Stereotypes and implicit biases in engineering: Will students need to "Whistle Vivaldi"?

Dr. Medha Dalal, Arizona State University

Medha Dalal is a postdoctoral scholar at Arizona State University. She received her Ph. D. in Learning, Literacies, and Technologies with an emphasis on engineering education from the Arizona State University. Her research seeks to build capacity for engineering education stakeholders at the grassroots, while also informing policy. Three thrusts that define her research interests at the intersections of engineering, technologies, and education include, ways of thinking that address complex educational challenges, democratization of K-12 engineering education, and online and technology-based learning.

Dr. Stacy S Klein-Gardner, Vanderbilt University

Stacy Klein-Gardner's career focuses on P-12 science, technology, engineering and mathematics (STEM) education, particularly as it relates to increasing interest in and participation by females and URMs and teacher professional development. She is an Adjunct Professor of Biomedical Engineering at Vanderbilt University where she is serving as the external evaluator on the NSF-funded Engineering For Us All (E4USA) project. Dr. Klein-Gardner serves as the chair of the American Society for Engineering Education Board of Director's Committee on P12 Engineering Education and is a Fellow of the Society.

Dr. Jennifer Kouo

Jennifer L. Kouo, is an Assistant Professor in the Department of Special Education at Towson University in Maryland. Dr. Kouo received her PhD in Special Education with an emphasis in severe disabilities and autism spectrum disorder (ASD) from the University of Maryland at College Park. She is passionate about both instructional and assistive technology, as well as Universal Design for Learning (UDL), and utilizing inclusive practices to support all students. Dr. Kouo is currently engaged in multiple research projects that involve multidisciplinary collaborations in the field of engineering, medicine, and education, as well as research on teacher preparation and the conducting of evidence-based interventions in school environments.

Dr. Kenneth Reid, University of Indianapolis

Kenneth Reid is the Associate Dean and Director of the R.B. Annis School of Engineering at the University of Indianapolis and an affiliate Associate Professor in Engineering Education at Virginia Tech. He is active in engineering within K-12, serving on the TSA Board of Directors. He and his coauthors were awarded the William Elgin Wickenden award for 2014, recognizing the best paper in the Journal of Engineering Education. He was awarded an IEEE-USA Professional Achievement Award in 2013 for designing the nation's first BS degree in Engineering Education. He was named NETI Faculty Fellow for 2013-2014, and the Herbert F. Alter Chair of Engineering (Ohio Northern University) in 2010. His research interests include success in first-year engineering, engineering in K-12, introducing entrepreneurship into engineering, and international service and engineering. He has written texts in design, general engineering and digital electronics, including the text used by Project Lead the Way.

Cheryl Beauchamp, Regent University

Cheryl Beauchamp serves as the Engineering and Computer Science Department chair of Regent University's College of Arts and Sciences. She is a PhD student in the Engineering Education program at Virginia Tech. She earned her Master's of Science degree in Computer Science from George Mason University and her Master's of Education degree from Regent University. Her research interests include motivation in engineering education, under-represented students in engineering and computer science, teamwork, online learning, and education practices in engineering, computer science, cybersecurity, and STEM.

Currently, she is a research assistant contributing to Engineering for Us All (E4USA) research, curriculum, and professional development.

Briana O'Neal, University of Maryland College Park
Jackelyn Raquel Lopez Roshwalb, University of Maryland, College Park

Jackelyn Lopez Roshwalb is the Assistant Director of the Keystone Program in the A. James Clark School of Engineering at the University of Maryland. She serves as the course coordinator and an instructor for the school's Introduction to Engineering Design course. Previously, Jackelyn taught high school mathematics and physics. She is a curriculum team member of the NSF-funded Engineering For Us All (E4USA) project, an initiative to deliver a nationwide standardized high school course in engineering that is available to and accessible for all high school students.

