Women in Engineering:

Addressing the Gender Gap,

Exploring Trust and our Unconscious Bias

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*Abstract*— There is still a large gender gap across the technology, engineering and physical sciences disciplines despite a number of efforts over the past three decades to address this. Creating a more diverse workforce including a better gender balance is important in order to meet the skills need of the future. There is also increasing evidence that organizations with a more diverse workforce are more creative and innovative and ultimately perform better and are more successful. The aim of this paper is to explore how to address the gender gap by exploring our own notions of trust and unconscious bias. The paper draws on the perspectives of four women at different stages of their career and their lived experiences of being female in the engineering sector. Together they provide an insight into this important issue, and how we can work together as a collective community across the sector to address it and provide environments that are welcoming and value each and every one of us.

Keywords— gender gap, unconscious bias, women in engineering, trust, STEM and diversity

# Background

A large gender imbalance remains in the technology, engineering and physical sciences across most regions of the world. This is despite a focus on this issue for the last three decades. Table 1 presents the percentage of the workforce that is female for different professional sectors in the United States (US) and illustrates the significant imbalance in gender across the engineering and technology sectors compared to the health and life sciences [1]. Table 2 shows the situation in higher education demonstrating a similar picture [2].

The situation in many countries in Europe and elsewhere are equally stark. For example, in 2016, the workforce in Australia comprised less than 13% female engineers [3]. In Japan, females represent about 2% of all engineers [4] and in Canada, 13.7% [5]. In India, about 32% earned degrees in engineering and technology [6] but overall female participation in the workforce dropped from 37% in 2005 to 28% 2016 [7]. Across the European Union, the total percentage of females in high technology manufacturing and services roles is about 32% [8]. In the UK, only 18% of engineering, technology and computer science undergraduates in 2015-2016 were female [9] and less than 10% of professional engineers were female in 2016 [10] with a minor increase to 11% in 2017 [11].

Table 1: Percentage of Females in the Professional Workforce [1]

|  |  |
| --- | --- |
| Professional Sector of the Workforce | Percentage of Females in the Workforce |
| Architects and Engineers | 14% |
| Computer Network Architects | 10% |
| Computer and Mathematics | 26% |
| Mechanical Engineers | 8% |
| Biological Scientists | 43% |
| Physicians and Surgeons | 38% |
| Veterinarians | 63% |

Table 2: Number and Percentage of Female Undergraduates in the US 2013-2014 [2]

|  |  |  |
| --- | --- | --- |
| Discipline | Total Number of Undergraduate Students | Number of Female Undergraduate Students (%) |
| Biological/ Biomedical Sciences | 104633 | 61206 (58%) |
| Computer and Information Sciences | 55367 | 9974 (18%) |
| Engineering and Engineering Technology | 108969 | 20031 (18%) |

Research suggests that fewer females are likely to enter a career in technology, engineering and physical sciences while more are likely to exit those career environments [12, 13, 14]. This gender gap has been attributed to many different factors. Gender disparity is widely observed across a number of areas of society. For example, in the workplace females are often paid less than males in nearly every occupation [15], due at least partially to bias (conscious and unconscious) in performance assessments [16]. Specific factors within technology engineering and physical sciences relate to a widely held perception of gender stereotypes such as engineering is ‘for men’ and the perception by some females that they do not have the necessary attributes to succeed as a scientist or engineer [17] or that their own self-assessment of their abilities is a limiting cultural factor [18]. For example, studies [18, 19, 20] have suggested that females may believe that their mathematical abilities are not strong enough and hold themselves to a higher standard compared to the males. This may be as a result of the perceived stereotype that males are inherently better at particular STEM subjects and abilities such as spatial awareness.

A further factor is the decline in interest in STEM subjects or disciplines [18]. Although the number of females in science and engineering has gradually been increasing over the years albeit slowly in some disciplines [21], some of these females leave their STEM career journey. It is commonly referred to as the “leaky pipeline” [22, 23] and this percentage is higher relative to the overall number of females compared to the number of males that leave, resulting in fewer females in the STEM workforce particularly at more senior levels. Other factors are insufficient role models (people like me) in those jobs [12, 17], concerns regarding work life balance [9]; inadequate support [12, 24], conscious or unconscious bias; lack of STEM career knowledge and the understanding of pathways to those careers [12]. These factors highlight the importance of not only encouraging more young females into the physical sciences, technology and engineering but also having plans to retain them once they are there.

Why does this matter? Diversity in the workforce is important and is neatly summarized by Kenneth Gibbs [25]: “*Diversity refers to difference. Science workforce diversity refers to cultivating talent, and promoting the full inclusion of excellence across the social spectrum. Diversity leads to better problem-solving, expands the talent pool and is important for long-term economic growth.*” It is even more important given today’s economic climate and workforce needs. In the US, the estimated size of the Science, Technology, Engineering and Mathematics (STEM) workforce needed by 2018 is 8,650,000 [1] and STEM jobs are growing faster than any other sector. STEM jobs are set to increase by 17 percent between 2014 and 2024, while non-STEM employment will grow by just 12 percent. In the UK, it is estimated that an extra 69,000 people with engineering skills are needed every year until 2020 to meet the projected growth in that sector [26]. Also about 60% of employers in the UK rate the employment of engineers with relevant skills a top priority in being able to attain their organizations’ set goals over the next few years [11]. All these further support the need for greater uptake of the physical sciences, technology and engineering by people from a range of diverse backgrounds including females. Research suggests that organizations are more likely to improve performance by 15% if the organizations are more gender diverse and by 35% if they are more ethnically diverse [12, 27].

