Understanding the 'us all' in Engineering 4 Us All through the Experiences of High School Teachers

Dr. Bruk T Berhane, University of Maryland College Park

Dr. Bruk T. Berhane received his bachelor's degree in electrical engineering from the University of Maryland in 2003. He then completed a master's degree in engineering management at George Washington University in 2007. In 2016, he earned a Ph.D. in the Minority and Urban Education Unit of the College of Education at the University of Maryland. Bruk worked at the Johns Hopkins University Applied Physics Laboratory, where he focused on nanotechnology, from 2003 to 2005. In 2005 he left JHU/APL for a fellowship with the National Academies where he conducted research on methods of increasing the number of women in engineering. After a brief stint teaching mathematics in Baltimore City following his departure from the National Academies, he began working for the Center for Minorities in Science and Engineering (CMSE) in the Clark School of Engineering at the University of Maryland. In 2011, he began working directly under the Office of the Dean in the Clark School, coordinating outreach and recruitment programs for the college. In 2016, he assumed the role of director of the Office of Undergraduate Recruitment and Scholarship Programs. His duties entailed working with prospective freshmen and transfer engineering students. In 2018, he transitioned to the role of Assistant Research Professor in the Department of Bioengineering at the Clark School. His research interests transfer students who first enroll in community colleges, as well as developing broader and more nuanced engineering performance indicators.

Dr. Medha Dalal, Arizona State University

Medha Dalal is a postdoctoral scholar at Arizona State University. She received her B.S. in Electrical Engineering from Gujarat University, M.S. in Computer Science from New York University, and Ph. D. in Education from 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. Adam R Carberry, Arizona State University

Dr. Adam Carberry is an associate professor at Arizona State University in the Fulton Schools of Engineering Polytechnic School. He earned a B.S. in Materials Science Engineering from Alfred University, and received his M.S. and Ph.D., both from Tufts University, in Chemistry and Engineering Education respectively. His research investigates the development of new classroom innovations, assessment techniques, and identifying new ways to empirically understand how engineering students and educators learn. He is currently the chair of the Research in Engineering Education Network (REEN) and an associate editor for the Journal of Engineering Education (JEE). Prior to joining ASU he was a graduate student research assistant at the Tufts' Center for Engineering Education and Outreach.

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 & 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 Computer Science education, STEM education, teamwork design, online learning, and cybersecurity.

Currently, she is on a research team examining the impacts of the Summer Engineering Education for Kids out-of-school program for racially underrepresented youth.

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. 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.

Understanding the 'us all' in Engineering 4 Us All through the Experiences of High School Teachers

Introduction

A sharp rise in K-12 engineering education programs and related research has taken place since our nation's need for engineering professionals has grown (Brophy, Klein, Portsmore, & Rogers, 2008; Purzer, Strobel, & Cardella, 2014). This prompted our efforts to develop a new high school level engineering education initiative called Engineering for Us All (E4USA). This National Science Foundation (NSF)-funded initiative was launched in 2018 as a partnership among five universities across the nation to 'demystify' and 'democratize' engineering for a diverse group of high school students and teachers. The program aims to create an all-inclusive high school level engineering course(s), professional development (PD) platform, and learning community to support student pathways into higher education institutions.

The initial E4USA course was developed with all students in mind in an attempt to be inclusive of those who both do and do not plan to pursue engineering as a career. The resulting design-focused course introduces engineering through four thrusts: 1) discovering engineering, 2) engineering in society, 3) engineering professional skills, and 4) engineering design. This allows teachers and students to make personal connections to the field of engineering. Complementary PD was designed with the same intent, to be inclusive of all teachers regardless of their previous experiences with engineering. The course consists of multiple project-based modules spanning seven units that offer students opportunities to think like an engineer and develop skills such as problem-solving, design thinking, innovation, and collaboration. The underlying goal is to enable students from across demographically and geographically diverse learning communities to become better prepared for academic challenges.