Dr. Darryll J. Pines, University of Maryland College Park

Darryll Pines became Dean and Nariman Farvardin Professor of Engineering at the Clark School on January 5, 2009, having come to the school in 1995 as an assistant professor and served as chair of the school's Department of Aerospace Engineering from 2006 to 2009. As dean, Pines has led the development of the Clark School's current strategic plan and achieved notable successes in key areas such as improving teaching in fundamental undergraduate courses and raising student retention; achieving success in national and international student competitions; giving new emphasis to sustainability engineering and service learning; promoting STEM education among high school students; increasing the impact of research programs; and expanding philanthropic contributions to the school. Today, the school's one-year undergraduate retention rate is 90%, the university's Solar Decathlon team placed first worldwide in the most recent competition against other leading universities, our Engineers Without Borders chapter is considered one of the nation's best, and the Engineering Sustainability Workshop launched by Pines has become a key campus event. Pines has testified before Congress on STEM education and created the Top 25 Source Schools program for Maryland high schools. He is also leading a national effort to develop an AP course in Engineering Design in partnership with the College Board. At $144 million, the school's research expenditures are at a record high, and the school is ranked 11th worldwide by the Academic Ranking of World Universities, which focuses on research citations. The Clark School has led the university in achieving and surpassing its $185 million Great Expectations campaign goal, going on to reach $240 million as of the most recent accounting. Pines also served on the university's strategic planning steering committee. During Pines' leadership of aerospace engineering, the department was ranked 8th overall among U.S. universities and 5th among public schools in the U.S. News and World Report graduate school rankings. Pines has been director of the Sloan Scholars Program since 1996 and director of the GEM Program from 1999- 2011, and served as chair of the Engineering Council, director of the NASA CUIP Program, and director of the SAMPEX flight experiment. During a leave of absence from the University (2003-2006), Pines served as Program Manager for the Tactical Technology Office and Defense Sciences Office of DARPA (Defense Advanced Research Projects Agency). While at DARPA, Pines initiated five new programs primarily related to the development of aerospace technologies, for which he received a Distinguished Service Medal. He also held positions at the Lawrence Livermore National Laboratory (LLNL), Chevron Corporation, and Space Tethers Inc. At LLNL, Pines worked on the Clementine Spacecraft program, which discovered water near the south pole of the moon. A replica of the spacecraft now sits in the National Air and Space Museum. Pines's current research focuses on structural dynamics, including structural health monitoring and prognosis, smart sensors, and adaptive, morphing and biologically-inspired structures, as well as the guidance, navigation, and control of aerospace vehicles. He is a fellow of the Institute of Physics, the American Society of Mechanical Engineers and the American Institute of Aeronautics and Astronautics, and has received an NSF CAREER Award. Pines received a B.S. in mechanical engineering from the University of California, Berkeley. He earned M.S. and Ph.D. degrees in mechanical engineering from the Massachusetts Institute of Technology.

Stereotypes and implicit biases in engineering: Will students need to Whistle Vivaldi?

Abstract

Despite numerous calls to increase representation of women and minorities, the engineering education system is still challenged to be more inclusive of women and underrepresented minorities. Scholars have suggested that the imbalance is largely related to sociocultural factors and prevalent stereotypes and implicit biases. This study investigated how high school teachers characterize engineering stereotypes, stereotype threat, and implicit biases, and conceive their roles and responsibilities amid calls for inclusivity in the field. Data was collected through focus group interviews during a professional development effort for high school teachers. Thematic analysis revealed teacher perspectives of long-standing issues affecting diversity in engineering especially in the frameworks of social culture. The study has implications for research as well as practice by providing insight into stereotype threats and implicit biases from the K-12 teacher angle and laying out grass roots solutions at the classroom level.

Keywords: Engineering education, high school, teacher professional development, stereotypes, biases, stereotype threat

Introduction

The field of engineering is vast and dynamic and encompasses cutting-edge occupations that yield innovative solutions to problems persisting in local communities as well as globally. Increasing and retaining a diverse engineering workforce is therefore critical for any country [1]. A diverse workforce not only renders a greater range of world-views, but also provides insight into the needs and motivations of the communities [2]. Yet, a racially and ethnically diverse engineering workforce has been an enduring concern for the past 25 years [3].

Despite numerous calls by national leaders and committees to increase representation of women and minorities [4], [5], the engineering education system is still challenged to be more inclusive of women and underrepresented minorities [6], [7]. According to Anderson et al. [1], numbers for both Hispanic and Black engineering graduates remain low. Hispanic students compose 19 percent of university undergraduates, but only 11 percent were conferred engineering bachelor's degrees in 2016. African-American students show similar gap. The disparities between females and males in engineering programs persist. Women are earning the majority of all bachelor's degrees across racial and ethnic groups, except in engineering. According to the *2018 Status Report on Engineering Education: A Snapshot of Diversity in Degrees Conferred in Engineering*, among bachelor's degrees conferred in 2016, engineering was the second-largest field of study for White males and Asian American males [1]. It was the fourth-largest field of

study for Hispanic males, and the tenth-largest for African American males. However, among female graduates in 2016, engineering was ranked significantly lower. It was the eighth-largest field of study for Asian American females and among White, Hispanic, and African American females, the field of engineering was ranked eighteenth. According to Katehi, Pearson, and Feder [8], the lack of diversity present in higher education is also mirrored in K-12 system. The authors state,

