experiences. Providing counselors who influence which classes students take, what extracurricular programs students join, what fields they explore for careers, and which programs they consider for higher education is one aspect that has been overlooked. Providing counselors with an opportunity to further understand engineering and relieve misconceptions addresses a missing link in the chain. Shifts in perceptions leading to changes in practice have the potential to excite a far more diverse group of students into pursuing engineering degrees and careers. Professional development programs for school teachers and/or officials should look at ways to meaningfully include counselors into their programming. Collaboration between teachers and counselors can help foster a unique environment where both groups can better understand each other's work and create ways to facilitate environments that will best serve students.

Future research will focus on ways to expand this program to more counselors and student advisors in an effort to reach more "gatekeepers" who work with students and can help broaden participation in engineering. We also intend to collect more data during the school year to shed light on lasting effects of the [PROGRAM NAME] on counselors' practices with students. Continuing to work on ways to expand engineering access will be critical for creating a more diverse, equitable field ranging across pre-college education to postsecondary and beyond to professional career pathways.

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