The pilot implementation of the curriculum during the 2019-2020 academic year enlisted nine high school teachers in geographically and distinctly different racially diverse schools across the nation. The teachers participated in the online PD during Spring 2019 and then attended one of two five-day workshops at one of the partner universities during Summer 2019. This study focuses on a subset of teachers' experiences as they started teaching the E4USA course in local high schools during the first year of the project. Our goal in documenting these experiences was to understand the extent to which teacher experiences vary as a function of student demographics (e.g., race, ethnicity, socioeconomic status) and resource level of the school.

This study takes into consideration distinct high school teacher experiences occurring when teaching the E4USA curriculum to gain insight into engineering education problems at the K-12 level. The study uses a qualitative case-study approach to highlight "multiple truths" (Arghode, 2012) with regard to high school level engineering teaching. The study adds to the existing body of literature at a time when there has been an unprecedented growth in the diversity of students within K-12 education (Cohn & Caumont, 2016) and illustrates how diversity support is practiced at the high school level.

The next sections describe current research efforts in the K-12 engineering space, our conceptual framework, methods used, and emergent findings in the form of case narratives. Each case

embodies diversity from the perspective of high school teachers and collectively provides insights into how student body diversity impacts teachers' pedagogy and experiences. The findings are then discussed highlighting themes across cases in the context of frameworks that represent teacher experiences in conceptualizing race, ethnicity, and diversity of students. Finally, we will describe the implications of this work in advancing K-12 engineering education and mentoring efforts as well as our future plans to continue this line of inquiry.

Literature Review & Theoretical Framework

The literature to date has focused primarily on students' perceptions and motivations, teachers' beliefs and knowledge, and curricula and program success. Though the existing research has expanded our understanding of new K-12 engineering curriculum development and teacher PD efforts, the empirical data on how racial and ethnic diversity of student population influences teaching methods, course content, and overall teachers' experiences remains limited. Specifically, Hynes, Mathis, Purzer, Rynearson, and Siverling (2017) note in their systematic review of K-12 engineering education research that merely two articles out of a total of 218 articles examined race and ethnicity, with both focusing on the perceptions of African-American students in middle and high school (Denson & Hill, 2010; Thompson & Lyons, 2008). Hynes et al. state that "P-12 students often make choices that impact their ability to pursue an engineering degree. They may choose not to pursue advanced science or mathematics courses that are the gateway into many undergraduate engineering programs" (p. 9). Despite the important role educators play in helping to engage diverse groups of students to pursue engineering, little attention has been paid to teachers' experiences and future research is necessary in this area. The growing attention and resources being committed to diversity and inclusion issues (Lichtenstein, Chen, Smith, & Maldonado, 2014; McKenna, Dalal, Anderson, & Ta, 2018; NRC, 2009) further underscore the importance of understanding teachers' experiences, with complementary research-based recommendations for how to implement engineering curricula in racially and ethnically diverse schools to engage all students. Therefore, the perspectives of engineering educators may support further improvement of teacher education and training, and address issues in equity and the achievement gap.

Research Questions

The overall implementation of E4USA fundamentally is guided by an interest in expanding the scope of engineering education to diverse high school classrooms. This particular research effort begins to unpack the degree to which racial and ethnic classroom composition, as well as socioeconomic diversity, influences the ways in which teachers prepare for and respond to their immediate environment in the context of E4USA. In other words, we seek to understand the ways in which E4USA educators' experiences are shaped by the demographic composition of their classrooms, as well as by their overall school environments (e.g., exploring distinctions between well-resourced schools and under resourced schools). Grounded in these lines of inquiry, our primary research question in this article is, *To what extent do E4USA teacher experiences vary as a function of student demographics and school resource levels?*

Limitations

We recognize that different terms like “diverse” and “underrepresented’ can lead to very different foci from one study to another. Indeed, NSF defines underrepresented groups in science and engineering as women, racial and ethnic minorities, individuals with disabilities, and members of economically disadvantaged groups (NSF, 2018). At the same time, diversity-focused investigations may include these categories, but also be more expansive to encompass a different geographic locations, learning styles, and family educational background. Rather than attempt to unpack all of these distinctions across research participants in E4USA, for the purposes of this investigation we primarily limit our definition of “diverse” and “underrepresented” students to racial and ethnic minorities. In particular, the population of minority students that we refer to in this article are students who are identified as African Americans or Hispanics based on data provided by participating high schools. Future articles on the experiences of E4USA participants will likely provide more of an expansive analysis of the impact of this initiative on other “diverse” or “underrepresented” audiences.

