# Guest Editorial
# Special Issue on Increasing the Socio-Cultural Diversity of Electrical and Computer Engineering and Related Fields

Universities and colleges struggle to achieve their diversity goals in disciplines including electrical engineering, computer science, and computer engineering. Even if entering students are sufficiently diverse, programs are challenged to provide appropriate support and develop engagement opportunities that enable these students to succeed. Some students from minority populations may have had schooling less well funded than that of their mainstream peers , and while capable of succeeding, may be differently equipped than their peers. As a result, more minority students leave their selected engineering disciplines. This special issue asks: How can efforts to increase success of minority students be designed and implemented? How can programs help faculty to understand challenges diverse students face? How can they change their teaching methods?

Prior research has shown that including diverse perspectives on STEM teams enables more robust and innovative designs [1], and that cross-disciplinary teaming that can facilitate pooling of diverse perspectives is difficult to achieve in practice [2]. Engineering educators are challenged to ensure perspectives of diverse students are fully heard, and their contributions considered and valued. Many instructors have had little or no training on pedagogical approaches within STEM. They may not understand how forming and managing teams, when done well, can help reinforce peer teamwork and student success. Conversely, they may not recognize that when poorly managed and conducted, teamwork can deplete the confidence of women and others outside the classroom's mainstream. Instructors may assign teams and team projects without providing sufficient support to help students to learn to work effectively together in diverse teams. Expecting students to be collaborative, equitable, and productive without guidance and support may leave them with negative impressions of group work, and a determination never to be a member of another team.

This special focus issue of the *IEEE Transactions on Education* (ToE) defines diversity broadly. A primary intention was to improve the participation of people from underrepresented groups—particularly in computer science, electrical and electronic engineering, computer engineering, software engineering, and biomedical engineering—and to support their success in these fields. The issue offers contributions from various geographic regions to the literature on promoting socio-cultural diversity in engineering and computing fields. All contributors offer concepts and techniques to foster equity and equality in engineering education

The guest editors, who have lived and worked in multiple countries across Africa, Europe, and North America, were acutely aware that many readers and authors of many U.S.-based journals lack exposure to work in engineering education research (EER) being conducted outside the U.S. Citation analysis of 4321 publications across four prominent platforms—the *Journal of Engineering Education* (JEE), the *European Journal of Engineering Education* (EJEE), and conferences of both the American Society of Engineering Education (ASEE) and European Society of Engineering Education (SEFI)—had shown ASEE and JEE citations "are dominated by sources with U.S. affiliations." As demonstrated in [3], SEFI and EJEE reflected wider diversity in that "while U.S. sources are frequently cited, European and other authors are also well represented," and "in citation terms, European EER is relatively global but US EER is not" (p. 190). The guest editors intended to provide "complementary perspectives" as encouraged by Borrego and Bernhard [4], whose comparative study of EER, originating in the US and extending to Northern and Central Europe, found that the latter region tends to explore "authentic, complex problems, while U.S. approaches emphasize empirical evidence" [4, p. 14]. They also found "disciplinary boundaries and legitimacy are more salient issues in the U.S., while the Northern and Central European *Bildung* philosophy integrates across disciplines toward development of the whole person". Informing this edition's intent, Borrego and Bernhard asserted that "understanding and valuing complementary perspectives is critical to growth and internationalization of EER".

This issue promotes research, advocacy, and action geared toward achieving equity by authors from India, Saudi Arabia, South Africa, Spain, the UK, and the United States, who consider many facets of diversity, including race, ethnicity, economic status, religious affiliation, age, and multiple understandings of the term gender. Supporting a range of approaches to diversity, this issue features empirical research on engineering/STEM pedagogies, focusing on their level of inclusivity for students and teachers from minority groups.

A study from Saudi Arabia, authored by Mariam Elhussein, Dilek Düştegör, Naya Nagy, and Amani Alghamdi, is entitled "The Impact of Digital Technology on Female Students'

Learning Experience in Partition-Rooms: Conditioned by Social Context" contributes new understanding of women's experiences studying engineering in in-country engineering programs only recently open to women; some of the engineering teachers are female, but many are male. Digital technologies are intended to bridge the divide in classrooms where a glass partition separates women from male teachers, but do not always achieve the desired aims.

"Using Mobile Application Development and 3D Modeling to Encourage Minority Male Interest in Computing and Engineering," by Jumoke Ladeji-Osias, LaDawn Partlow, and Edward Dillo studied racially diverse learners in the US. It describes outcomes of an ongoing after-school and summer program to engage black male youths in engineering and computing. Students develop mobile apps and build 3D-printed models to ignite their interest in science, technology, engineering, and mathematics (STEM). The participants showed an increase in their positive ideas about STEM and their interest in attending university and entering a career in either science or app development but did not show corresponding interest in taking science courses in school.

