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ScienceDirect

IFAC PapersOnLine 58-3 (2024) 129–133

Beyond Boundaries: Harnessing Unique Intellectual Abilities through Inclusive Engineering Education

Ille C. Gebeshuber*. Marion Hersh **

**Institute of Applied Physics, TU Wien, 1040 Vienna, Austria (Tel: 43-1-58801-13483; e-mail: gebeshuber@iap.tuwien.ac.at).*

*** Biomedical Engineering, University of Glasgow, Scotland (Tel: 44-141-3304906; e-mail: marion.hersh@glasgow.ac.uk)}*

Abstract: The foundational belief that everyone has the potential to contribute to engineering underpins this examination of diversity and inclusion within engineering education. Special attention is given to individuals with disabilities, whose potential for driving innovation is often overlooked. This paper delves into strategies aimed at enhancing diversity and inclusion, with a particular emphasis on supporting disabled individuals in the engineering educational landscape. It is posited that overcoming the social, infrastructural and attitudinal barriers encountered by disabled individuals is crucial for their full participation in engineering education and the profession. Advocacy for a paradigm shift towards a more inclusive and equitable engineering education ecosystem is strong, highlighting the need to recognize and utilize the potential contributions of disabled individuals. Discussions include the adoption of universal design principles in educational environments, the initiation of targeted outreach efforts and the establishment of support structures tailored to the unique needs of disabled students and staff. These recommendations are supported by an analysis of existing literature, personal narratives and case studies, which collectively underscore the importance of dismantling barriers to participation and success. By emphasizing the untapped potential of disabled individuals as a source of creativity and innovation, the paper contributes to the broader discourse on diversity and inclusion in STEM fields. It calls for a unified approach among educators, policymakers and industry leaders to acknowledge and harness this potential, thereby enriching and advancing the engineering discipline.

Keywords: engineering education, STEM, diversity and inclusion, universal design, intellectual abilities.

1. INTRODUCTION

Research shows the value of organizational diversity e.g. regarding organizational resilience (Duchek et al, 2020). This is particularly important in engineering due to its importance to society as a whole, the need to design systems and products for the population as a whole, which requires involving the whole population, and the potential for greater diversity in the engineering community leading to more creative and innovative solutions. Making the engineering profession more diverse will require engineering education to become more inclusive. This is the subject of this paper.

There are many aspects to diversity and we will be paying particular attention to increasing the representation of disabled engineers, a group which is poorly represented and whose underrepresentation has received little attention in the literature.

At the heart of our discourse is a dual assertion. Firstly, disabled people are a reservoir of untapped potential that can profoundly enrich the fields of control, biomedical and other types of engineering. Secondly, in line with the social model of disability developed by organizations of disabled people (Barnes, 1992; Barnes, 2019), it is the social, infrastructural and attitudinal barriers that disabled people encounter not their impairments (physical and mental differences) that impede their full participation. Unfortunately, barriers are still prevalent in the educational ecosystem. Many university websites and online learning systems such as Moodle, are not fully accessible. There are still stereotypes and stigma associated with being disabled e.g. (Green et al, 2005), leading, for instance to disabled students not wanting to use assistive technology when other students are present (Parette and Scherer 2004). Negative stereotyping may lead to assumptions about disabled people's lack of ability and the gifted disabled students experiencing barriers to participation in academic programs for gifted students, further contributing to their marginalized status amongst the school/university gifted population (Ivicevic, 2017).

MH, one of the authors, draws upon their extensive expertise, research, and personal experience to articulate a compelling viewpoint: 'I start from the perspective that all (or almost all) people, including disabled individuals, are capable of contributing and are also entitled to do so.' This perspective goes beyond mere advocacy for inclusivity; it necessitates a paradigm shift in how we perceive and integrate people with diverse characteristics within engineering education.