As it relates to racial and ethnic minorities, we further acknowledge that the identifiers “African American” and “Hispanic” have been interrogated by scholars to date. In higher education literature, for example, George Mwangi, Fries-Britt, Peralta and Daoud (2016) have articulated experiential differences between Black STEM students who are born in the U.S., and those born in African or Caribbean countries. Similarly, Espinosa, Turk, Taylor, and Chessman (2019) distinguished between the educational outcomes of Hispanic subgroups, including students with family origins Mexico, Cuba, Puerto Rico, El Salvador, and South American countries. In the context of these important contributions to the literature, we acknowledge that our study does not explore particular differences between educators who interact with specific subgroups of African Americans and Hispanic students. This is a topic that we may address in a later study.

Methodology

Analysis of these experiences was undertaken using a collective case-study approach (Creswell, 2013) involving in-depth analysis of a limited number of cases “to focus on fewer "subjects," but more "variables" within each subject” (Campbell & Ahrens,1998, p. 541).

Participants were purposively sampled for the cases in order to gather an information-rich data set (Creswell, 2013). The study focuses on three of the nine teachers participating in the first cohort to implement the E4USA curriculum. Table 1 details demographic information for the nine teachers from which three participants were selected considering the maximum level of variation they presented with regard to geographical location, student diversity, and school context. The participating educators teach in Arizona, Maryland and Tennessee with predominantly Hispanic, African American, and Caucasian student bodies, respectively. To better understand similarities and differences among teaching experiences of these teachers, a rich data set was collected consisting of: 1) semi-structured interviews with teachers at multiple stages during the academic year, 2) reflective journal entries shared by the teachers, and 3) multiple observations of classrooms.

Table 1
Demographic information for all E4USA teachers

Teacher	Location	Gender	Race/Ethnicity	Engineering (Eng) education	Engineering experience	School context (U.S. News & World Report, 2019)
1	TN	M	Caucasian	B.S. (Chemical Eng)	4 years teaching high school Eng classes	Suburban, affluent with 18% minority enrollment
2	AZ	M	Caucasian	None	None	Suburban, 54% minority (majority Hispanic) and 37% economically disadvantaged enrollment
3	MD	F	African American	B.S. (Electronics Eng and Technology)	10 years as a senior quality assurance engineer and 20 years teaching high school Eng and technology classes	Urban, 92% minority (51% African American, 39% Hispanic) enrollment
4	MD	M	Caucasian	1.5 years in eng school before transferring to another major	None	Suburban, well-resourced, 91% minority (64% African American, 18% Hispanic) enrollment
5	DC	M	African American	None	Worked for the Army Corps of Engineers, 12 years teaching high school Eng classes	Urban, under-resourced, 98% minority (66% African American) enrollment
6	DC	F	African American	None	4 years teaching high school Eng classes	Urban, 100% minority (98% African American) enrollment
7	VA	F	Caucasian	None	3 years teaching high school Eng classes	Rural, 1% minority enrollment
8	PA	M	Caucasian	B.S. (Chemical Eng)	11 years teaching high school Eng classes	Suburban, well-resourced, with 25% minority enrollment
9	MD	M	Caucasian	None	5 years teaching high school Eng classes	Suburban, well-resourced with 88% minority (majority Hispanic) and 37% economically disadvantaged enrollment

The interview data was analyzed with an inductive approach outlined by Miles, Huberman, and Saldaña (2014). All teachers' interview transcripts were coded together to

identify common themes across participants. Participants' reflections were analyzed similarly, seeking to characterize their experiences, and observation notes were used to triangulate the findings. Descriptions for each case were written emphasizing the aspects that related to the identified themes. Finally, we looked for commonalities and differences across cases. The results section describes the cases at the individual participant level followed by a cross-case analysis. Please note that the names of teachers, and the names of students that are referenced, are pseudonyms.

