Received: 30 June 2022 | Revised: 4 November 2022 | Accepted: 1 March 2023

DOI: 10.1111/ssm.12576

RESEARCH ARTICLE

WILEY | SSMA

Expanding access to STEM pathways: Professional learning for high school counselors

Lydia Ross[1] | **Medha Dalal**[2] | **Adam Carberry**[2]

[1]Mary Lou Fulton Teachers College, Arizona State University—Tempe Campus, Tempe, Arizona, USA

[2]Ira A. Fulton Colleges of Engineering, Arizona State University—Tempe Campus, Tempe, Arizona, USA

Correspondence
Lydia Ross, Mary Lou Fulton Teachers College, Arizona State University—Tempe Campus, 1050 S Forest Ave. Tempe, AZ, USA.
Email: llross1@asu.edu

Funding information
Mary Lou Fulton Teachers College–Office of Scholarship and Innovation

Abstract

This study is situated within a large-scale national 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. Counselors participated in a series of PD activities centered on the following components: (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. We utilized an exploratory qualitative research design to understand counselors' perceptions and experiences. Through their own hands-on experiences, counselors had concrete examples to share with students about engineering as a field to consider for postsecondary education and careers. Further, through a broadened understanding of the skills needed to excel in engineering, counselors expressed that they would work with all students to recommend them towards engineering, rather than just the "math and science" students. Through this study, we identified an important gap in the engineering pipeline: high school guidance counselors. In order to broaden participation in engineering, we must first expand the knowledge of those people working closely with high school students on postsecondary plans.

KEYWORDS

attitudes/beliefs, counselors, equity, inquiry/discovery, learning processes, misconceptions, professional development, students and learning, students and learning

Numerous reports have called for the need to bolster the science, technology, engineering, and mathematics (STEM) workforce to avoid dire economic, technological, and national security consequences. Specifically, *A Nation at Risk* (National Commission on Excellence in Education, 1983) and *Before It's Too Late* (National Commission on Mathematics and Science Teaching for the 21st Century, 2000), and *Revisiting the STEM Workforce* (National Science Board, 2015) called for a need to advance our STEM workforce in the United States. Policymakers and researchers have emphasized the essential relationship between the country's economic development, participation in the STEM workforce, and progress (Hrabowski, 2011). Racial and gender gaps in STEM disciplines are well documented (Okrent & Burke, 2021) and stand to prevent the nation from addressing this call.

A joint report from the National Science Foundation, National Science Board, and National Center for Science and Engineering Statistics, provides a landscape of the contemporary STEM labor force (Okrent & Burke, 2021). STEM workers account for nearly 25% of the U.S. labor market with just over half of these workers having bachelor's degree. Approximately 35% of STEM workers are women, and despite accounting for 30% of the employed workforce, people who identify as Black, Latinx, and Native American only comprise 23% of the total STEM workforce. These racial and gender gaps are especially pronounced in the so-called "hard sciences," such as engineering, physics, and computer science.

This economic rationale, coupled with the focus on the need for more diversity in STEM, has been a key point of discourse and focus of national policy initiatives. Recently, researchers, policymakers, and workforce leadership have pointed to a new issue within the STEM workforce: a shortage of skilled technical workers (STWs) (National Science Board, 2019; National Science Board, 2020). STWs use specialized technical skills and knowledge but do not have a bachelor's degree (Chen & Roterrmund, 2020; Rothwell, 2016). Nearly two-thirds of the STEM workforce are STWs (Okrent & Burke, 2021). By 2029, STWs are projected to comprise nearly 19 million workers (National Science Board, 2020). There is a need to focus on STWs to better understand how to expand the pathways for future STWs (National Science Board, 2018).

One avenue to increase pathways and participation of STWs in the STEM workforce is focusing efforts on the pre-college educational system. Most pre-college curricula require courses in mathematics and the sciences with increasing offerings in technology and/or engineering. These courses are merely one touch point to excite students about STEM career pathways. High school counselors in particular play a critical role in the career exploration and postsecondary decisions of high school students (Falco, 2017; Katehi et al., 2009). This study focuses on the 'E' in STEM by examining the perceptions and practices of high school counselors who participated in professional development (PD) designed to build an understanding of engineering and pathways for students in engineering or engineering-like careers.

The study is situated within Engineering for Us All (e4usa), a large-scale national project designed to expand access to engineering (e4usa, 2022). The e4usa program has three key elements: (1) a full-year, high school-level engineering curriculum; (2) summer PD for teachers with varying backgrounds, and (3) an online learning community of teachers, school officials, university educators, and practicing engineers. pre-college educational curricula high school counselor professional development (HSCPD) program was developed to further create awareness about engineering. We explored shifts in high school counselors' understandings of engineering, pathways to engineering and engineering-like skilled technical careers, and professional practices with students after participating in the HSCPD program. We detail the PD program, data collection and analysis, and major findings to address the following research questions:

1. What are counselors' perceptions of engineering before and after participating in the HSCPD program?
2. What are counselors' perceptions of pathways to engineering and engineering-like careers after participating in the HSCPD program?
3. How did counselors' professional practices shift after participating in the HSCPD program?

1 | LITERATURE REVIEW

1.1 | Current landscape for pathways into STEM careers

There are four main pathways by which people find their way into the STEM workforce: (1) secondary school experiences, (2) secondary career and technical education (CTE), (3) postsecondary education, and (4) certificates, certifications, or licenses (Okrent & Burke, 2021; Wang et al., 2013).