> This problem is manifested in two ways. First, the number of girls and underrepresented minorities who participate in K–12 engineering education initiatives is well below their numbers in the general population. Second, with a few exceptions, curricular materials do not portray engineering in ways that seem likely to excite the interest of students from a variety of ethnic and cultural backgrounds. For K–12 engineering education to yield the many benefits its supporters claim, access and participation will have to be expanded considerably (p. 10).

Scholars have suggested that the imbalance at the K-12 level is also related to socio-cultural factors [9], [10]. School teachers' beliefs and actions could negatively influence students' educational experiences and serve as obstacles to minority group's pathways from high school to engineering degree-seeking programs. Students of color, especially Hispanic and African-American students are often questioned by teachers regarding their academic abilities, more so than their White and Asian American counterparts [11], [12]. Similarly, there are commonly held gender-related stereotypes and discrimination experiences that negatively impact female students' engineering identities and often dissuade them from considering or pursuing engineering [13], [6].

Past studies have examined the beliefs and expectations of educators about pre-college engineering instruction [14], [15], [10]. However, few have investigated the perspectives of high school engineering educators and their perceived roles and responsibilities in addressing efforts to bolster inclusivity in the field. The present study attempts to address this gap. The study is situated in the Engineering for Us All (E4USA), a new high school level engineering education initiative funded by the National Science Foundation. The E4USA initiative aims to 'demystify' engineering for high school students and teachers by creating an all-inclusive high school level engineering course. Two key components of the project include: 1) in-person and online teacher professional development (PD) and 2) a learning community of teacher educators, engineering educators, and practicing engineers. The PD specifically includes a session that aims to create awareness regarding implicit biases and negative stereotype threats concerning engineering education. The overarching goal of the PD and the learning community is to help teachers make positive changes in their classrooms to affect student pathways to higher education institutes.

High school educators are critical change agents in promoting the pursuit of engineering degree programs among diverse students [14]. They have the opportunity to challenge harmful

stereotypes by increasing social belonging and confidence, and empathizing with students' lived experiences. Given the opportunity for teachers to act as change agents to promote the pursuit of engineering degree programs among diverse students, we aimed to learn more about teachers' perspectives regarding engineering stereotypes and inclusive practices. The purpose of the current study was to examine how high school teachers characterize engineering stereotypes, stereotype threats, and implicit biases in relation to their roles and responsibilities.

The specific research questions addressed by the study in the context of the E4USA PD, include:
> 1. How do high school teachers participating in the E4USA professional development characterize engineering stereotypes, stereotype threats, and implicit biases?
> 2. How do high school teachers participating in the E4USA professional development intend to address negative stereotype threats in their engineering classrooms?

Stereotype, Implicit Bias, and Stereotype Threat in Engineering Education

A stereotype is a simplified or standardized conception or image invested with special meaning and held in common by members of a group. The tendency for stereotype-confirming thoughts to pass spontaneously through a person's mind is implicit bias. These thoughts may be contrary to one's conscious or declared beliefs. Research has shown that implicit bias and prejudice are typically not the source of an avoidance behavior where a member of one group might choose not to be near a member of another group. Instead, it is the threat of confirming a stereotype about your own group that one fears [16].

Stereotype threat is defined as the condition of being at risk of confirming a negative stereotype about a group to which one belongs. For example, stereotype threat exists for girls taking a math test because of the stereotype that girls cannot "do math". In *Whistling Vivaldi*, Claude Steele [17] summarizes,

> Stereotype and identity threats increase vigilance toward possible threats and bad consequences in the social environment, which diverts attention and mental capacity away from the actual task at hand, which worsens performance and general functioning, all of which further exacerbates anxiety, which further intensifies the vigilance for threat and the diversion of attention. A full scale vicious cycle ensues, with great cost to performance and general functioning (pp. 125-126).

