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## **Insights on Diversity and Inclusion from Reflective Experiences of Distinct Pathways to and through Engineering Education**

### **Dr. Ann F. McKenna, Arizona State University**

Dr. Ann F. McKenna is a Professor of Engineering and Director of the Polytechnic School in the Ira A. Fulton Schools of Engineering at Arizona State University. Prior to joining ASU, she served as a program director at the National Science Foundation in the Division of Undergraduate Education. She received her B.S. and M.S. degrees in Mechanical Engineering from Drexel University and Ph.D. from the University of California at Berkeley. Her research focuses on design and innovation, entrepreneurial thinking, mentorship approaches of engineering faculty, and she is particularly interested in how to scale and sustain educational innovations to help tell the story of impact.

### **Ms. Medha Dalal, Arizona State University**

Medha Dalal is currently a doctoral student in the Learning, Literacies and Technologies program at Arizona State University. She received her master's degree in Computer Science from NYU-Poly. Medha has worked as an instructional designer/research assistant at the Engineering Research Center for Bio-mediated and Bio-inspired Geotechnics. Prior to joining the doctoral program, Medha was teaching Computer Science and Information Science classes at an engineering institute in Bangalore, India. Her research interests include interdisciplinary design collaborations, hybrid/blended learning for engineering education and pedagogy of technology integration.

### **Ieshya Anderson, Arizona State University**

Ieshya Anderson is Naakét'áhi (Tohono O'odham), born for Tl'ááshchí'í. Her cheii is Naakét'áhi and her náli is Tódich'í'ni. Ieshya graduated from Arizona State University, Ira A. Fulton Schools of Engineering with a Bachelor of Science in Engineering, emphasis in electrical systems. She is pursuing her PhD in Engineering Education Systems and Design at Arizona State University. Ieshya also continues to work with Dr. Shawn Jordan to develop engineering design curricula for middle school students on the Navajo reservation and facilitates Dr. Jordan's STEAM Machines<sup>TM</sup> outreach camps across the Navajo Nation with the ambition to expand to Tohono O'odham Nation.

### **Ms. Thien Ngoc Y Ta, ARIZONA STATE UNIVERSITY**

Thien was born in Phu Yen province in Vietnam. She started PHD program of Engineering Education Systems and Design at ASU in August in 2017. She graduated M.S. in Mechanical Engineering at ASU in August in 2017, M.S. at Ho Chi Minh city University of Technology in 2012 and bachelor in Mechanical Engineering at Ho Chi Minh city University of Education and Technology in Vietnam in 2009. She has taught at Cao Thang technical college since 2009.

# **Insights on Diversity and Inclusion from Reflective Experiences of Distinct Pathways to and through Engineering Education**

## **Abstract**

The topic of diversity and inclusion has been a longstanding topic of exploration within the engineering education community. There are several well-known issues such as 1) the percentage of female students remains low and unchanged for decades despite the desire to influence a change, 2) the typical demographics of engineering students, and by effect future engineering professionals, also do not reflect the demographics of society, thereby leaving out critical perspectives necessary to advance multi textured solutions to diverse needs and challenges, 3) the culture and climate of engineering can be chilly towards non-dominant groups, and 4) the curriculum itself can be enhanced to embrace inclusive pedagogies, and emphasize engineering as a profession that provides value to society . These are just a few of the many topics associated with engineering education, and diversity and inclusion. In our work, we document four distinct individual's pathways that led to the pursuit of engineering, and reflect on how each story provides insights into how experiences and context impact decisions to persist. The stories and corresponding reflections illustrate a "systems view" of engineering education, and embody diversity from the perspective of gender, international identity, career stage, underrepresented minority status, and first-generation. We will present salient features from each pathway that connect to potential recommendations for advancing recruitment and retention efforts in engineering. We will also highlight themes across each pathway in the context of frameworks that represent the college experience, and conceptualizing value within a system.

## **Introduction**

The topic of diversity and inclusion has been a longstanding topic of exploration with the engineering education community. From the onset and over a century long period, societal needs have influenced the evolution of the engineering education field and the field in turn, has shaped society [1], [2]. However, the engineering education system is still challenged to be more inclusive of women and underrepresented minorities to reflect the demographics of society [3]. According to the Census Bureau, women were slightly more than half of U.S. residents, and minorities constituted 36% of the U.S. population in 2010 [4]. The projections also suggest that minorities will be about half of the resident U.S. population by 2050 [4]. However, women represented 21.4% of enrolled engineering undergraduates, 24.1% of enrolled Master's engineering students, and 26.2% doctorate students in the United States in 2015 [5]. These percentages have remained steady for decades and do not approach the 50.6% representation of women in current U.S. society.