1.1.1 | Secondary school experiences

Students' experiences in high school can directly influence plans of whether to pursue a STEM education or career (Wang, 2013). Using data from the High School Longitudinal Study of 2000, Okrent and Burke (2021) examine high school students' reasons for taking math and science courses and explore relationships with their decision to pursue STEM after graduating. Most students report their primary reason for taking a math or science class is because it is required for graduation. Another primary driver for students was because a teacher, counselor, or parent recommended they take a math or science class. Female students were more likely to take a math or science class because it was recommended by someone else. Male students were more likely to enroll in a math or science class as a personal choice because they enjoyed the subject. Exposure to math and science classes in high school can help foster STEM identity and self-efficacy, which can influence students' decisions to pursue STEM postsecondary education or careers (Flowers III & Banda, 2016; Gushue et al., 2006; Smit et al., 2020). Encouraging students to participate in STEM courses in high school is critical to exciting more students to consider pursuing further STEM education and STEM careers.

1.1.2 | Secondary CTE

CTE programs in high school allow students to tailor their educational experiences based on their unique needs and interests. CTE comprises courses or formalized programs with a specialized focus on career or technical skills needed in a particular area. CTE programs can directly connect students to the STW labor market after graduating from high school (U.S. Department of Education, 2019). Approximately three-quarters of high school students participated in at least one CTE credit in high school in 2013; though many of these students did not concentrate on a particular area (U.S. Department of Education, 2019). Students who participated in some form of CTE in high school were more likely to directly enter the STW workforce when compared to their counterparts who did not earn any CTE credits (Rotermund & Burke, 2021). CTE courses such as computer-aided design (CAD) or Design Craftsmanship enable students to pursue engineering-like skilled technical careers (National Academies of Sciences, Engineering, and Medicine, 2017).

1.1.3 | Postsecondary education

The primary pathway that people enter the STEM workforce is through postsecondary education, including 2- and 4-year degrees. Nearly one-half of all STEM workers have at least a bachelor's degree (Okrent & Burke, 2021). Vocational or 2-year degree programs are a critical mechanism for expanding access and participation in the skilled technical workforce (Bureau of Labor Statistics, 2019; Trapani & Hale, 2019). Just under 25% of all associate degrees were in STEM-related fields in 2019 (Okrent & Burke, 2021). The American Community Survey showed that 22% of the STW workforce in STEM had an associate degree. STWs in STEM generally had higher percentages of associate degrees than their counterparts in non-STEM fields (Okrent & Burke, 2021).

1.1.4 | Certificates, certifications, and licenses

Certificates, certifications, and licenses are another way for people to enter the STEM workforce. Students can obtain certificates at community colleges or other 2-year institutions, including for-profit institutions (Trapani & Hale, 2019). Certifications are offered by non-governmental bodies, while licenses grant legal authority for work in a particular area (Bureau of Labor Statistics, 2019). These alternative pathways meet the demand for people who tend to have nonlinear pathways within education and provide an option for some to return to college to augment and/or supplement their skills.

1.2 | Guidance toward the skilled technical workers workforce

A report by the National Science Board (2019) found that it is critical to expand diversity and inclusivity in STEM fields to foster ongoing support and dedication. A specific focus was placed on the need for STWs as part of the solution for ongoing prosperity in STEM. The report identified four major strategies to increase the number of STWs in STEM: (1) change the message, (2) focus on the data, (3) leverage the portfolio of federal investments, and (4) build partnerships (National Science Board, 2019).

Career counseling is one strategy that can change the message and help bolster the entrance of students into STEM and STEM STW pathways. Conn et al.'s (Conn et al., 2017) literature review of 18 studies examined the role of career counseling services to promote entrance into STEM careers. Career counseling was shown to have a positive impact on intention to enter STEM careers (Kerr & Robinson Kurpius, 2004; Stoeger et al., 2013) and career self-efficacy (Fouad, 1995; Kerr & Robinson Kurpius, 2004).

1.3 | Role of school counselors

The pre-college educational system directly affects educational outcomes and transitions to either postsecondary education or the workforce. According to Katehi et al. (2009), the lack of diversity present in undergraduate engineering has its roots in the pre-college system where "access and participation will have to be expanded considerably" (p. 10). High school coursework can prohibit students from pursuing an engineering or engineering-like career and degree before they even graduate high school, especially due to perceptions that engineering is very heavy in math and science (Gillen et al., 2018; Nathan et al., 2010). School counselors and officials play a key role in influencing students' future educational and career pathways by assisting students in course selection, achievement, and overall environment that can influence college selection and major (Gillen et al., 2018; Jolly et al., 2004; Lewis, 2013). School counselors can play a critical role in guiding students toward STEM or CTE courses in high school (Mobley et al., 2017). This can also translate into counselors assisting students with future career choices (Lewis, 2013). The added emphasis on CTE, coupled with knowledge in STEM, could help guide more students toward becoming an STW in STEM.

Research indicates that a lack of basic engineering knowledge is a major barrier for school counselors when working with students to guide them toward future engineering or engineering-like careers. (Beck et al., 2009; Falco, 2017; Ross et al., 2021). Falco (2017) asserts that school counselors need a greater understanding of STEM pathways and career development. Sharing the benefits of STEM careers and the ways that STEM work translates into helping people and society is a powerful motivator for students (Wang et al., 2013). PD can serve to educate counselors about career pathways in engineering (McCuen & Greenberg, 2009).