In our narrative, we draw upon Hersh's prior work, particularly their paper titled 'Ethical engineering and respect for the 'other'' (Hersh, 2017), which underscores the crucial role of involving disabled individuals in the engineering process. This

Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2024.07.138

is essential to ensure that the products and standards developed are genuinely useful and relevant to a wider array of users, to include the disabled population who are an increasing minority. Many disabled people have required great creativity, resourcefulness and ingenuity to overcome or develop work-rounds for the barriers they would otherwise have experienced (Wästerfors, 2021). While it is important not to stereotype disabled people as having special and unusual abilities, some groups of disabled people do have different abilities to the general population. For instance, many deaf people have a wider field of peripheral vision (Huang et al, 2023) and some autistic people have different cognitive strengths and ways of perceiving things (Prizant and Fields-Meyer, 2022).

In their paper titled '21st century engineering workplace: How an inclusive culture can deliver innovation and value' (Hersh and Doyle-Kent, 2023), the authors emphasize the underrepresentation of women and minority groups in engineering. They highlight the significant loss this poses to innovation, the profession and society. It advocates for a cultural shift in engineering workplaces towards equality, diversity and inclusion (EDI), arguing that this can lead to more innovative solutions and increased value for companies.

The authors discuss the importance of involving diverse voices in engineering decision-making, citing research that diverse teams are more innovative and profitable e.g. (Doyle-Kent et al, 2020). They explore the concept of narrative ethics in engineering. (Hersh, 2016), suggesting that understanding different perspectives, especially of marginalized groups, is crucial for ethical and inclusive engineering practices.

The paper examines various strategies and recommendations for promoting EDI in engineering, including physical accessibility, diverse hiring practices and creating an inclusive workplace culture. It also highlights the importance of narrative approaches in understanding and addressing the challenges of EDI.

The authors conclude that improving EDI in engineering is not only a moral imperative but also beneficial for innovation and business success. They recommend recognizing the value of EDI, considering all aspects of inclusion, using narrative approaches for perspective-taking, ensuring physical and material accessibility and using data for benchmarking best practices.

2. ETHICAL ENGINEERING AND RESPECT FOR THE 'OTHER'

Hersh (2017) delves into the significant role of diversity in engineering, with a specific focus on the underrepresentation of women and disabled engineers. The paper discusses how this lack of diversity not only limits the field's creativity but also fails to meet the needs of a diverse population. Engineering, predominantly dominated by males and non-disabled individuals, faces a challenge in embracing diversity.

The paper highlights that engineering is still perceived as a male-dominated field and efforts to increase female participation have been limited. Women engineers often confront stereotypes and barriers, such as being perceived as less capable or too emotional for engineering roles. Hersh suggests that incorporating different perspectives, including emotional ones, can enhance engineering design and creativity.

Regarding disabled engineers, the paper contrasts the social and medical models of disability, advocating for the social model, which views disability as a result of societal barriers. The lack of disabled engineers is a significant concern and their involvement is crucial in designing products and systems, especially for disabled users.

The paper also discusses the barriers faced by disabled engineering students, including inaccessible environments and a lack of inclusive teaching methods. It mentions various projects and resources aimed at making engineering education more accessible to disabled students.

A major emphasis of the paper is on the importance of involving disabled end-users in the design process. Hersh suggests methods for effective user involvement, including participatory action research and co-production with disabled individuals. The paper argues for the inclusion of accessibility, usability and design-for-all principles in engineering education, discussing the Universal Design Education Project (Welch, 1995) as an example, which integrated universal design principles into design education.

Hersh's paper calls for more research to understand the experiences of women and disabled engineers better. It advocates for further exploration of participatory design and the application of narrative ethics to comprehend the challenges faced by these groups. The paper underscores the need for a more inclusive approach in engineering, emphasizing the value of diversity and the necessity of involving a broader range of perspectives, particularly those of women and disabled individuals, in the engineering process.