Results

Arizona Case

The teacher from Arizona, Mr. Melvin Rogers teaches at a public high school. He is phenotypically a White American male, and is 45 years old. He has been teaching music for the past 22 years with extensive background in symphony orchestra. This is his first time teaching an engineering class. There are 38 students (21% identified as females) in the engineering class. It is a highly diverse student group with 16 Hispanic American students, 14 Non-Hispanic White Americans, three African Americans, two Asian Americans, two Mixed Race students and one student identified as Middle Eastern American. The diversity reflects the overall population of the school. The elective engineering class is also a mixed group of 20 freshmen, seven sophomores, eight juniors and three seniors.

The engineering class is a new experience for the teacher and his students as the engineering course is being offered for the first time at the school. When asked about student diversity in his classroom, Melvin's immediate response is, "you mean things like what we talked about in the summer PDs about minorities and having female engineers and things of that nature?" He admits,

I honestly never really looked at things in that context in the first place. There's a very real possibility that there's all kinds of dynamics of that nature that are actually happening sort of under the surface and I am literally oblivious to them. I don't want to make them uncomfortable or whatever. Something that I feel that, you know, that should not be a consideration.

When interviewing Melvin after he completed the first of seven units in the course and begun the second unit, he is more concerned and conflicted about:

having such a mixed group of students in terms of freshman versus senior […] the range is way bigger, the maturity level, and the prior experience [...] That's not to say that I do not respect the various cultures and ethnicities of my students. But, as I said, to me this should not be an issue that changes the educational experience of students.

He believes that the new setting, higher number of students, and the mixed group of freshmen to seniors has made it challenging "to create a safe space where students feel secure to outwardly personalize their thoughts and ideas."

Interestingly, as conversations progressed over the school year, Melvin mentions, "some of my students have like 504 plans and one [Individualized Education Program, or IEP] with some learning issues (e.g., distracted, always distracting) that come into play with what they submit."

His initial thoughts were “I just want them to survive the process of learning.” Three months later, he writes:

[The IEP student] has taken to [computer aided design]. To the point where he can create the designs required in the tutorial projects just from a single picture. He doesn't seem to need the instructions. Again, not something I want to jinx, but this is a student who has been totally, it seemed, unmotivated and uninterested. Now that's all changed. He's got a long way to go to really understand the design process - this CAD element, to be fair, requires interpretation not actual creation - but I am thinking that his interest, and obvious intuitive skills, with CAD could be a true way forward. If this could give him a way forward, a way out of the academic hole he seems to be in....

Upon further probing, during an interview at the end of the second of seven units in the course Melvin realizes that even his “music classes have [also] been just a mix of anything for years.” He realizes,

I'm so comfortable with the music stuff that I address it immediately. Like, literally on day one, I tell them; Nobody's going to care if it's your first year, and nobody's going to care if you’re a freshman. What they're going to care about is do you have interesting musical ideas and you are easy to work with. I tell the kids flat out. That's actually my only one rule you violate that rule...We’ll deal with anything else that comes up. But if you're going to make people feel less about themselves because of their ideas or anything of that nature […]I'm now realizing that there are things that if I had set up on day one and emphasize, and I mentioned it, but everything on day one for me, and even the first couple of weeks was. Yeah, I know you're not sure why I'm here. I'm not sure why I'm here. We're going to see what happens. It's all going to be good […] If I made it a little more explicit you know hindsight is 2020. These are all things that apply to the engineering class. I think I just wasn't, I wasn't aware of how many parallels there are.

It is unclear if Melvin’s awareness of diversity is lacking, or if he does not consider *having* an awareness of diversity in the classroom as important. It turns out,

That was all my own hang up. I'm now seeing ways of executing things in a much different way as they start out for next year. These kinds of differences should only, in my view, be enhancements. Benefits. These are the things that make a person better to work with. Now, as I write this, I am realizing that I should consider, in the future if nothing else, how I might foster this more directly. How I might work direct positive spins on this. But truthfully I am not there yet with the content of the curriculum. I am, however, putting this on my list of priorities for next year.