2 | CONCEPTUAL FRAMEWORK

This work was guided by the Diffusion of Innovation (DoI) Theory (Rogers, 2003). DoI Theory suggests a five-stage model—knowledge/awareness, persuasion, decision, implementation, and confirmation—by which individuals adopt an innovation. This framework has frequently been used by researchers to examine PD programs (e.g., Mahony & Wozniak, 2005; Ross et al., 2021; Scott & McGuire, 2017). DoI allows for the examination of the process by which people undergo social change (Robinson, 2009). The innovation explored in the context of this study is understanding or knowing engineering as a field of study and a profession through participation in a PD program.

The first stage of knowledge/awareness includes when an individual is exposed to innovation or concepts. The individual learns about the topic and becomes aware of this new idea or innovation. Individuals at this stage lack awareness about the particular innovation and have not been inspired to (or have not thought of) learn more about particular innovation. The knowledge/awareness phase provides foundational building blocks for innovation, which are required for people to advance to subsequent stages.

The second phase occurs when individuals advance to persuasion. In this stage, the Individuals' interest in the innovation is piqued and they decide that the innovation has merit. This leads to an active pursuit of information about the innovation, that is, they participate in PD activities to advance their understanding of the topic.

Weighing of advantages and disadvantages in the persuasion phase leads to the decision phase, where the individual can become an adopter of the innovation. The individual decides during this phase to adopt the innovation based on information gleaned in the first two stages. Some individuals will decide not to adopt the innovation and will not advance to further stages. This stage is highly individualistic, and people often advance through these phases at different rates, which can make this difficult to empirically study (Rogers, 2003).

Adopters who decide to adopt the innovation then advance to the implementation phase, wherein they implement the innovation in their practice. There are multiple ways that people can implement an innovation. Some might try out small-scale implementations, such as augmenting one or two minor parts of their practice. Others might overhaul their practices and do a large-scale implementation of the innovation. Successful implementation of the innovation can lead some to the final stage of confirmation. Individuals affirm whether they will continue the long-term implementation of the innovation during this phase.

The level and rate of adoption are different for each individual. Not all people will advance through all five innovation stages (Rogers, 2003), especially within the context of PD programs. Instead, individuals will typically advance through the first three stages, where they gain initial interest in the innovation and collect more information. PD programs need to infuse the program with information and focused discussion on how to implement and advance the use of the innovation to support the advancement of the later stages (Coburn, 2003).

3 | PROGRAM DETAILS

The HSCPD program was situated within the context of e4usa, a large-scale, nationwide project funded by the National Science Foundation. e4usa aims to demystify engineering for high school students and teachers through an inclusive engineering curriculum and professional learning for teachers (e4usa, 2022). The focus is to connect all schools, teachers, and students to engineering by developing students' technical and professional skills (e.g., interdisciplinary thinking, creativity, innovation, communication, and collaboration) that crosscut a broad range of fields (Ross et al., 2021). The e4usa project provides (1) ongoing PD to high school teachers, and (2) an online community consisting of teachers, school officials, university educators, and practicing engineers to support the implementation of engineering courses in high school classrooms. Initial activities within e4usa identified a significant gap in the community of practice, namely the absence of high school counselors. School counselors play a pivotal role in the educational choices made by students through encouragement to take classes, think about future careers, and overall support (Falco, 2017). A PD modeled after the e4usa teacher PD program was created for high school counselors to address this gap. The study detailed in this paper focuses specifically on the HSCPD program.

3.1 | Recruitment

Recruitment was conducted via snowball sampling and outreach to local networks. The e4usa program had already recruited teachers from partner high schools to participate in the summer PD program. All participating teachers were asked to invite their school counselors to participate in the HSCPD program. Teachers were provided with a script and a flyer to share with counselors at their schools. We also developed a database of local high schools to recruit additional counselors. A total of 75 counselors were invited to participate in the HSCPD program; 29 completed an initial interest survey, and 15 of those individuals completed the program. Participants received a $75 Amazon gift card and a certificate of completion, which counted toward continuing education credits.

3.2 | Professional development structure

The HSCPD was initially developed as a two-day, in-person event to accompany the larger e4usa teacher PD. The COVID-19 pandemic required a shift in the program to a 5-week, fully online professional learning experience in the summer of 2020. The HSCPD consisted of both synchronous Zoom meetings and asynchronous activities. The learning management system, Canvas, was used as the central hub for all PD information and activities. Participants received a kit in the mail with the necessary materials for activities before the start of the HSCPD.

Participants attended at least one synchronous session (approximately 3 h) each week, which allowed time for counselors and teachers to engage in collaborative activities and follow-up discussion time. Each week also included asynchronous content, which afforded counselors time to complete engineering design tasks individually, read literature, and participate in reflection activities (e.g., mind maps to depict understanding of engineering and the engineering design process).

The HSCPD comprised three phases (see Figure 1). The first two phases were common for the counselors and e4usa teachers. The third phase was designed specifically for counselors separate from the teachers. The first phase was focused on introducing engineering as a field. Counselors explored how engineering is embedded in our daily lives and its connections to other disciplines. A session was conducted regarding inclusive practices within engineering. Counselors learned about the phenomena of implicit bias, stereotypes, and stereotype threat and how they influence diversity and inclusion in engineering. This session was followed by group discussions and reflections on their practices and potential changes toward inclusiveness (Dalal & Ross, 2022).

The second phase of the HSCPD engaged counselors in hands-on engineering design activities to help them act and "think like an engineer." The hands-on approach was intentionally employed so counselors could "experience" being an engineer and practice key traits engineers need to possess (e.g., problem-solving, design thinking, creativity, innovation, and collaboration). Activities were completed individually or in small groups collaborating with teachers. Participants created a spaghetti tower, constructed a rain shelter from newspapers, and built a robotic arm (see Figure 2).