Individuals who are more likely to be affected by the effects of stereotype threat are ones who are strongly invested in the domain in which they are being evaluated or are strongly committed to their group identity [17]. Continuing with the mathematics example, a girl who either

identifies strongly with being female or a girl who prides herself on her mathematics skills is particularly susceptible to stereotype threat. Stereotype threat is most robust in situations that include a variable that "triggers" the stereotype.   Tests that are explicitly framed as ability tests or difficult tests are more likely to heighten stereotype threat [18]. As Ben-Zeev, Fein, & Inzlicht reported [19], an identity threat, such as telling women who identified with math that they would take a very difficult math test, was enough to cause them to perform poorly on a test completely unrelated to math and easy to do - writing their name backwards.

Literature recommends numerous techniques to reduce stereotype threats in a learning environment:

- Teach students about the phenomenon of stereotype threat [20].
- Provide students with situational (as opposed to stereotype-based) explanations for anxiety experienced in evaluative situations [17].
- Provide students with alternate, positive stereotypes [21].
- Emphasize high standards as you provide feedback to students, holding them accountable to those standards. Reassure students that they are capable of meeting the standards [22].
- Teach students to self-affirm – the act of reflecting on a valued, personal attribute. [23], [24].
- Teach female math students about women who have achieved high levels of success in math [25].
- Limit or eliminate variables that are likely to "trigger" negative stereotypes during test-taking situations [26].
- Improve a group's critical mass in a setting as this may allow the marginalized group to increase its members' trust, comfort, and performance in that setting [27].

Methodology

Context

During the first year of the E4USA project, nine high school teachers were recruited to teach the E4USA course in local high schools. Each teacher attended one of two five-day PD workshops at a large U.S. university during the summer of 2019. Instructors were university professors, many of whom had helped design the curriculum. To address implicit biases and stereotype threat, a continuing issue within engineering education, teacher participants were tasked to read the first three chapters of the book "*Whistling Vivaldi - How stereotypes affect us and what we can do*"

[17] before attending the PD. Through personal stories and research results, the author provides a rich understanding of how being aware of negative stereotypes toward one's racial/ethnic group diminishes the ability to perform. On the third day of the workshop, an hour-long session was conducted by one of the instructors with expertise in broadening participation in engineering. She addressed topics including stereotype threat [17], implicit bias, imposter syndrome, engaging underrepresented students in engineering, and adopting a growth mindset [21].

Participants

Seven teachers participated in the study. They are currently teaching the E4USA course in public high schools located in Arizona, Maryland, Washington, D.C., rural Virginia, and Pennsylvania with predominantly either Latino, African-American, or White student bodies. The teachers themselves included three White males, one White female, two African-American females, and one African-American male. Four of the seven teachers were already teaching some type of engineering topics in their high schools before joining the E4USA program. Note that the terms 'participants' and 'teachers' are used interchangeably throughout the paper.

Data Collection

Toward the end of the PD week, building on the readings and classroom presentation described earlier, an approximately 90 minute long focus group discussion was conducted with the participants. The following five questions were used to collect data, followed by additional questions based on the participant's responses:

1. Share something that stuck out to you from the first three chapters of the book *Whistling Vivaldi* [17].
2. How do you see stereotype threat as relevant to the efforts of advancing engineering education in the K-12 space?
3. What have you observed regarding some student groups not feeling as comfortable as others in the engineering classrooms?
4. What are some concrete ideas in which teachers can address the negative stereotypes and embed a sense of belonging in engineering classrooms for underrepresented populations?
5. What kind of messaging can teachers give at the beginning of a course, when starting a unit and/or at the start of a final exam to possibly lower stereotype threats for females and minority students?

Analysis

Qualitative data analysis followed an inductive approach outlined by Miles, Huberman, and Saldaña [28]. In the first cycle, data units were open-coded by two members of the research team

based on the concepts underscored by participants during discussion [29]. The coding scheme was reviewed by another member of the research team and code definitions were revised where necessary. In the second cycle, the constant comparative method was used to develop a common set of repeated themes [30]. Codes were merged or expanded to yield major themes of interest with 100% agreement among the research team.

Results

During the focus group discussion, teachers not only shared their present-day school experiences but also reflected on their own life experiences that touched upon stereotyping and biases. They talked about actions they could take to mitigate the effects of negative stereotypes and reshape their students' identities. Thematic analysis resulted in seven themes including, magnitude of the problem, characterizations of stereotypes, characterizations of stereotype threats, characterizations of implicit biases, onus falling on the stereotyped, teacher roles, and societal influence. In the following subsections we present the results for each of the research questions in a narrative with embedded participant quotations.