Reports across the world show that the proportion of women in engineering schools remains low [6]. Here, we summarize a few. In the United States, while the demographic composition of students planning to major in science and engineering has become more diverse over time, the gender ratio remains poor with women receiving only 19% of the total undergraduate engineering degrees in recent years [7]. Lucas, Claxton, and Hanson [8] referring to the situation in Britain state, “lamentably low numbers of women choose to study or practice engineering.” King [9] reported a decline in the proportion of women in Australian engineering schools from a peak of 20% to 16% in 2006. Likewise, despite representing 1.3% of the U.S. population in 2015, Native Americans only represented 0.4% of all students enrolled in undergraduate, 0.2% of all students enrolled in Master’s, and 0.2% of all students enrolled in Doctoral engineering programs in 2015 [5]. These numbers suggest that the efforts to promote diversity in the student body of engineering schools, even in different parts of the world, have produced modest gains.

Seymour and Hewitt’s [10] seminal work concluded that the challenges of minority and women recruitment are also coupled with the challenges of retention. The authors argued that environmental factors and classroom instruction affect minority students differently, leading to issues of retention and persistence. Since then a well-established body of research has identified several factors that hamper participation of women in engineering schools including unnecessary masculine stereotypes in engineering topics, discrimination, lack of role models, poor advising, and neglected accommodation of family issues [6], [11], [12].

With the purpose of further illustrating these factors and providing potential recommendations for advancing recruitment and retention efforts in engineering we present our own journeys in the ‘system’ of engineering education. Using collective autoethnography, we voice our experiences in the system from the perspective of gender, international identity, career stage, underrepresented minority status, and first-generation students. Our reflections and stories show how experiences and context impact decisions to persist.

## **Methodology**

The idea for the present study was formed as part of a doctoral level engineering education research course, Engineering Education Systems in Context, offered at a large public research university. The course was designed specifically for engineering education students with two primary objectives: 1) provide a systems level understanding of the evolution of the field and current trends, and 2) enable students to frame their research using a systems-level, holistic perspective, considering the future trajectory of the field, and to position how their works adds value within the system. This course has been offered twice since its inception in 2016. During the Fall, 2017 term it so happened that the course was being taught by a female faculty member and the three students enrolled in the course were also all female, each coming from a different ethnicity. As we progressed through the course, from our class discussions, readings and journal writing, it became clear that we all felt strongly about the issues of inclusion and diversity.

Consequently, the instructor, a first generation student herself, suggested it would be fitting to generate a collective article for a collaborative conference focused on exploring current research and practices to enhance diversity and inclusion of all underrepresented populations in the engineering profession.

The collaborative self-study documenting our own experiences is consistent with the theoretical framing of community autoethnography which emphasizes collaboration and community building around an issue among researchers who are also participants [13]. As Ellis, Adams, and Bochner [14] describe, community autoethnography enables researchers to study “the personal experience of researchers-in-collaboration to illustrate how a community manifests particular social/cultural issues” (p. 279). In our case, the issues that emerged in our writings and discussions centered on the challenges of the gender gap, underrepresented minority status, international identities, and first generation students.

The data was generative, embracing the researcher's subjectivity in the spirit of autoethnography. The data emerged from the dynamic communication as we discussed the class readings, related entries in our journals, and our own perspectives of the engineering education system. One researcher's story impelled another's, the instructor's prompts made us question our assumptions, and during writing exercises we examined our own relationship with the system at various stages. Our data were primarily our experiences in the engineering education system which were supplemented by class notes and journal entries. Caulley [15] clarifies that while use of first-person is most common in narratives of auto-ethnography, researchers may use second and third person voice to establish context and to bring readers into the experience. Thus, to provide consistency and coherency for the reader, we present our stories taking on a persona with a pseudonym in the third person.

### **Data: Individual's Stories**

#### *Nisha's Story*

Nisha's perspective of the engineering education system has evolved from a diverse set of experiences in India and in the United States over a period of 25 years and continues to expand with each encounter. However, one realization and related apprehension that has remained a constant across these experiences, and over the years is her status in the system – a minority woman.