The final phase was designed to help participants learn more about engineering careers and higher education pathways for 2-year and 4-year degree-granting institutions. Content for this phase was created specifically for the counselors. Counselors learned about different engineering disciplines and pathways through activities, including speakers from colleges and universities discussing different engineering majors, professional certificates, and outreach opportunities. The focus was placed on pathways into postsecondary institutions, but also included an emphasis on pathways for STWs after leaving secondary schooling, different engineering disciplines, and the broad array of careers that are available in each discipline. For example, learning CAD (typically taught in mechanical and aeronautical engineering) at a 2-year institution could lead to a job as a CAD drafter, CAD technician, graphic designer, architectural technologist, or 3D artist. This phase explicitly focused on how to encourage a broader array of students to

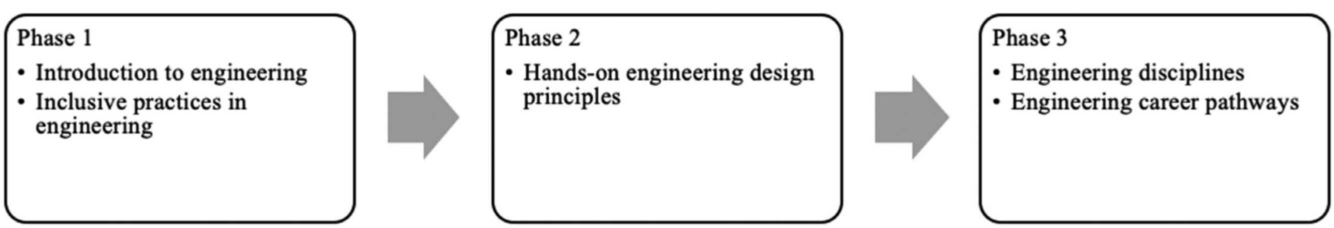

FIGURE 1 HSCPD project phases.

FIGURE 2 Sample Projects from the PD Program: (a) spaghetti tower, (b) newspaper shelter, and (c) robotic arm.

consider an engineering course and potentially engineering and/or engineering-like future careers.

3.3 | Positionality statement

The authors of this paper include engineering education and social sciences researchers who are a subset of the overall research team. The e4usa project invites all schools, teachers, counselors, and students to fully participate in the program regardless of their technical background or preparation. This open approach aims to achieve the greater programmatic mission of a nationwide, inclusive, pre-college engineering curriculum. The authors have a shared and invested interest in the success of the e4usa program for all involved, and our beliefs may have caused an unintentional bias when we qualitatively examined the data for this study. We state awareness of this bias and note that an effort was made to ensure these biases were recognized throughout the data analysis process.

4 | METHODS

4.1 | Participants

The 75 participants recruited using snowball sampling and outreach to local networks were invited to participate in the HSCPD program. The sample of 15 participants who completed the program was majority female ($n = 13$, 86%) and white ($n = 10$, 66%); a quarter of the participants were Black ($n = 4$, 26%), and one participant was Multiracial. Participants came from seven states or U.S. territories: Florida, Maryland, Pennsylvania, Tennessee, Texas, Virginia, and the U.S. Virgin Islands.

4.2 | Data collection

Multiple data sources were collected across the HSCPD program for this exploratory qualitative study (Creswell & Guetterman, 2019). We facilitated pre-focus and post-focus groups, conducted delayed post-interviews, and collected participant-created artifacts.

4.2.1 | Focus groups

Pre- and post-PD focus groups were conducted to understand the counselor: (a) understanding of engineering, (b) expectations (pre) and experiences (post) with the program, and (c) professional counseling/advising practices with students. The counselors were split into three groups comprising three to six participants. The focus groups lasted between 45 and 60 min and were recorded, transcribed, and checked for accuracy before analysis.

4.2.2 | Participant created artifacts

Counselors participated in multiple activities with tangible outcomes throughout the HSCPD program. We collected a variety of artifacts, including (a) photos of all products created (e.g., spaghetti towers, rain shelters, and robotic arms), (b) mind maps created to visually represent conceptualizations of the engineering design process, and (c) letters to the next cohort written by the counselors at the end of the PD. The writing of letters was intentionally included to allow counselors to reflect and share their PD experiences.

4.2.3 | Delayed post-interview

Five months after completing the PD program, participants were invited to participate in a delayed post-interview. These interviews were designed to discover how the PD program had influenced professional practices. A subset of five counselors volunteered to be interviewed for these delayed post-interviews. Interviews were conducted via Zoom and followed a semi-structured interview protocol.

5 | DATA ANALYSIS

Our qualitative data analysis was informed by an interpretivist theoretical framework with a constructivist epistemology, allowing us to acknowledge each participant's contextualism (Flick, 2014). Focus groups, interview, and artifact data were used by the research team to uncover valuable interpretations from the shared experiences of HSCPD participants (Koro-Ljungberg et al., 2009). The focus groups, interviews, and letters to the next cohort were analyzed via open coding and the constant comparative method (Corbin & Strauss, 2015) to explore counselors' perceptions of engineering as a discipline, pathways to engineering, and professional practices post-HSCPD. Two researchers initially went through the transcripts individually to complete a preliminary round of coding. Next, the two original coders met with two additional team members to review emergent codes and discuss any discrepancies. The two original coders then went back through the transcripts and letters for the second round of coding. These codes were then reviewed again by all team members to form a codebook (Table 1) indicating consensus on codes and sample excerpts. An additional researcher then went back through all data using the codebook for a final review of the data.