Characterizations of engineering stereotypes, stereotype threats, and implicit biases

Themes of magnitude of the problem, characterizations, and onus falling on the stereotyped conveyed participants' views on engineering stereotypes, stereotype threats, and implicit biases. All participants recognized that stereotypes and implicit biases were a "critical problem" because there are many "pockets in the country" where "classrooms are not diverse." Teachers admitted that stereotyping was "human nature". They compared stereotypes and implicit biases to "physical conditioning [that is] built from all the life experiences" as "unintentional consciousness."

```
The consciousness that we possess when we walk down the
street, things that we determine from a distance, not
always correct, but we do stereotype. A lot of times we do
it as a matter of safety, just like animals do things as
being cautious.
```

Specific to the high schools and perceptions of engineering classrooms, the teachers indicated that there is a prevailing engineering stereotype that "you have to be good in school, you have to have good grades in the math, or science side of things." This kind of stereotyping "still impacts our lives, but not in such a critical way as, as well as law enforcement can, in terms of stereotyping different groups." A teacher said, "Students also have their own sense of stereotype. They come in with them from the experiences." To add to their challenge, students also have stereotypes about

> Being a freshman or a senior, it is a big deal. They will
> get caught up in things that they, you know, these
> stereotypes about cliques or who's popular, who's not
> popular over who is good at or not good at and it will
> overwhelm them.

While stereotypes were accepted as omnipresent, stereotype threat was a revelation for the participants. As one teacher explained,

> What stood out to me in the first three chapters was the
> word threat. Everyone has stereotypes, for someone or
> something, you know, in their life, but a perceived threat
> has a major impact. It is good people and the students that
> mean no harm. That harm happened to them.

Though teachers agreed that stereotype threat "is an issue that we definitely need to talk about [as] it impacts us in learning and our ability to perform," there was also an indication of the acceptance of the issue because of its pervasiveness:

> We all have our perceived threats, you know, but it's just
> that. Because of the society we live in. It is one dominant
> group to another or, several groups to the other [...] you
> shouldn't have to whistle. But in a lot of cases, you do.
> And until we, until people overcome that by finding a way.
> I think with the diversity, over time, maybe you will need
> to. Hopefully.

As the discussion progressed, the teachers questioned the fact that the onus of overcoming the threats falls on the people who are stereotyped.

> Why should I always have to be the one to do the whistling
> to calm others, whether I wear a hoodie or a suit? But the
> onus goes on. It shouldn't be anyone's on this, but it
> seems like the onus falls on the people, people who are
> stereotyped [...] so what do we have to do in order to seem
> non-threatening? I mean, first is whistling, then what
> else?

Overall, the teachers agreed that the underrepresented groups often ended up 'whistling' i.e. adopting behaviors to "make people see you for what you wanted them to see you." "Working harder to prove" one's capabilities, "presenting oneself professionally by dressing up", "putting

the hood down", and "showing hands on the steering-wheel" were 'whistling' actions that should not be needed.

Addressing negative stereotype threats

The theme of teacher roles conveyed what teachers perceived as their responsibility to address the classroom issues related to stereotype threats as evident from this statement:

> ```
> It is not that it is every day. But when you are presented
> with opportunities to kind of break those stereotypes or
> educate about those stereotypes, you sort of have that
> responsibility to do so, whether it is about math, whether
> it is on race.
> ```

Teachers talked about the importance of creating a "friendly, competitive, positive student centered atmosphere" by including "team building and icebreaker game kind of activities" and "give[ing] the female students confidence to want to assimilate to other groups that they originally did not feel they belong to or could." They discussed various actions that they could take such as engaging students in role-play activities, inviting students to become peer tutors to build their confidence, providing role-models and vicarious experiences, arranging buddy programs to invite other students to experience the engineering classroom and the curriculum, and initiating after school robotics programs. They recognized that "you have to make the step. Nothing changes if you don't make the step, [even if] a small one."

Specifically addressing the stereotypes around female students in engineering, one teacher said,

> ```
> There is a perceived stereotype that the girls are not
> interested in engineering. My biggest problem is that they
> are interested. They just need support mechanisms. We have
> grown, the number of girls in our program over the last
> seven years, and most of the girls turn out to be some of
> the better engineers when you get right down to what the
> skills of an engineer are.
> ```

When asked about support mechanisms, participants mentioned "funding in terms of stipends, scholarships, paid internships, bank loans that the parents can afford", "student support groups at the college level", "mentorship from employers and former students." Teachers also included themselves in the support mechanisms:

I saw a statistic. It was something like 80% of the female
engineers became engineers at the invitation of their
teachers. Since then I can, I recruit them from Physics. I
try to reach out to the girls way more so than I do, to the
boys just for that reason.