Tennessee Case

The teacher from Tennessee, Mr. Mark King teaches at a public high school. He appears to be a White American male, is 43 years old, and holds an undergraduate degree in engineering. He has participated in five years of an NSF Research Experiences for Teachers (RET) program, working in several engineering labs. He has been teaching science for the past 20 years, including AP Physics 1, AP Physics 2, AP Physics C, AP Physics B, Physical Science, Chemistry, and AP Chemistry. This is his fourth year teaching an engineering class, entitled

"Engineering as Service Learning." There are 23 students (13% females) in the engineering class. It is a moderately diverse student group with two Hispanic American students, 18 Non-Hispanic White American students, and three Asian American students. The diversity reflects the overall population of the school. The elective engineering class is comprised entirely of high school seniors.

When asked about student diversity in his classroom two months into the academic year, Mark replies,

I like to view people as people. And I like to whether you're male, female, this culture, this culture, this race, this race, I just like to view people as people. And so I'm not always cognizant of, Oh, well, this room has three girls and 20 guys in it, or this room has five Asian American and 18 something else. I never really paid that much attention to it, because I look at it as Oh, you're behind me. What do you like to do? What are you as a person, [Adam]? What are the things that you symbolize as being you and then treat [Wendell] as [Wendell] and treat [Wendell] different than [Cheryl] or somebody else?

After the summer PD, which included reading chapters of Whistling Vivaldi [Steele, 2010], Mark has begun to be more reflective about diversity.

But it has made me go back and look and see. Is there something that I do or say that unintentionally has been biased? Or has unintentionally kept people out or brought people in to STEM classes, including the engineering class?

When asked to reflect upon this course, Mark adds,

One, I would say, making students and making me go through that process of intentionally looking at bias, intentionally looking at differences and valuing those differences. And seeing how those differences can be an asset to a group and in a classroom, makes me look at say, [Wendell], and go, Oh, this is your demographic, this is things that might be and then when I get to know [Wendell], I actually look for the things that are different than aka the stereotype, right? And so it makes me dig a little deeper into getting to know them. That's good.

Pushed further to think about whether or not there have been lessons learned in the E4USA experience to do that he would take to his other science courses (such as AP Physics), Mark affirms,

I actually have seen myself do it. Like when I'm doing a physics lab, where is the usual time I get to go around and talk to them, talk to them and get to know them a little bit better see what they're up to, I find myself looking intentionally to see and ask questions that are more cultural based or more directed, like, "Hey, I see that you are Jane Doe 23. What are you thinking about taking next year? Why are you thinking about taking that next year? Have you looked into these resources, STEM and girls and how that could fit in?" More? Here is John Doe 48. "Oh, I see that you are our typical Caucasian male student here... What career [are] you interested [in]?" Oh, if you thought about these resources, and one of the big ones that I've been utilizing lately is one I learned about at our conference in June was I've been really pushing this whole engineering without borders concept of people. "Do they have this club at this school? Do you know anything about it? Would it be something you're interested in?" Especially with the

students that I know already have a heart for missions, ones that have are I know have already gone to Honduras, Puerto Rico, Louisiana...

When interviewing Mark after he completed the second of seven units in the course and begun the third unit, late in the first semester, his awareness and cognizance of the implications of diversity seem to have increased. His statements are a bit contradictory in that he senses his own increase of awareness, even names some actions, but still states that his teaching practice hasn't changed and downplays his actions.

I'm not going to really say so sure that it has. I think I'm more aware of it. Try to be encouraging for everybody regardless of gender, race…So I don't know that it has. And I know that might not be the answer that people may or may not be looking for. I know I see your face, but I think in reality, that's just where I am. But I am more aware of it. And I would also say that I'm more intentional about making sure that I am encouraging to all sub groups. That I am and I don't know that makes me feel like I've played favorites a little bit, but I do think I am more aware. Or I'm more cognizant, like, Oh, I encouraged this Asian American student. Good job, [Sam] or I have encouraged this female student...You're making sure you're working on that, but I don't know that that's necessarily changed. I don't feel like I've changed what I do day in and day out because of it. Other than I'm more cognizant.

Mark was asked about whether the design solutions made him think about the students' diverse backgrounds or diversity in general, Mark acknowledge a variety of types of diversity, not limited to gender, race or ethnicity, but more focused on the uniqueness of each student's background that he referenced in the first interview.