# diversity in the workplace

Given the importance of diversity there have been more calls for a more diverse workforce across organizations particularly in the technology ecosystem. Although there is greater awareness and gradual progress to improve diversity, only about 15% of employers in the UK from the Institution of Engineering and Technology 2017 study [5] have made deliberate efforts over and above the regulatory requirements to reduce the attrition of females and attract more women into engineering workplace roles. Table 3 illustrates the diversity of the workforce in 2017 for some leading technology companies. Although the total number of females in engineering and technology companies is gradually increasing, the percentages of females and ethnic minority in engineering and technology roles are still low, with the majority comprising of white and/or Asian males. To improve diversity, it is necessary to be aware of the stereotypes and bias either conscious or unconscious that might be embedded in individuals, culture or environment [18]

# stereotypes and bias

Although progress is being made to reduce stereotypes and bias, some subtle or unconscious bias still persist [17]. Apart from the cultural or environmental stereotypes or bias females are exposed to, females also have some gender bias which they may or may not be conscious about which could influence decisions made knowingly or unknowingly [17]. For example, when a female feels that males do better in specific subjects, she may decide not to even compete in those areas or pursue careers along those disciplines.

# Lived Experiences from Women Working in the Engineering Sector

Experiences either learnt or exposure to other people’s experiences has been identified as an important influence of career choices [4]. This section showcases the lived experiences of four participants for the ‘Women in Engineering’ round table session Educon 2018 and highlights some of the challenges and how these might be addressed collectively by the sector.

## Professor Rebecca Strachan, Northumbria Univesrity, UK.

Rebecca Strachan is a Professor of Digital Technology and Education and Associate Pro Vice Chancellor for Knowledge Exchange in the Faculty of Engineering and Environment at Northumbria University. She is a leading expert in the exploitation of digital technologies to improve daily life and believes we should be using technology in transformational ways to support student learning. She has developed a keen interest in gender, diversity and STEM, is Deputy Chair of the University’s Athena Swan Self-Assessment team [42] and supports equality of opportunities for all. A strong advocate of partnership working, she is a fellow of the Higher Education Academy and member of the Council for Professors and Heads

Table 3: Number of Females and ethnic minority groups in the workforce of some tech companies

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Organization | Number of Females Globally (%) | Females in leadership (%) | Females in Tech Role % | Ethic minority (%) | Ethnic minority in tech role | Ref |
| Apple | 32 | 29 | 23 | 7 | - | [28] |
| Adobe | 29^ | 21 | 20^ | 8\*^ | - | [29] |
| Square | 36.7 | 25.2 | 18 | 17.6 | 7 | [30] |
| Google | 31 | 25 | 20 | 9 | 8 | [31] |
| Facebook | 35 | 28 | 19 | 11\* | 7\* | [32] |
| PayPal | 43 | 36 | 25 | 17\* | 9\* | [33] |
| LinkedIn | 42 | 38 | 21 | 9\* | 5\* | [34] |
| Intuit | 39 | 32 | 29 | 14\* | - | [35] |
| Pinterest | 45 | 19 | 29 | 12 | 7 | [36] |
| Lyft | 42 | 36 | 18 | 17 | 11 | [37] |
| Uber | 36.1 | 22 | 15.4 | 19.3 | 5.9 | [38] |
| Yahoo | 37^ | 22^ | 17^ | 11^ | 7^ | [39] |
| Amazon | 39^ | 25^ | 37^ | 18^\* | - | [40] |
| Intel | 26 | 24.1 | - | 12.6 | 13 | [41] |

(^) numbers in 2016; \*numbers in the United States only)

of Computing. Internationally she is a committee member of the IEEE Education Society and was part of the team that developed their MOOC on Open Education. She is the faculty executive lead for NUSTEM, a major widening participation program to engage more young people, particularly females in STEM [43] working in the UK and more recently in Nigeria. She is also the university lead for the BRIDGE project, aimed at encouraging greater diversity in the construction sector [44].

She enjoys the diversity of her current role as each day is different and brings new challenges and rewards. She feels very privileged to be paid to learn and research. During her career has been able to travel to Asia, Europe and USA and work with a variety of people and organizations. A key challenge she experienced during her career was taking time off to have a family. Although she worked part-time during this period, her research suffered and did not progress as much as her male peer colleagues. She is also aware of being ‘female’ in a male dominated environment and taking care not to be ‘labelled’ as a ‘the feminist’ yet sill challenging gendered language and attitudes.