There was a consensus that "college is going to be quite different, professors may not necessarily treat you as one of their own because that's not that's not what they do." So, it is necessary to "help the students in high school, understand the next level before they get there [...] to look for where the support groups are, and if there isn't one, create them." Recognizing that female and minority students often want to work in isolation or homogeneous groups, teachers talked about "calling the elephant out as soon as you identify it" –

Sending the message that you are part of a team and you
need to figure out how you are going to work together, and
you know, getting them out of their comfort zone. When you
explain to them, you are going to need to get over,
overcome this and learn how to work together. If you are
going to be successful, you are going to need to apply
those skills in the real world. So better off you
experienced this now, when you have a safety net.

Despite showing willingness to make a difference in their classrooms, there was a "feeling of diminishing returns" among teachers as they talked about "the messages that society sends to these young minds." Citing his daughter's example, a participant explained,

One thing that kind of struck me as a father of a girl who
you wanted to do all this wonderful stuff, you know that
we're doing in engineering. My wife and I can both tell her
as many times as we want, but there's a bigger society out
there that she's part of. You want to buy a million LEGO
sets or drop all those wonderful things you can, but at the
same time, what is she receiving or not.

Another teacher pointed out,

I think growing up, both my grandfathers were carpenters
and those tools were passed down the generations. Tools
weren't intimidating because my dad had me in the garage.
But I found that special that no kids get to use tools like
that anymore. That is not happening. You know the numbers

```
of engineers are low across the board [because] tools are
intimidating. Female students especially never had access
to tools or a chance.
```

Teachers also conveyed feelings of having limited influence on students' engineering pathways because of often conflicting messages from within the school. Continued support and encouragement from administration were deemed crucial for teachers and students.

Discussion

It is interesting that, in just one focus group after one reading assignment and one session of discussion, the teachers brought up long-standing issues affecting diversity in engineering with relative ease. The ideas are well-established and in many cases, have persisted through decades: societal, social, and peer pressure serve to dissuade some people from pursuing engineering and groups that have been traditionally underrepresented and continue to be underrepresented [31] - [33]. Indeed, we know that, beyond the concept of stereotypes, stereotype threat is directly applicable: for example, a female student considering engineering as a field of study, who experiences multiple messages indicating that 'engineering is for male students,' could steer away from engineering. The focus group of teachers had no trouble acknowledging and accepting that stereotypes of engineering students exist, stereotype threat could dissuade students from engineering, and implicit bias plays a role in the classroom.

We found the emergence of "threat" early in the discussion, and some participants were struck by the term. Understanding that stereotypes exist is almost a certainty, but an appreciation that stereotypes can pose a legitimate threat is a significant realization: "`but a perceived threat has a major impact.`" Understanding stereotype threat is a first step toward mitigating its effects and addressing potential solutions.

In Whistling Vivaldi [17], an adult African American male found that simply walking down the street could cause a reaction based on a stereotype. He found that by whistling the tune of Vivaldi's music while walking, he was able to mitigate the perceived threat and disrupt the perceived stereotype. How can we break the negative stereotypes that keep students away from STEM? As Steele [17] explains, the first step is to understand their effect and acknowledge that "you shouldn't have to whistle."

Discussion on solutions ranged from an acknowledgement of one's own implicit biases - while we likely intend to disavow those stereotypes, our implicit biases are reinforced through societal influences, such as social media and can manifest themselves quietly and without warning. Discussion for the students themselves focused on self-advocacy, such as finding or creating a support group. Finally, institutional mechanisms were discussed, such as different financial aid

models, availability of internships, and support mechanisms. However, possibly the greatest value of the introduction to these topics was the identification of the teachers themselves as advocates and agents of change: `something like 80% of the female engineers became engineers at the invitation of their teachers.` By understanding and challenging stereotypes and implicit biases, restructuring the messages to be more inclusive, and recruiting - or introducing engineering to more diverse audiences, teachers can make a tremendous difference [31], [32].

While our efforts appear to be valuable, we worked with a small group of teachers who understood that they were in the initial cohort of teachers for this program. In general, they may be considered somewhat 'early adaptors,' or innovators, and may be more willing to adopt change. A larger group may have a different dynamic than a small number of focused, willing participants. Further, our PD and research teams were also integral parts of this specific curriculum and have done research in this area, and the results may not be easily transferable.