TABLE 1 Subset of codebook.

Parent code	Parent code definition	Sub-codes
Engineering is for everyone	Engineering is not only for those who are good at math and science. An education in engineering can teach a wide array of skills, such as problem-solving, collaboration, critical thinking, and communication. Engineering is also a great way to help people and solve problems in the world.	• Coming to understand engineering beyond math and science • Diversity • Motivation for professional development • Broadening participation in engineering
Practices	Counselors discuss the duties and roles of a counselor, and how engineering can be incorporated into their practice.	• Role of counselor • Shift in counseling approach

6 | RESULTS

We organize our findings around our previously stated research questions. These results capture shared perceptions by the counselors who participated in the HSCPD and the resulting shifts in practices.

6.1 | Research question 1: What are counselors' perceptions of engineering before and after participating in the HSCPD program?

Initial perceptions of engineering were informed by the pre-focus groups conducted at the start of the HSCPD program. Most of the counselors had very limited or flawed understandings of the discipline of engineering. Counselors explicitly stated they did not have much knowledge at all or that they knew their perceptions were probably incorrect. For example, when asked what engineering is, one participant replied, "I guess the first thing that comes to mind, and I have a feeling you're going to tell me I'm wrong, is math and science and needing to be strong in those" (pre-focus group data, 2020). Others possessed similar ideas, with nearly all participants explicitly mentioning math and science when describing the discipline of engineering.

These perceptions of engineering as a discipline of "math and science" extended beyond the counselors to their students. One counselor remarked that students also held the same misconceptions saying, "everyone equates engineering with mathematics" (pre-focus group data, 2020). Another counselor confirmed this issue, saying their students would self-select out of engineering, "There's that oh, I'm not very good at math, therefore I shouldn't be an engineer" (pre-focus group data, 2020). Lastly, another counselor stated, "I know engineering. I'm afraid of the word engineering. So, I know a lot of my students are afraid of the word engineering because we do associate it with hardcore math and science" (pre-focus group data, 2020). This last quote highlights two important issues. First, students' perceptions are incorrectly grounded in the idea that engineering is esoteric, only for those who excel in math and science. This can be a gatekeeping idea, which blocks students from the opportunity to consider engineering as a possible subject for study or future career options. Second, this fear of engineering continues to perpetuate stereotypes of engineers, while also deterring participation from broader groups of students.

Counselors experienced shifts in their perceptions of engineering as they underwent HSCPD. They learned what engineering is and what skills are needed as well as who can excel in engineering. These shifts were captured by the codes *not just math and science* and *engineering is for everyone*.

"Not just math and science." Counselors predominantly entered the program believing that engineering was a discipline best suited for those who excelled in math and science. They left with the understanding that engineering was more than the application of math and science. Engineering was revealed to also be about creativity, design, teamwork, and collaboration. When asked about their biggest takeaway from the program, one counselor said: "It was all about just learning that it's just not math and science, because I would say that's the big thing that people assume, Oh, you must like math and science in order to do engineering when it just connects to so many other disciplines, it's just not something that you would think about" (post-focus group data, 2020). Another counselor remarked: "When we started this, I would have said all math, science careers, and things like that. And I've come more around to understanding that engineering involves a lot of creativity and problem solving and group work. And I would not necessarily have said that a few weeks back" (post-focus group data, 2020).

Counselors also had dramatic shifts in their understanding of the skills needed in engineering. One counselor stated:

> "I would say for myself, I think definitely when you don't have a science or math background or technology background, I think the biggest assumption is that's what you have to love and really, it could just be a critical thinker. It could be someone who loves building things, and so, for me, I think it's just always, and I think in general for students, it's just easy to make the assumption of, you have to be just good at this piece when in actuality is all about problem-solving, and really thinking through things, and really being patient while you're trying to figure something out." (post-focus group data, 2020).

Others affirmed this understanding by describing engineering as a "process" that involves "problem-solving" and the application of "creativity, design, and … knowledge." (post-focus group data, 2020). Yet another counselor aptly mentioned the importance of communication in the field of engineering. Counselors in the end "learned what engineering is" (post-focus group data, 2020). The most mentioned skills included teamwork, creativity, multi-disciplinary, collaboration, and learning from failure.

"Engineering is for everyone." As counselors expanded their definition of engineering as a discipline, they also broadened their understanding of *who* can be an engineer. One counselor remarked that they learned that they needed to "have a broader, more open-minded approach to recommending this class/program to students" (post-focus group data, 2020). The PD program helped counselors understand that engineering is a broad and diverse field that could be a viable option for a large group of students. This understanding, coupled with an emphasis on inclusivity in engineering throughout the program, helped counselors think about ways to help expand access to engineering for *all* students. One counselor stated that "it is equally as important to encourage females, minorities, and students of all backgrounds to explore engineering…" (post-focus group data, 2020). Another counselor echoed that it is important to make sure that all students are given the chance to participate in engineering, "even the program itself, Engineering for US All, we just want to ensure that all students get that exposure" (post-focus group data, 2020). These statements suggest that counselors learned that engineering has a place for everyone.

6.2 | Research question 2: What are counselors' perceptions of pathways to engineering and engineering-like careers after participating in the HSCPD program?

Through an expanded understanding of engineering, counselors also reconceptualized pathways to engineering careers. Counselors initially thought of engineering as a field directly connected to higher education. In the pre-focus groups, many counselors mentioned college in conjunction with engineering. One counselor stated that when thinking about strong engineering students, they initially looked to whether they were "successful in math and science courses" because those "are the ones that a college might pay more attention to" (pre-focus group data, 2020). Others affirmed this idea of thinking of engineering careers progressing through four-year colleges.

