

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. 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 [item 1) in the Appendix], and that cross-disciplinary teaming that can facilitate pooling of diverse perspectives is difficult to achieve in practice [item 2) in the Appendix]. 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 to avoid group work.

This special focus issue of the IEEE TRANSACTIONS ON EDUCATION (ToE) defines diversity broadly. A primary intention has been 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 student 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 [item 3) in the Appendix], 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 U.S. EER is not” (p. 190). The guest editors intended to provide “complementary perspectives” as encouraged by Borrego and Bernhard [item 4) in the Appendix], whose comparative study of EER, originating in the U.S. 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, with articles by authors from India, Saudi Arabia, South Africa, Spain, the U.K., and the U.S., 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 Düşteğör, Naya Nagy, and Amani Alghamdi, 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 with 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 studies racially diverse learners in the U.S. 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 STEM. 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. They use survey data from more than 1000 women (graduates and current students) in six different schools in one institution. About 40% of participants were in computing, communications, electrical and electronic engineering, and the rest in other STEM 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 U.S., “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 bio-engineering/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 U.S.-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. Students’ written team assessments and interviews described effective collaboration and a lack of gender bias, but these did not match teacher observations. 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.

Similarly, 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.

“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, analyzes 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 become 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 LGBTQ+ 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.

The guest editors hope readers will 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 students 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 diverse and inclusive community of engineers who can address global challenges, act with vision and confidence, and develop effective and robust responses to engineering problems.

SHANNON M. CHANCE, *Guest Editor*
Centre for Engineering Education
University College London
London WC1E 7JE, U.K.
(e-mail: s.chance@ucl.ac.uk)



Shannon M. Chance (F'15) received Bachelor and Master's of Architecture degrees from Virginia Tech and a Ph.D. degree in higher education from William and Mary University. She is a Registered Architect in Virginia and was a tenured Full Professor of architecture with Hampton University (HU), an Historically Black College/University from 1999 to 2014. In addition to teaching architecture and urban design, she led HU students on study abroad trips to Africa and Europe and taught environmental sustainability courses for doctoral students studying higher education. She is currently a Lecturer with the DIT's School of Multidisciplinary Technologies and is completing a second Marie Curie Research Fellowship with University College London's new Centre for Engineering Education. She is an Associate Editor of the IEEE TRANSACTIONS ON EDUCATION, on the Editorial Board of the European Journal of Engineering Education, and on the board of the global Research in Engineering Education Network.



Laura Bottomley (F'15) has worked in the area of Engineering Education for over 30 years, specializing in diversity and inclusion as well as K-16 engineering. She was a recipient of the individual Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring in 2009. She is a fellow of ASEE.

LAURA BOTTOMLEY, *Guest Editor*
College of Engineering
North Carolina State University
Raleigh, NC 27695 USA
(e-mail: laurab@ncsu.edu)

KAREN PANETTA, *Guest Editor*
Department of Electrical and Computer Engineering
Tufts University
Medford, MA 02155 USA
(e-mail: karen@computer.org)

BILL WILLIAMS, *Guest Editor*
CEG-IST, Instituto Superior Técnico
Universidade de Lisboa
1049-001 Lisbon, Portugal
(e-mail: bill.williams@estbarreiro.ips.pt)

APPENDIX RELATED WORK

- 1) V. Hunt, S. Prince, A. S. Dixon-Fyle, and L. Yee, "Delivering through diversity," McKinsey & Company, New York, NY, USA, Rep., Apr. 2018. [Online]. Available: https://www.eetimes.com/author.asp?section_id=36&doc_id=1333020&0.1452448
- 2) A. C. Edmondson and J.-F. Harvey, "Cross-boundary teaming for innovation: Integrating research on teams and knowledge in organizations," *Human Resour. Manag. Rev.*, vol. 28, no. 4, pp. 347–360, Dec. 2018.
- 3) B. Williams, P. C. Wankat, and P. Neto, "Not so global: A bibliometric look at engineering education research," *Eur. J. Eng. Educ.*, vol. 43, no. 2, pp. 190–200, 2018.
- 4) M. Borrego and J. Bernhard, "The emergence of engineering education research as an internationally connected field of inquiry," *J. Eng. Educ.*, vol. 100, no. 1, pp. 14–47, 2011.

¹https://www.eetimes.com/author.asp?section_id=36&doc_id=1333020

²<https://deansdiversity.asee.org/>

³<https://www.sefi.be/wp-content/uploads/2018/05/Diversity-2018-links.pdf>



Karen Panetta (S'83–M'85–SM'88–F'08) received the B.S. degree in computer engineering from Boston University and the M.S. and Ph.D. degrees in electrical engineering from Northeastern University. She is the Dean for Graduate Education and a Professor of electrical and computer engineering and an Adjunct Professor of computer science with Tufts University and is the Editor-in-Chief of the *IEEE Women in Engineering Magazine* and an Editor of the IEEE Boston “Reflector” Newspaper. She inspires youth across the globe to pursue engineering through her “Nerd Girls” Program. In 2011, the U.S. President Obama presented her with the NSF Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring.



Bill Williams received the Ph.D. degree in engineering management from IST, University of Lisbon. He trained as a Chemist with University College Cork, Ireland, then worked in education in Ireland, U.K., Eritrea, Kenya, Mozambique, and Portugal, and ran international distance courses for the International Labour Organization in various African countries. He is a member of the Centre for Management Studies (CEG-IST), Instituto Superior Técnico, Universidade de Lisboa, a *Professor Jubilado* of Instituto Politécnico de Setúbal, Portugal, and an Adjunct Senior Research Fellow with the Dublin Institute of Technology, Ireland.