Growing up, Nisha loved physics and enjoyed solving math problems and puzzles. She opted for engineering undergraduate studies in India and realized that she was one of five female students in a class of 46 that soon turned into one of four among 46. Faculty was all male. During her freshman year she often wondered, “Is this going to be a lonely journey? Do I really belong here?” Maybe the remaining three girls also sensed the same. A silent pact was formed to ignore

the male hegemony in the system and be ‘one of the boys’. There were other practical matters to consider. It wasn’t clear if she changed her major, she would continue to get the government financial aid meant for women pursuing higher education. The education system in India also did not make it easy to transfer to another discipline.

Halfway through the second year, things changed. A female faculty member, Ms. Rao joined the department and was assigned to teach microprocessors course to Nisha’s class. Her lectures were easy to relate to. She included examples of musical instruments, washing machines, or thermostats in teaching. What a relief to get away from car engines, gears, and turbo-jets, even for an hour! Ms. Rao did not teach just from the textbook. She often cited current news items and talked about how engineering advances were changing the lifestyle of people all around the world. Nisha didn’t realize when, but Ms. Rao had become her role-model and an authentic example of “can do” spirit.

This spirit brought Nisha to the United States for further studies and work in the hope of finding a better, and equitable world. To her surprise, the system here was no different. In fact, this new environment added the issue of identity among the predominantly white, male population of peer group. She felt like a Lilliputian on the island of Brobdingnag (reference from Gulliver’s Travels by Jonathan Swift, see [16]). Nobody understood her “funny” English and she felt lost. With a strong desire to learn and succeed, she simply immersed herself in the studies oblivious to the surroundings. However, the feeling of loneliness and apprehension came back on her first day at work. Meeting the entire team for the first time, she learned that she was the only female and a minority in a group of 24 software engineers. Gender issues were not talked about in the group to any extent, not even when they were discussing user experience of the product. If she brought it up, the discussion soon turned to other issues. With deeply ingrained sense of “dharma” and “karma,” she continued to work. The reality was that being “different” meant that she had to work harder to prove her worth.

Years later, now when Nisha teaches engineering classes or works with engineers on instructional design, she is aware that explicit efforts and positive acknowledgements of differences go a long way in creating the cultural shift. She highlights people and processes over the technical knowhow. She is conscious of the “micro-inequities” and tries to listen, speak, and act inclusively with gender-neutral language, examples, and analogies. She volunteers her time for STEM awareness programs for girls. She believes that successful reform requires both top-down and bottom-up change. She tries to be the change, she wants to see. Who knows, she might be someone’s role-model too!

### *Gloria’s story*

Gloria’s perspective of the engineering education system is anchored in her experience as a first-generation Native American woman earning an engineering bachelor degree. Gloria’s parents,

elders, and teachers all engrained in her the importance of higher education to better serve her community. When she started her undergraduate career, she soon noticed three things. First, she was one of only two or three Native American students in her engineering program. Second, Gloria was also one of the few women in the program. Third, Gloria struggled to relate her core undergraduate courses to her goal of contributing to her community.

Gloria felt out of place and isolated among her engineering peers who were primarily male and non-Native American. The combination of isolation, engineering identity uncertainty, and her struggle to find relevance in core engineering courses led to Gloria dropping out of the engineering program in her second semester. Years later, when Gloria returned to complete her engineering program, the engineering curriculum had evolved. The program better aligned to her engineering goals of directly contributing to community. One example is a project design course which involved designing sustainable solutions based on real global projects sponsored by the university. The project class was comprised of students from various engineering disciplines with the awareness of user-centered design. The course projects were intentionally designed to engage a variety of student interests. The classes were small (about 30 students) and included a higher ethnic and gender ratio than Gloria had experienced years before. The change in curriculum, student diversity, and classroom pedagogy allowed Gloria to connect with the theoretical content in a meaningful way.

During Gloria's senior year, she became involved in a research study investigating cultural connections to engineering among middle school students in schools on tribal land. Her involvement reminded her of her own participation in bridge programs in 8th and 9th grade. The programs Gloria experienced specifically recruited Native American students and had an even gender ratio. Although these bridge programs did not prepare Gloria for the real-world engineering demographic representation, they afforded Gloria the opportunity to see college campuses and introduced core STEM concepts. They had also helped Gloria envision herself in college, making a higher education degree seem attainable.