Participation in the HSCPD program led to new perceptions about engineering career pathways. One counselor stated that after participating in the program, they learned "how many opportunities there are for my students" (post-focus group data, 2020). Another counselor talked about how they used to view the engineering course in preparation only for those likely to major in engineering, but that they now viewed the course "as a pathway for students to just learn more about engineering" and to generate "broader interest in STEM, even outside of college" (post-interview, 2020).

In the post-focus groups and follow-up interviews, a few counselors mentioned educational practices that would lend well to technical school or two-year degree programs. For instance, one counselor discussed a dual enrollment program at their school as a good option for students to start establishing postsecondary options (post-interview data, 2020). Another counselor specifically talked about the benefits of CTE courses in high school to engage students. They mentioned that some students might struggle academically, but also excel in CTE classes, such as product design, CAD, or robotics. "Not only do these students thrive in the classes, but they tend to do better when they leave high school because they have a skill, they are passionate about" (post-interview data, 2020). Finally, another counselor mentioned that after participating in the PD program, they and their school were establishing a STEM certificate program for students, as "this can help set students up after they leave high school" (post-interview data, 2020). These results suggest that counselors broadened their ideas about postsecondary options for their students through the HSCPD.

6.3 | Research question 3: How did counselors' professional practices shift after participating in the HSCPD program?

Counselors reported considerable shifts in their professional practices after participating in the HSCPD program due to new insights into what engineering is, the necessary skills, and a broadened understanding that engineering is for everyone. They left the PD with a stronger understanding of engineering, and the different ways it connects to other disciplines. One counselor reported that the program gave them the "opportunity to share, learn and participate in the engineering design process," which gave them "more concrete examples and experiences that make [them] more relatable to the students" (post-focus group data, 2020). This broadened understanding of engineering directly affected their ability to talk about engineering with students and better inform students about engineering. One counselor said they would be able to "say a lot more to students about engineering than, are you good at math and science?" (post-interview data, 2020).

Counselors talked about how they would explicitly suggest engineering to their students after the PD program. Two counseling teams established new practices to encourage students into the program. One school sent high school counselors and teachers to the middle school to talk about engineering with students (post-interview data, 2020). Another school implemented more inclusive practices with their career readiness team to explicitly encourage underrepresented students into STEM classes (post-interview data, 2020).

Counselors reported that they were able to provide concrete examples and real-world applications of engineering to their students following the HSCPD. This information, coupled with new knowledge of various engineering disciplines, careers, and pathways allowed them to better connect with their students and share engineering information.

7 | DISCUSSION

Counselors play a critical role in the educational choices and pathways of students (Gillen et al., 2018; Jolly et al., 2004; Katehi et al., 2009; Lewis, 2013). Prior research indicates that counselors typically lack knowledge of engineering, which could directly influence whom they recommend engineering to, potential processes, and suggestions for career pathways (Beck et al., 2009; Falco, 2017; Ross et al., 2021). Counselors particularly help students enter the STEM workforce, so we need to expand their understanding of these careers. The guidance provided by counselors can be pivotal in student selection of elective courses, achievement, and fostering a welcoming environment through outreach activities. Each of these factors can influence students' career interests, college choice, and major selection, which can have a strong impact on diversifying those who pursue 2- or 4-year STEM degrees to join the nation's skilled technical workforce (Kerr & Robinson Kurpius, 2004; Stoeger et al., 2013). Our HSCPD program greatly improved counselors' understanding of engineering, which in turn shifted their practices.

The HSCPD program expanded the counselor's understanding of engineering and initiated changes in counseling practices. Counselors entered the program thinking of engineering as a discipline for those who excelled in math and science. Their perceptions changed after completing hands-on activities that emulated the engineering design process because they learned that engineering as a discipline, field of study, and career path requires skills that go beyond math and science. Counselors realized that engineering requires creativity, collaboration, problem-solving, adaptability, and learning from failures. The program emphasized the importance of inclusivity in engineering and the importance of broadening understanding of engineering to not only expand the discipline but create awareness about STEM and STW career options to a wider range of students. The emphasis on the 'E' within STEM allowed counselors to adjust their understandings of *what* engineering is and *who* could be a good engineer. The HSCPD successfully disseminated engineering knowledge, allowing counselors to move through the first phase of DoI: *awareness* (Rogers, 2003).

The program deeply engaged counselors throughout the program in hands-on activities and frequently requested additional information. A session was added at the end to discuss different engineering majors and career pathways to accommodate additional requests. While not formally measured, the request for additional information suggests that counselors moved through the *persuasion* stage (Rogers, 2003). Counselors paired their new understanding with adjustments to their counseling practices. Post-focus group meetings and follow-up interviews indicated that counselors planned to or did change their practices with students. These shifts in practice indicate that most counselors moved on to the *decision* phase where they decided to use the information garnered from the PD to adjust how they worked with students. They also indicated plans to be more intentional about whom they referred to engineering, due to understanding new skills and intentionally wanting to help broaden access and participation in the discipline. In the follow-up interviews, counselors explicitly stated that they considerably adjusted their practices to recommend engineering to more students, signaling a transition to the *implementation* and *confirmation* stages (Rogers, 2003).