3. HARNESSING UNIQUE INTELLECTUAL ABILITIES THROUGH INCLUSIVE ENGINEERING EDUCATION

The integration of people with diverse intellectual abilities in control engineering education is of paramount importance to provide a large talent pool of engineer with different cognitive strategies and approaches to problem solving. O'Neill and co-workers (2021) discuss the integration of people with diverse intellectual abilities in control engineering education by emphasizing the importance of diversity and inclusion within the International Federation of Automatic Control (IFAC). The IFAC Diversity and Inclusion Working Group was established in 2021. Its efforts are to promote values that reject exclusion and embrace diversity in all forms. O'Neill and co-workers (2021) underscore the significance of including diverse perspectives in engineering, as this drives innovation and enriches the organizational ecosystem, and advocate for the inclusion of individuals from various backgrounds at all levels of organizations. Strategies for the progression and promotion of disabled engineers are particularly important, as it often seems to be assumed that disabled people should be satisfied with entry-level positions (Gupta and Priyadarshi, 2020). However, disabled engineers are likely to have similar aspirations and ambitions to non-disabled ones and experience

frustration if they experience discrimination in promotion and being left behind compared to colleagues.

In this section we will focus on disabled people with very high IQ who have sometimes been referred to as twice exceptional (Prior, 2013; Coleman and Roberts, 2015; Klingner, 2022). As Prior (2013) states, James Gallagher first coined the term 'twice exceptional' in 1975 (Coleman et al, 2005). On the one hand, the term exceptional has positive connotations. On the other, it can hinder recognition that disabled people are an integral part of the population rather than separate from it, leading to marginalization.

One of the authors of this article, ICG, has for nearly 20 years been part of women in science network with annual interdisciplinary symposia on research methodology, scientific ethics and gender perspectives (http://winet.info). At one such symposium, Wiebke Funkel née Beckmann, a specialist in education for children with disabilities, mentioned the concept of „people from the edges of the Gaussian curve". ICG was thrilled and ever since pondered this concept in her mind. ICGs and Mary Doyle-Kent's invited open session on engineering education for the TECIS 2024 conference in Waterford now gives the framework to cast these ideas into an article. The other author, MH, is concerned that people ends of the Gaussian curve are considered part of normal human diversity and experience appropriate conditions and support to achieve their full potential and make their best possible contributions to society.

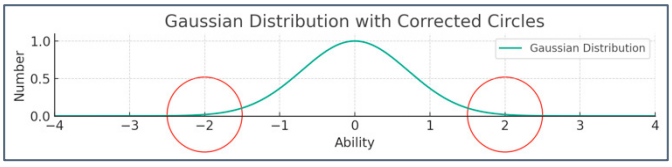

Figure 1. People from the edges of the Gaussian (red circles) can hold great promise for radical innovation and novel creative approaches in automatization and control engineering.

Disabled people with a very high IQ have great potential to contribute to innovation in engineering, though like the rest of the population, not all of them will be interested in a career in engineering. Achieving this potential require engineering education to become more inclusive and fully accessible to disabled students and staff (Alvarez et al, 2018, Pearson & Alexander, 2021). According to Alvarez et al (2018) disabled engineering students face diverse additional challenges compared to non-disabled students. A combination of universal design principles (Lombardi and Murray, 2011) and consideration of individual accessibility requirements is needed to ensure equitable access to education and study support. The study identified gaps in support structures and made the following recommendations to address them and ensure equal access to engineering education.

- Targeted outreach efforts to engage disabled engineering students and address their specific accessibility requirements, fostering a culture of accessibility.
- Implementation of universal design principles in engineering classrooms, labs and maker spaces to accommodate diverse abilities.
- Increased awareness of available resources among engineering students, faculty, and staff to improve access to support services.
- Development of targeted support structures for engineering students, particularly in their first and second years, to enhance their academic success.

An area of engineering education which requires particular attention with regards to accessibility, but has frequently been neglected is laboratory classes. Work in this area includes a small project on the Accessible Electronics Lab (Hersh et al, 2004) which made a number of recommendations.

While many practical classes are now computer based, there are still issues of compatibility of software and accessibility and usability with screen readers, switches, joysticks and a range of other assistive input devices and a range of computer accessibility settings. There are several sets of guidelines for making websites accessible, of which the World Wide Web Consortium Web Content Accessibility Guidelines (WCAG, 2023) are the most frequently used. However, in practice many websites, including those in education, do not comply with them (see, e.g., Conte et al, 2022). In addition, content, particularly that in PDF format, is often also poorly accessible (Azadbakht et al, 2021). While computer based laboratory work can frequently be done from home and this has benefits in reducing fatigue for many disabled students, it has disadvantages of reducing opportunities for interaction with fellow students. As discussed in (Hersh et al, 2004) for classes taking place in laboratories and or hardware there are a number of issues associated with making the equipment and the laboratory space fully accessible to all disabled people. However, the availability of necessary infrastructure such as variable height laboratory tables is often limited or non-existent.