Gloria has since earned her engineering bachelor's degree and continues work to find cultural connections to engineering. To further this goal, she has decided to pursue an Engineering Education System and Design Doctoral degree to find ways give-back to her tribal community and promote STEM education in schools serving Native Nations.

### *Thiennes' story*

Thiennes has experiences with engineering education as a female engineering student and a faculty member in Vietnam. She studied mechanical engineering at Ho Chi Minh city University of Technology and Education (HCMUTE), one of the top technological universities in South Vietnam. However, very few women students (~ 3%) pursued engineering majors. Thiennes was shocked on the first day of school where most of the students and professors were men. This

made it hard for her to start conversations with her classmates or even ask professors for lecture clarification as she was a quiet and shy girl.

HCMUTE did not have any special policy or scholarship that encouraged women in higher engineering education. Thiennes thought about transferring to a non-engineering major at HCMUTE or another university. Unfortunately, there was no transfer policy at HCMUTE or to another university. She would need to take one year off to retake the entrance exam to be accepted into another university. This might be risky. Besides, she had the common Vietnamese view that she should achieve a bachelor degree to get a job and societal position even if that job does not relate to her professional degree. She decided to stick with her major. Soon she got familiar with the educational environment and realized it was very friendly and supportive. Her classmates and professors were willing to help her with anything they could. She made friends with other women from different majors within common basic classes and shared female stories with them. She did not feel lonely or isolated anymore, instead she had more motivation and inspiration to pursue her major.

After finishing the undergraduate program, she became a lecturer in the mechanical engineering department of Cao Thang technical college (CTTC). Similar to HCMUTE, CTTC had a huge gender gap in engineering majors, and did not have any dedicated focus on diversity of female students before 2011. Since then CTTC has been making steps to increase female enrollment and to retain engineering students as part of the HEEAP (Higher Education in Engineering Alliance Program) program [17]. CTTC has made further improvement to facilities, faculties, and curricula, holding fun and useful contests for CTTC students, and presenting admission or professional orientation sessions for high school students. In addition, the Intel Corporation, a major sponsor of HEEAP, has been offering scholarships for technical female students since 2012. These programs have helped CTTC increase the persistence and retention of technical students, especially women.

In 2016 Thiennes received the Advancing Women in Higher in Engineering Fellowship sponsored by HEEAP. She enrolled in a U.S. university in the Southwest to complete a one-year engineering Master's program, and she graduated in August in 2017. She decided to stay and pursue a PhD in Engineering Education Systems and Design. The fellowship gave her an opportunity to learn abroad as an international student, and make contributions to diversity and inclusion in engineering education. Studying and working with people from different cultures gave her a more holistic view, made classes more interesting, and provided a global perspective that could lead to better ideas or solutions for increasing diversity.

#### *Amy's story*

Amy is the youngest of five children and the only member of her family to have graduated from college. Her father was one of eight children and he completed his formal education at the end of

eighth grade in order to find a job to help support the family. This was typical of the time (1930's), and within his community and social economic status of first generation immigrants to the United States. Amy's father learned a trade (welding) that enabled him to have a lifetime of steady employment in order for him to provide for his family. Amy remembers that her father at various times worked overtime, double time, second or third shift, each of which had different incentives that increased the hourly wage for the extra shift. He was conscientious, honest, and hardworking and use to say that he was able to do better than his father, and that his goal was that his children would do better than him. Amy learned many important lessons from her family but knowledge of college such as how to prepare, apply, and be competitive for admission was beyond their reach, and there was very little discussion about college at home.

Amy was fortunate to have attended a high school where all juniors and seniors were required to take the SAT. Other than knowing the date and time for when to show up for the test, there was no other preparation. Amy completed the test and received a good enough score for admission to one of the two universities she applied. The first financial cost was the \$100 fee to matriculate, which she paid from her savings from the several part-time jobs she held during high school. Amy chose the major mechanical engineering because it seemed like it would lead to a good job, and it was a major her father understood and approved. She did well in math in high school, which was helpful, but did not take advanced courses or have coaching on strategies for how to be successful in college.

She started college at a time when engineering school orientations included statements like "look to your right, look to your left, only one of you will end up graduating." The messaging was that engineering is "hard" and only a few would make it. It seemed like the intent was to create a climate that was intimidating and daunting but that was not a deterrent for Amy. The fact that not everyone would make it confirmed that engineering was a good choice for a fruitful career, since there would perhaps be more jobs available than graduates. Also, the suggestion that engineering was hard was viewed as a challenge, and she was determined to do her best to be successful. Many lessons were learned in the first year of college including the importance of working together in study groups, strategizing about how to approach problem sets, and sharing experiences with peers and learning from more senior students.