Our study had interesting findings regarding how counselors and schools thought about engineering. Counselors initial thoughts regarding engineering centered on "brainiacs" in math and science and traditional, 4-year degree programs. We saw a critical shift in counselors' understanding of pathways to engineering after completing the HSCPD program. Multiple counselors indicated that they had new ideas about how people could access engineering careers, either through CTE programs in their high school or via technical schools after graduating. One counselor mentioned that they saw the value in technical schools because these programs allowed students to thrive. Another counselor specifically mentioned starting a STEM certificate program to help increase interest and expand access to STEM careers after high school. This affirms the three main pathways identified by Okrent and Burke (2021) for people to enter the STEM workforce.

8 | LIMITATIONS AND FUTURE WORK

This study is not without limitations. The generalizability of qualitative findings is inherently limited. We aimed for this study to be exploratory in nature, so there is much work to be done in understanding how counselors understand engineering. Future work with a broader sample of counselors should also consider how counselors work with students to promote engineering career development. Efforts could aim to expand these educational programs to inform counselors about STEM careers more generally. This work would also benefit from explicitly including information about careers and pathways for STWs. Specifically, schools could consider adding more CTE opportunities for students. Providing clear information on career options for STWs would be a value-add for counselors in schools when working with students. We found that collaborations between teachers and counselors can be beneficial too. Future PD programs should work to explicitly integrate these connections more deliberately into the program structure. Finally, future work should consider looking at providing PD experiences for counselors in schools with less STEM presence as this effort was undertaken primarily with counselors at schools with an engineering presence, e4usa.

9 | CONCLUSION

This study identified an important gap regarding the role and importance of high school guidance counselors within the STEM education ecosystem. We must expand the engineering knowledge of those who work closely with high school students on postsecondary plans to broaden participation in engineering and engineering-like careers for stronger STW. Teachers and counselors play key roles in high school students' future educational choices. Aiming for more initiatives that improve counselors' understandings of and practices around engineering will be key to encouraging more students to enter the engineering or STW workforce. School districts and administrators should consider providing PD opportunities and resources for counselors to learn about engineering curricula, design skills, and pathways.

PD and research efforts should aim to reach more "gatekeepers" who work with students to help broaden the participation of other people in the future engineering and skilled technical workforce. This includes providing additional opportunities for these individuals to collaborate within a PD setting as a mechanism to integrate these connections more deliberately into the program structure. Continuing this work will be critical for creating a more diverse, equitable field starting in precollege education and extending into industry.

ACKNOWLEDGMENTS

The authors would like to thank the Office of Scholarship and Innovation at the Mary Lou Fulton Teachers College for their generous support of this work. We'd also like to thank the Engineering for US All program for its partnership in this venture.

REFERENCES

Beck, M., Diefes-Dux, H., & Reed, T. K. (2009). *K12 school counselors: A pilot study of support needs for advising students about engineering*. American Society for Engineering Education conference paper. https://peer.asee.org/4949

Bureau of Labor Statistics. (2019). *Labor force statistics from the Current Population Survey (CPS): Data on certifications and licenses*. https://www.bls.gov/cps/certifications-and-licenses.htm

Chen, X., & Roterrmund, S. (2020). *Entering the skilled technical workforce after college. RTI press publication No. RB-0024-2004*. RTI Press. https://doi.org/10.3768/rtipress.2020.rb.0024.2004

Coburn, C. E. (2003). Rethinking scale: Moving beyond numbers to deep and lasting change. *Educational Researcher*, *32*(6), 3–12.

Conn, K., Park, E., Nagakura, W., Khalil, S., & Corcoran, T. (2017). *Strategies for strengthening the technical workforce: A review of international evidence*. Research Report (#RR 2017–1). Consortium for Policy Research in Education, Teachers College, Columbia University.

Corbin, J., & Strauss, A. (2015). *Basics of qualitative research* (4th ed.). Sage.

Creswell, J. W., & Guetterman, T. C. (2019). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (6th ed.). Pearson.

Dalal, M., & Ross, L. (2022). Whistling Vivaldi: Examining stereotypes and implicit biases in the context of engineering career counseling. In *Paper presented at the annual meeting of the American Educational Research Association (AERA)* April 22–25, 2022. AERA.

Engineering for Us All. (2022). About Us. https://e4usa.org/about-us

Falco, L. D. (2017). The school counselor and STEM career development. *Journal of Career Development*, *44*(4), 359–374.

Flick, U. (2014). *An introduction to qualitative research* (5th ed.). Sage.

Flowers, A. M., III, & Banda, R. (2016). Cultivating science identity through sources of self-efficacy. *Journal for Multicultural Education*, *10*(3), 405–417. https://doi.org/10.1108/JME-01-2016-0014

Fouad, N. A. (1995). Career linking: An intervention to promote math and science career awareness. *Journal of Counseling & Development*, *73*(5), 527–534. https://doi.org/10.1002/j.1556-6676.1995.tb01789.x

Gillen, A., Carrico, C., & Matusovich, H. (2018). Gatekeepers to broadening participation in engineering: A qualitative investigation of a case site in Virginia (work in progress). In *Proceedings of the 125th Annual Conference of the American Society for Engineering Education*. ASEE.

Gushue, G. V., Scanlan, K. R. L., Pantzer, K. M., & Clarke, C. P. (2006). The relationship of career decision-making self-efficacy, vocational identity, and career exploration behavior in African American high school students. *Journal of Career Development*, *33*(1), 19–28. https://doi.org/10.1177/0894845305283004

Hrabowski, F. A. (2011). Boosting minorities in science. *Science*, *331*, 125.

Jolly, E., Campbell, P., & Perlman, L. (2004). *Engagement, capacity, and continuity: A trilogy for student success*. GE Foundation.