I don't know that I necessarily see ideas based upon ethnicity or gender roles so much as I see different ideas based upon background. Like, some of them came up with what I've lovingly called the car hood idea. Well, what do you know, they're into cars, or they're into mechanical things that open and close in certain ways with hinges. I think what I see from them, it's more of their experiences in life, whether that has come from parents or culture or whatever that is, I think what I'm seeing is just a product of what they know.

Maryland Case

The teacher from Maryland, Mr. Ben Sones teaches at an online based charter school. It is a combination middle/high school with a total enrollment around 700. It is a bring-your-own-device (BYOD) school so online resources are used heavily. He is phenotypically a White American male of age 37. He teaches US History and volunteered to teach the new engineering class. This is his first time teaching an engineering class, but shared that he had some engineering background; he initially was an engineering major in college, and therefore took several STEM courses before changing his academic pathway. There are 19 students (26% females) in the engineering class. It is a diverse student group with several multi-racial students. When asked for his best estimate, Ron stated that he has five White Americans, four African Americans, four Hispanic Americans, and two Middle Eastern Americans. The diversity in the class is somewhat close to reflecting the ethnic diversity of his school, but the percentage of White Americans in the class is higher than the school average. The overall population of the school is about 65 percent African American, 20 percent Hispanic Americans, and only eight

percent White Americans. The elective engineering class is also a mixed group of four sophomores, seven juniors and eight seniors.

Similar to Melvin, our Arizona teacher, and his students, the engineering class is a new experience for both Ben and his students as the engineering course is a new offering at his school as well. When asked about student diversity in his classroom, although he felt his students were indeed diverse, he also noted that he doesn't try to identify their diversity.

Ethnically kind of all over the board, so much so that I can't even attempt to put it – you know, and then they're not – I don't like to try to pick out what people are and, you know, you always get those forms.

However, later, in his interview, he did admit to his selection of students to participate in the course was driven by awareness of diversity and a desire to introduce engineering to those who may not already have an interest in it.

*So I did have some say into who was in the course, but just by simply who I asked to be in the course. So I did try to boost diversity through that and get students that I knew wouldn't have an interest in engineering but would get something out of th*e course.

Ben admitted in his interview that many of the students signed up for the course, not because they were interested in learning more about engineering, but because they enjoyed him as a teacher.

A lot of the students that I had signed up for the class signed up not necessarily because it's an engineering class but because I'm teaching it, and they had me in US history and liked me, and were like, eh, it'll be fun with Mr. [Sones]. It'll be good times. But that's also cool because I was able to kinda open the doors for some students to engineering.

When asked if his teaching practice changed with regard to students' diversity as a result of the course, Ben shared that the course did not change his teaching practices, but that in general, teaching at the school has changed his practices.

I'll say my teaching style, not just the course but the school I'm at, my teaching style changed, 'cause I did my education courses over in the [other part of Maryland] area where it's not very diverse, while saying over here it's much, much, much more diverse. You know, there's times I'm the only white person in the room, so I think that's very cool. And that we get a good respect both ways. The students respect me. I respect them. It's just kind of learning to be more aware and, you know, more culturally aware.

When sharing his feedback regarding the first unit, Ben shared that his students preferred the hands-on activities. One of the lesson activities enabled students to select the medium to communicate their findings. Other teachers in the program shared their students' preferences for digital media; however, Ben's students, who have had access to digital devices since middle school, preferred to use non-digital supplies.

For the most part my students have been at the school (using their own computers) since middle school so the thrill of being able to use a computer in class has pretty much worn off for them.

When given the option to make a hard copy or digital poster students chose a hard copy. Other schools, it's a treat to be on the laptops. Ours, it's like oh, no, it's a laptop. Okay. So. Since the students used the computer so much in other classes, they really value the hands-on time, and even just stuff with paper and pencil, regular drawings and things like that. They really value that.

In addition to the hands-on learning opportunity, he felt that including examples of engineers not succeeding and making mistakes was valuable for students to learn as well. Recognizing that engineers struggle and don't always have the best solution was useful for his students as they work through the activities in the course.

I think that to kind of get in their mind that engineers can make mistakes and can cause problems as well. When you're trying to do well, you can inadvertently cause issues. And I also think the robotic arm, 'cause giving them the stuff and having them struggle to figure out how to do it. So it was – those two together I think built – the robotic arm built some good camaraderie in the class, even amongst the different groups, and the PlayPumps activity allowed the students to realize that mistakes can happen, and you really need to think about what are the long-term goals of the project you're doing.