One anecdote where knowledge passed down from older students helped, comes from an experience in a first-year mechanical drawing course. This class was pre-computer aided drawing where students learned hand-drawing mechanical mechanisms using drafting tables, T-squares, etc. The instructor had been teaching for many years, was an older white male, and his approach embodied the climate of intimidation. There were maybe three female students in the class of 30, and Amy was one. At the start of the class the instructor displayed a picture on the overhead projector and proceeded to ask each female student, one-by-one what it was. Amy knew, because her roommate was a junior and she warned Amy this would happen and she told



Amy what the picture most likely was. The image was the cross-sectional view of a spark plug. For those who have ever seen this type of image, it is not obvious. The reality was that there were probably very few students, male or female, who would have been able to identify it. This was one of Amy's first experiences where female students were intentionally singled out sending the tacit message that they needed to "prove they belonged."

Amy eventually graduated and went on to receive a master's and PhD degree, worked as an engineer overseas for two years, and is fortunate to have had academic positions that enable her to contribute to changing the climate for the next generation of engineering students.

## **Discussion**

The use of collective autoethnography and resulting stories highlight the nuanced experiences of those that represent diversity and inclusion in the system of engineering education. A commonality across these narratives was each woman's realization that they were the odd one out whether in class, or the engineering workplace. While numerous efforts are underway to recruit women to apply for engineering programs, the pathways through which women navigate in their student and professional journeys are rarely examined [18]. We attempted to outline this journey through our own lived experience in the system.

Taken together our stories illuminate several well-known issues such as 1) the alarmingly low percentage of female students despite the desire to influence a change, 2) the culture and chilly climate -towards non-dominant groups, and 3) the need to enhance curricula in order to embrace inclusive pedagogies, and emphasize engineering as a profession that provides value to society.

These stories also provide insights into how experiences and context impact decisions to persist and finding one's identity. As Tonso [19] indicates, the aspect of engineering identity is entwined in inclusion and diversity. Experiences of gender gap and exclusion in engineering for these women, led to various ways of coping, building resilience and developing an identity of belonging. Nisha found a role-model in a female faculty member, whereas Thiennes responded by staying self-motivated through connecting with peers, faculty and other university resources. The community mindedness instilled in Gloria's early years provided the anchor for her to persist in her second attempt at engineering education. Amy realized that peers are a critical resource to not only help each other through a challenging curriculum, but to also provide support through sharing experiences and wisdom on how to navigate a potentially chilly climate.

Busch-Vishniac and Jarosz [11] have argued that the engineering curriculum needs to be enhanced to embrace inclusive pedagogies and emphasize engineering as a profession that provides value to society. Salminen-Karlsson's [20] study reported that a reform in teaching methods that eliminated most of the lectures and built the entire master's program on teamwork saw an increase in women enrollment from 10% to 25%. Nisha connecting with gender-neutral

examples or Gloria involving herself in community engagement projects to find her engineering identity affirm these research findings. The Women's Experiences in College Engineering [21] project suggested that women value social relevance and accordingly, engineering courses should include multiple examples of relevance of course content to humanity [22].

Prior studies [23], [24] have concluded that education in a diverse context is highly effective for all involved as it entails "continuous negotiation of meaning;" leading to meaningful learning and personal growth. However, "leveraging the perspectives and experiences of diverse peers cannot happen without a practice of inclusion and emotional safety" [25].

## Summary

As a community we have identified diversity and inclusion as important goals for engineering education, and for the engineering profession. There is a general agreement that we are increasingly operating in a global society and the profession would benefit by being more inclusive. Even so, the pace of change has been slow, despite our collective agreement and calls for change. Our work adds to the conversation by providing distinct stories that represent a range of diverse pathways to and through engineering education from international, first generation, underrepresented, and female perspectives. These stories provide texture and nuance to what "non-inclusive" or non-dominant groups experience, and have the potential to provide additional insights for what leads to success, and how we might advance change for greater results. One limitation of this paper is that the stories were intentionally brief, and open-ended. Future work could expand on the stories where each individual could reflect on specific aspects of their experience (e.g. faculty interaction, financial challenges, peer support, etc.) where similarities and differences could be compared and contrasted.

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