Katehi, L., Pearson, G., & Feder, M. A. (2009). *Engineering in K-12 education: Understanding the status and improving the prospects*. National Academies Press.

Kerr, B., & Robinson Kurpius, S. E. (2004). Encouraging talented girls in math and science: Effects of a guidance intervention. *High Ability Studies*, *15*(1), 85–102. https://doi.org/10.1080/1359813042000225357

Koro-Ljungberg, M., Yendol-Hoppey, D., Smith, J. J., & Hayes, S. B. (2009). (E)pistemological awareness, instantiation of methods, and uninformed methodological ambiguity in qualitative research projects. *Educational Researcher*, *38*(9), 687–699. https://doi.org/10.3102/0013189X09351980

Lewis, F. L. (2013). Closing the Racial Achievement Gap: The Impact of the Guidance Counselor. http://njpsa.org/documents/pdf/RacialAchievementGap.pdf

Mahony, M., & Wozniak, H. (2005). Diffusion of innovation and professional development in eLearning: The CHS eLearning resource case study. In *Breaking down boundaries: International experience in open, distance and flexible education: Selected papers 17th Biennial Conference Of The Open Distance Learning Association of Australia*. Charles Sturt University.

McCuen, R. H., & Greenberg, J. (2009). Educating guidance counselors on engineering as a career & academic choice. *Journal of Professional Issues in Engineering Education and Practice*, *135*(3), 91–94. https://doi.org/10.1061/(ASCE)1052-3928

Nathan, M. J., Tran, N. A., Atwood, A. K., Prevost, A., & Phelps, L. A. (2010). Beliefs and expectations about engineering preparation exhibited by high school science, mathematics, and technical education teachers. *Journal of Engineering Education*, *99*(4), 409–436.

National Academies of Sciences, Engineering, and Medicine. (2017). *Building America's skilled technical workforce*. The National Academies Press. https://doi.org/10.17226/23472

National Commission on Excellence in Education. (1983). *A nation at risk: The imperative for educational reform. An open letter to the American people. A report to the nation and the secretary of education*. Department of Education.

National Commission on Mathematics And Science Teaching for the 21st Century. (2000). *Before it's too late: A report to the nation from the National Commission on Mathematics and Science teaching for the 21st century*. Department of Education.

National Science Board. (2015). *Revisiting our STEM workforce*. National Science Foundation https://nsf.gov/pubs/2015/nsb201510/nsb201510.pdf

National Science Board. (2018). *Our nation's future competitiveness relies on building a STEM-capable US workforce: A policy companion statement to science and engineering indicators 2018*.

National Science Foundation https://www.nsf.gov/pubs/2018/nsb20187/nsb20187.pdf
National Science Board. (2019). *The skilled technical workforce: Crafting America's Science & Engineering Enterprise*. National Science Board, NSB-2019-23 https://www.nsf.gov/nsb/publications/2019/nsb201923.pdf
National Science Board. (2020). *The state of U.S. science and engineering*. https://ncses.nsf.gov/pubs/nsb20201
Okrent, A., & Burke, A. (2021). *The STEM labor force: Scientists, engineers, and technical workers*. National Science Foundation https://ncses.nsf.gov/pubs/nsb20212/executive-summary
Robinson, L. (2009). *A summary of diffusion of innovations*. http://www.enablingchange.com.au/Summary_Diffusion_Theory.pdf
Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.
Ross, L., Dalal, M., Carberry, A. R., & Roarty, J. (2021). Professional Development Program for High School Counselors on the Engineering Design Process (Evaluation). Paper presented at the *ASEE Annual Conference and Exposition*, Virtual Online. https://peer.asee.org/37604
Rotermund, S., & Burke, A. (2021). *Elementary and secondary STEM education*. National Science Foundation. https://ncses.nsf.gov/pubs/nsb20211/
Rothwell, J. (2016). Defining skilled technical work: The nation needs to better understand and more effectively develop this essential component of the US workforce. *Issues in Science and Technology*, *33*(1), 1–29.
Scott, S., & McGuire, J. (2017). Using diffusion of innovation theory to promote university designed college instruction. *International Journal of Teaching and Learning in Higher Education*, *29*(1), 119–128.
Smit, R., Robin, N., & de Toffol, C. (2020). Explaining secondary students' career intentions for technology and engineering jobs using an expectancy-value model. *Frontiers in Education*, *5*, 1–13.
Stoeger, H., Duan, X., Schrriner, S., Greindl, T., & Zieglerr, A. (2013). The effectiveness of a one-year online mentoring program for girls in STEM. *Computers & Education*, *69*, 408–418.
Trapani, J., & Hale, K. (2019). *Higher education in science and engineering: Science & engineering indicators 2020*. National Science Foundation. https://ncses.nsf.gov/pubs/nsb20197/
U.S. Department of Education. (2019). *Bridging the skills gap: Career and technical education in high school*. U.S Department of Education.
Wang, M. T., Eccles, J. S., & Kenny, S. (2013). Not lack of ability but more choice individual and gender differences in the choice of careers in science, technology, engineering, and mathematics. *Psychological Science*, *24*, 770–775.
Wang, X. (2013). Why students choose STEM majors: Motivation, high school learning, and postsecondary context of support. *American Educational Research Journal*, *50*(5), 1081–1121.

How to cite this article: Ross, L., Dalal, M., & Carberry, A. (2023). Expanding access to STEM pathways: Professional learning for high school counselors. *School Science and Mathematics*, *123*(3), 102–113. https://doi.org/10.1111/ssm.12576