The issues poignantly described in *Whistling Vivaldi* [17] and the implicit biases within engineering classrooms persist to this day. Therefore, these conversations and actions to enact change must continue with adequate support for teachers. To that extent, the E4USA instructional team and teacher educators will engage in multiple reflections and discussions throughout the remainder of the project. Educators will be asked to reflect upon how their preparation for the academic year has been impacted by reading the *Whistling Vivaldi* [17] text. At the end of the school year, educators will be asked to share how their plans aligned or needed to be altered based on increased rapport with students as well as the actions they may have taken to create an inclusive engineering classroom culture with an intention of mitigating implicit biases and stereotype threats. Furthermore, educators will be asked to read the remaining chapters of *Whistling Vivaldi* [17] and engage in meaningful dialogue in an effort to make changes beyond their classrooms. Such changes may include collaborating with school guidance counselors or engaging with other high school students to encourage their participation in engineering classrooms. We are planning a longitudinal study with E4USA participants to examine their actual classroom practices in the following year. Future studies with more participants in different high school settings would provide evidence on a larger scale.

Conclusion

Despite the role K-12 teaching may play in students' choice of seeking engineering degrees, teachers are rarely provided with adequate support to develop effective approaches for working with underrepresented students. As the student populations at the K-12 level become increasingly diverse in various parts of the nation, the importance of enacting change in teacher practices with regard to stereotype threats and implicit biases will continue and grow.

Acknowledgements

References

[1] E. L. Anderson, K. L. Williams, L. Ponjuan and H. Frierson. "The 2018 status report on engineering education: A snapshot of diversity in degrees conferred in engineering", Association of Public & Land-grant Universities, Washington, D.C., 2018.

[2] D. E. Chubin, G. S. May, and E. L. Babco, "Diversifying the engineering workforce," Journal of Engineering Education, vol. 94, no. 1, pp. 73-86, 2005.

[3] J. Passel and D. V. Cohn, "Immigration projected to drive growth in US working-age population through at least 2035", Factank: News in the Numbers, vol. 8, 2017.

[4] Committee on Equal Opportunities in Science and Engineering (CEOSE), "Broadening participation in America's STEM workforce," 2013–2014 Biennial Report to Congress, National Science Foundation, Arlington, VA, 2015.

[5] National Academy of Engineering, "Changing the conversation: Messages for improving public understanding of engineering," Committee on public understanding of engineering messages. Washington DC: National Academies Press, 2008.

[6] A. F. McKenna, M. Dalal, I. Anderson, and T. Ta, "Insights on diversity and inclusion from reflective experiences of distinct pathways to and through engineering education," in Proceedings of the 1st annual CoNECD - The Collaborative Network for Engineering and Computing Diversity Conference, Crystal City, VA, April 29-May 2, 2018.

[7] D. Riley, A. E. Slaton, and A. L. Pawley, "Social justice and inclusion: Women and minorities in engineering," in *Cambridge Handbook of Engineering Education Research*, A. Johri and B. M. Olds, Eds. New York: Cambridge University Press, 2014, pp. 335-356.

[8] L. Katehi, G. Pearson, and M. A. Feder, "Engineering in K-12 education. [electronic resource] : understanding the status and improving the prospects," Washington DC: National Academies Press, 2009.

[9] M. H. I. Scutt, S. K. Gilmartin, and S. Sheppard, "Informed practices for inclusive science, technology, engineering, and math (STEM) classrooms: Strategies for educators to close the gender gap," in *120th ASEE Annual Conference and Exposition, Atlanta, GA, June 23-26, 2013*.

[10] H. H. Wang, T. J. Moore, G. H. Roehrig, and M. S. Park, "STEM integration: Teacher perceptions and practice," *Journal of Pre-College Engineering Education Research (J-PEER)*, vol.1, no. 2, pp. 1-13, 2011.

[11] J. Anyon, "Social class and the hidden curriculum of work," *Journal of Education*, vol. 162, no. 1, pp. 67-92, 1980.

[12] G. Gay, "Preparing for culturally responsive teaching," *Journal of Teacher Education*, vol. 53, no. 2, pp. 106-116, 2002.

[13] N. Marsden, M. Haag, L. Ebrecht, and F. Drescher, "Diversity-related differences in students' perceptions of an industrial engineering program," *The International Journal of Engineering Education*, vol. 32, no. 1, pp. 230-245, 2016.