"Persistence, Resilience and Mathematics in Engineering Transfer Capital," by Simon Winberg, Christine Winberg, and Penelope Engel-Hills, studied socially and economically diverse learners entering engineering via two-year colleges in South Africa. Data from institutional databases was mined to analyze and compare the performance of transfer and non-transfer students. Factors associated with persistence-to-graduation in Bachelor of Science programs in electrical, computer, and mechanical engineering were identified by comparing averages, pass/fail frequencies, withdrawals and repeats. A correlation was found between math performance in two-year colleges and persistence to graduation in the four-year degree. Such research can help educators advise students more effectively and recruit those likely to complete degrees.

In "Do Female Motives for Enrolling Vary According to STEM Profile?" Noelia Olmedo-Torre, Fermín Sánchez Carracedo, Núria Salán Ballesteros, David López, Antoni Perez-Poch, and Mireia López-Beltrán assess factors that attract women to join STEM and select specific branches of engineering, using survey data from more than 1000 women (graduates and current students) in six different schools in one institution. About 40% were in computing, communications, electrical and electronic engineering (CCEEE), where women are greatly underrepresented, and the rest in other STEM (non-CCEEE) fields. Women in CCEEE were significantly less motivated by "the possibility of working on projects" and "the possibility of working as part of a team" than those outside CCEEE.

In a similar study from the US, "Gendered Interests in Electrical, Computer and Biomedical Engineering: Intersections With Career Outcome Expectations," Geoff Potvin, Catherine McGough, Lisa Benson, Hank Boone, Jacqueline Doylek, Allison Godwin, Adam Kirn, Beverly Ma, Jacqueline Rohde, Monique Ross, and Dina Verdin assessed how gender relates to an individual's level of interest in electrical, computer, and biomedical engineering and how these interests relate to students' career expectations. They collected and analyzed data from people in these fields, comparing those who identified themselves as women and those who did not. Females showed more interest in bioengineering/biomedical engineering and less in electrical and computer engineering.

Laura Hirshfield's "Equal But Not Equitable: Self-Reported Data Obscures Gendered Differences in Project Teams," a small-scale US-based study with clear relevance in engineering classrooms worldwide, shows that students' self-reports of team performance and team dynamics may fail to see and/or report differences in how they interact and allocate tasks. Submitted team assessments and interviews describe effective collaboration and a lack of gender bias, but these did not match observations or interview data. Despite visible gender bias, male and female students reported the same levels of confidence in, and satisfaction with, their teams. The author recommends deeper consideration of the stereotyping and gender bias that influences students' experiences.

"Analysis of Students' Ratings of Teaching Quality to Understand the Role of Gender and Socio-Economic Diversity in Higher Education," by Anika, Deepak Garg, and Parteek Kumar, analyzed teaching quality ratings assigned by male and female students in India. Statistically significant differences were found corresponding to teachers' gender and socio-economic status. They also found same-gender and cross-gender biases in scores for teaching. Over 100,000 survey responses were used to reveal perceptions of students in five different majors. The interaction between a student's gender and socio-economic status and that of the teacher influenced students' evaluation of the teacher. Since student evaluations inform faculty promotion and retention decisions, administrators must be aware of the biases in the reports and adjust their evaluations accordingly.

Another paper that focuses on educators' experiences, "The Impact of Gender on Conference Authorship in Audio Engineering: Analysis Using a New Data Collection Method" by Kat Young, Michael Lovedee-Turner, Jude Brereton, and Helena Daffern, assesses participation in audio engineering conferences, a strongly male-dominated field. A new tool is provided to determine the gender of participants not reporting their own data, that also considers individuals who do not identify in a binary way. New knowledge is presented related to LGTBQ+ and the determination of what gender an author would self-ascribe when not asked. Data was analyzed by conference topic, presentation type, position in the author byline, and number of authors, revealing low representation of non-male authors, significant variance in topic by gender, and a lack of diversity across invited presentations.

Finally, Robin Fowler and Magel Su, in "Gendered Risks of Team-Based Learning: A Model of Inequitable Task Allocation in Project-Based Learning (PBL)," explore how gender can inequitably affect the allocation of roles within PBL teams. Individual gender-related characteristics of students were found to interact with their goal orientations to lead to individual preferences for tasks, which further leads to teams distributing tasks in a non-gender-neutral way." They propose a conceptual

model for allocating tasks among student working on projects in teams.

The guest editors hope readers incorporate the insights presented here to create a generation of future leaders and innovators able to promote diversity and inclusion. By bridging the gulf many students experience moving from secondary school into higher education, diverse students' expectations can be met, so they do not find themselves isolated. The editors encourage readers to review emerging calls for action in diversity recently published by The Power Electronics Industry Collaborative[1], ASEE[2], and SEFI[3]. Preparing students with superior STEM skills and life-skills, who can build their own interest-related cohorts and seek out the resources they need, in a context of fairness and holistic wellbeing, will foster a community of engineers who can address global challenges, act with vision and confidence, and develop effective and robust responses to engineering problems.

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