In their chapter titled 'The Inclusion of Persons with Disabilities in Engineering Education and Careers,' Yvette E. Pearson and Quincy G. Alexander (2021) shed light on the often overlooked dimension of disability in engineering education. Despite many countries now having respective inclusive legislation, challenges persist in fully integrating gifted disabled individuals into STEM, particularly engineering. Pearson and Alexander emphasize that while existing diversity initiatives in engineering have primarily focused on gender and race, the lack of attention to disability neglects a significant portion of the talent pool. They argue that, in addition to depriving disabled individuals of interesting career opportunities, this also denies society their unique perspectives and contributions to innovation. The authors stress the importance of identifying and removing the barriers to success faced by disabled students and employees in engineering education and practice. They advocate for comprehensive strategies aligned with academic standards to promote the inclusion and success of disabled individuals in the field. Pearson and Alexander (2021) assert that disability inclusion in engineering education is a moral imperative,

essential for fostering a truly inclusive and innovative profession that benefits both individuals and society at large.

In 'Perfectly able: How to attract and hire talented people with disabilities,' Jim Hasse (2010) draws on both his professional expertise and his personal experience of cerebral palsy to present a compelling narrative that challenges conventional perceptions about the employment of disabled people, particularly those with high IQs. The book delves into the often-overlooked pool of about 42.5 million disabled people in the United States (U.S. Census, 2021). It argues that this demographic, which includes a significant number of highly intelligent individuals, remains largely untapped due to prevailing misconceptions about their capabilities. Hasse's narrative is supported by empirical evidence and real-world examples, demonstrating that disabled people, through their experiences of overcoming personal challenges, often develop highly sought-after qualities in the workplace such as resilience, adaptability and innovative problem-solving skills.

The book provides various tools and strategies for employers to effectively recruit and retain disabled workers and the importance of recognizing their abilities and potential, as with all workers. The book also addresses the psychological and social dynamics at play in the workplace, including the importance of fostering an organisational culture that values diversity and inclusion. This will contribute to preventing workplace adaptations to overcome the barriers otherwise experienced being seen as special treatment which privileges disabled individuals.

5. RECOMMENDATIONS

We have the following recommendations for making engineering education more inclusive:

- Involve and draw on the expertise of disabled engineering students and staff, including consulting them on changes to practices and procedures.
- Organise disability equality training carried out by disabled trainers for all staff and students.
- Ensure that inclusion covers all aspects of education, including social integration and laboratory classes.
- Consider usability (ease and satisfaction of doing things) as well as accessibility.
- Combine universal design with identifying and meeting specific individual needs.
- Recognise the value of the full integration of disabled students and staff to the educational institution and that this outweighs any costs.
- Ensure inclusivity, accessibility and usability cover staff as well as students and that progression and promotion policies do not have any hidden barriers and unintentionally disadvantage disabled staff members.

6. CONCLUSIONS AND OUTLOOK

However, we would note that considerable further work is required in this area and envisage a series of future papers that continue to explore and expand upon the work presented here. Potential themes and further research include the following:

- A detailed study of the barriers experienced by disabled people in engineering education and the workplace, their strategies for overcoming these barriers and proposals for changes in engineering education and the engineering profession.
- A detailed study of positive measures to make engineering education and the profession more inclusive to disabled people, including ethnic minorities, female and LGBT+ disabled people.
- A detailed study of the experiences of ethnic minorities, female and LGBT+ disabled people in engineering education and employment.
- The need for and approaches to achieving cultural shifts in engineering resulting in greater respect for diversity, including disabled engineers and engineering students.
- Co-production and co-design with disabled people of products and systems which are accessible to them.

ACKNOWLEDGEMENTS

ICG thanks Wiebke Funkel from the Förderschule Geistige Entwicklung in Hamburg, Germany, for bringing the concept of people from the edges of the Gaussian curve to her attention.

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