[14] M. M. Hynes, "Middle-school teachers' understanding and teaching of the engineering design process: A look at subject matter and pedagogical content knowledge," *International Journal of Technology and Design Education*, vol. 22, no. 3, pp. 345-360, 2012.

[15] M. J. Nathan, N. A. Tran, A. K. Atwood, A. M. Y. Prevost, and L. A. Phelps, "Beliefs and expectations about engineering preparation exhibited by high school STEM teachers," *Journal of Engineering Education*, vol. 99, no. 4, pp. 409-426, 2010.

[16] P. A. Goff, Steele, and P. G. Davies, "The space between us: Stereotype threat and distance in interracial contexts," *Journal of Personality and Social Psychology,* vol. 94, pp. 91-107, 2008.

[17] C. M. Steele,*Whistling Vivaldi: and Other Clues to How Stereotypes Affect Us*. New York, NY: W.W. Norton & Company, Inc., 2010.

[18] C. M. Steele and J. Aronson, "Stereotype threat and the intellectual test performance of African Americans," *Journal of Personality and Social Psychology,* vol. 69, pp. 797-811, 1995.

[19] T. Ben-Zeev, S. Fein, and M. Inzlicht, "Arousal and stereotype threat," *Journal of Experimental Social Psychology*, vol. 41, no. 2, pp. 174-181, 2005.

[20] R. W. Grossman, S. Kim, L. Tan, and T. E. Ford, "Stereotype threat and recommendations for overcoming it: A teaching case study," *National Center for Case Study Teaching in Science*, Oct. 29, 2008.

[21] C. Dweck, "Carol Dweck revisits the growth mindset," *Education Week*, vol. 34, no. 5, pp. 20-24, 2015.

[22] G. L. Cohen, C. M. Steele, and L. D. Ross, "The mentor's dilemma: Providing critical feedback across the racial divide," *Personality and Social Psychology Bulletin,* vol. 25, pp. 1302-1318, 1999.

[23] G. M. Walton and G. L. Cohen, "Stereotype Lift," *Journal of Experimental Social Psychology*, vol. 39, pp. 456-467, 2003.

[24] G. L. Cohen, J. Garcia, N. Apfel, and A. Master, "Reducing the racial achievement gap: A social-psychological intervention," *Science*, vol. 313, pp. 1307-1310, Sept. 1, 2006.

[25] R. B. McIntyre, R. M. Paulson, C. G. Lord, "Alleviating women's mathematics stereotypes through salience of group achievement," *Journal of Experimental Social Psychology*, vol. 39, pp. 83-90, 2002.

[26] G. M. Walton and S. J. Spencer, "Latent ability: grades and test scores systematically underestimate the intellectual ability of negatively stereotyped students," *Psychological Science,* vol. 20, no. 9, pp. 1132-1139, 2009.

[27] V. Purdie-Vaughns, C. M. Steele, P. G. Davies, R. Ditlmann, and J. R. Crosby, "Social identity contingencies: How diversity cues signal threat or safety for African Americans in mainstream institutions," *Journal of Personality and Social Psychology,* vol. 94, pp. 615-630, 2008.

[28] M. Miles, A. Huberman, and J. Saldaña, *Qualitative Data Analysis: A Methods Sourcebook* (3rd Ed.). Thousand Oaks, CA: Sage Publications, 2014.

[29] S. J. Tracy, *Qualitative Research Methods: Collecting Evidence, Crafting Analysis, Communicating Impact*. Hoboken, NJ: John Wiley & Sons, 2013.

[30] J. Corbin and A. Strauss, *Basics of Qualitative Research* (4th ed.). Los Angeles, CA: Sage, 2015.

[31] National Academy of Engineering, "*To Recruit and Advance: Women Students and Faculty in U.S. Science and Engineering,*" Committee on the Guide to Recruiting and Advancing Women Scientists and Engineers in Academia, Committee on Women in Science and Engineering. Washington DC: National Academies Press, 2006.

[32] National Academy of Engineering, "*Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads,*" Committee on Underrepresented Groups and the Expansion of the Science and Engineering Workforce Pipeline; Committee on Science, Engineering, and Public Policy. Washington DC: National Academies Press, 2011.
[33] G. Lichtenstein, H. L. Chen, K. A. Smith, and T. A. Maldonado, "Retention and persistence of women and minorities along the engineering pathway in the United States," in *Cambridge Handbook of Engineering Education Research,* A. Johri and B. M. Olds, Eds. New York: Cambridge University Press, 2014, pp. 311-334.