Finally, Ron was also asked about whether the design solutions made him think about the students' diverse backgrounds or diversity in general. Although he stated their writing activity on future career interests and engineering did reflect differences, he felt that their design solutions did not necessarily reflect diverse backgrounds. In fact, Ron, shared his belief that not being able to distinguish who is who to be a good thing, as if being able to detect differences in designs based upon his students' diversity, would not be a good thing.

I guess some of the stuff early in like the first unit where they were talking about different careers for engineers and stuff, because I did have people with all sorts of different and diverse careers that they wanted to do. As far as physical and [ethnic] and social diversity, I don't really see that in the output that the students are giving. It's more, you know, if I just had papers with no names on them, a lot of times I'll struggle to know who wrote that paper. Which I think is also a good thing, you know?

Similar to Melvin, Ron also does not seem to consider the awareness of diversity as entirely relevant to the goals of the course. Diversity seems to be a more contextual element of the school that he considers in some sense, rather than a fundamental element of this specific course.

Analysis/Discussion

Melvin, Mark, and Ben each seem to acknowledge that diversity should be a goal for all engineering classrooms, and yet their answers suggest that their experiences as a *function* of diversity (e.g., student demographics, school context) do not vary in any notable manner. Melvin, from Arizona, remarks that considerations of diversity in his classroom "should not be an issue. That should not be a consideration." Similarly, Mark, the Tennessee-based educator, states that he "like[s] to view people as people. And I like to whether you're male, female, this culture, this culture, this race, this race, I just like to view people as people." In addition, Ben

explains that "as far as physical and [ethnic] and social diversity, I don't really see that in the output that the students are giving."

These responses are consistent with findings in other studies in engineering education, in which participants have tended not to consider – at least overtly or consciously – the significance of student demographics like race, ethnicity, or gender. For instance, Jorgenson (2002) found in her work on professional women in the engineering workforce that they tended to credit their success in the field to hard work, rather than discuss gender disparities that they may have had to overcome. Respondents in her research were in fact reluctant to describe themselves as a marginalized group. Berhane (2016) also cited Black engineering transfer students who were more likely to highlight the importance of factors like challenging coursework than the relevance of race, as being pivotal along their engineering trajectories. In general, these students seemed to have more of a *transfer* or *engineering identity* than a *racial, ethnic,* or *cultural identity.* Furthermore, Berhane (2016) found that while his participants were willing to discuss challenges of marginalization or racism, they seemed to position these challenges outside of their experiences in engineering; these issues, from the perspective of his interviewees, exist outside, rather than inside, of the engineering educational context. Collectively, contributions to literature like those from Jorgenson (2002) and Berhane (2016) illuminate a tendency for at least some engineering stakeholders to focus more on the curriculum than differences among student populations. Within this context, it is not an aberration that educators referenced in this study tended to discuss topics related to the course in general, rather than how the course was taught as a function of student demographics or school context.

One might expect that the theme of race or gender might be incorporated differently in an engineering classroom, if the lead instructor happened to be a female and/or teacher of color. Indeed, the work of scholars like Ong, Wright, Espinosa, & Orfield (2011) and Johnson (2011) reveal the complex nature of negotiating being a woman and a racial/ethnic minority in engineering and other STEM fields. In future articles, we hope to provide the voices of women who serve as educators in E4USA, and reflect on their experiences of how their pedagogy varies with student demographics.

Conclusion and Future Work

This article reveals the complexities of considering the experiences of engineering instructors in the context of diverse student classrooms. The original research question, *To what extent do E4USA teacher experiences vary as a function of student demographics and school resource levels?,* seems to generally suggest that there is very little variation across the three White and male teachers in this course. Whether these findings remain true for the duration of the course is a subject for future articles, particularly since, as Melvin says, he is "putting this [topic] on [his] list of priorities for next year." As suggested earlier, it would also be interesting to compare and contrast the reflections of these educators with those of female and/or racial/ethnic minority educators. We hope to interrogate these themes in more detail in future work.

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