Her advice to those starting out on their careers is to stay positive, be confident, be strategic, take risks, try things out and do not be afraid to ask for help or delegate work to others. This may also mean that you need to be ‘selfish’ at times, to develop your own career, something she struggled with in her early career. She is now better at being strategic and focused and carving out time for herself to support her own career development.

## Dr Aruquia Peixoto, Assistant Professor, CEFECT/RJ, Rio de Janeiro, Brazil.

Dr. Aruquia Peixoto is an Assistant Professor at CEFET/RJ in Rio de Janeiro, Brazil. She has a B.S. in Mathematics from UFRJ (Federal University of Rio de Janeiro), a M.S. in Engineering of Computing and Systems from COPPE/UFRJ and a PhD in Mechanical Engineering from PUC/RJ, all based in Rio de Janeiro, Brazil, and among the best universities in Brazil. She worked on the implementation of the State University of Roraima in North Brazil, in 2006. She advised undergraduate students in scientific projects in UERJ (State University of Rio de Janeiro), where she won four prizes. She has been a member of the ACM SIGGRAPH International Resources Committee since 2013, member of the SIGGRAPH Asia Symposium on Education Committee since 2016 and 2017, and co-organized the meetings Women in CG during the SIGGRAPH and SIGGRAPH Asia Conferences, organized the meeting Girls in STEM in SIGGRAPH Asia 2016, and a round table Women in Engineering: Issues and Perspectives at the IEEE EDUCON 2017. During the year 2016 to 2017 she was visiting faculty at University of Kansas. Since 2017 she has been a member of the council ACM-W (ACM Council for Women), as SIG Liaison. For IEEE EDUCON 2018 she is Chair of the Special Session IDEE (Inclusion and Diversity in Education Engineering), and Chair of the Publication, Web and eMedia Committee.

She has been passionate about research since she was a young girl and enjoys her research in computer graphics and education, especially linked to the important and developing themes of gender, diversity and inclusion. During recent years she has particularly appreciated and liked being part of the professional organizations and participating in round tables and panels on gender, diversity and inclusion at the conferences ACM SIGGRAPH and SIGGRAPH Asia and IEEE EDUCON. Some of the challenges Dr Peixoto has experienced include being a professor in a technical institute where only about one third of the faculty members have a PhD degree. She feels she does not get the kind of support extended to other colleagues. She has to pay for her international work travels from her own resources or professional bodies whereas other colleagues can access university resources for funding. She finds it challenging being a black woman in Brazil doing the career she does. She received support during her career from her undergraduate advisor and the Masters and doctoral co-advisors

Her recommendation to women aspiring to similar career is to look to groups that can provide support and find places where your work and talents are valued, and avoid the places that disrespect them as such places will disappear in time due to mediocrity.

## Itoro Emembolu, Northumbria University, UK.

Itoro Emembolu is a PhD researcher in the Faculty of Engineering and Environment at Northumbria University. Her research is on evaluating the impact of academic research on young people’s uptake of the STEM disciplines with a focus on the interface between outreach activities developed from the research of academic staff and practical applications that bring STEM subjects to life for young people. She is currently working on developing a multidisciplinary impact evaluation framework which can be applied in different interventions across the STEM disciplines. She also works for NUSTEM [8] on impact evaluation and data analysis of NUSTEM’s outreach activities. NUSTEM works with young people and their circle of influence to cultivate more interest in STEM from under-represented socio-economic groups and to reduce the gender gap and increase diversity in those fields, originally in the UK, but more recently in Nigeria. Itoro has a Bachelor of Engineering in Mechanical Engineering, an MSc in International Business, Energy and Petroleum and an MPhil in Management. She is interested in raising aspirations and widening awareness of STEM careers and their pathways in young people.

Some of the challenges she has experienced include undertaking a mechanical engineering undergraduate program in a class of less than 6% females and a department that had no female lecturer at the time. She felt she had to always show that she was as competent as the male students. The scarcity of females in the department re-enforced the stereotype. Also, cultural attitude on the balance between family obligations and the demanding nature of some engineering careers has also been a challenge where one is expected to choose one or the other. She is grateful she has much family and friends support and in her current role, has female supervisors and line managers that understand the challenges of being a female in the engineering discipline.

Itoro’s recommendations to women aspiring to a similar career include creating awareness of self-bias (either conscious or unconscious) because this is the first step to overcoming it. Once there is awareness, deliberate work can be done to reduce bias and break down stereotypes. Also, having self gender bias and belief of stereotypes can limit a person’s choices and decisions and possible applications to job roles in disciplines where such stereotypes exist. She also advocates for a positive and ‘can do’ mindset because such attitude can help one learn and grow even in challenging circumstances.

## Dr. Maria Teresa Restivo, Principal Researcher at Faculty of Engineering, Universidade do Porto, Portugal.

Dr. Maria Teresa Restivo has a Physics degree in Solid State Physics and a Ph.D. in Engineering Sciences, both from the University of Porto. She is a senior researcher and teacher at the Faculty of Engineering of University of Porto where, between 1992-1994 she was the coordinator of the Automatic Systems area of the Mechanical Engineering Research Centre, between 1994-2000 she was joint coordinator of the Physics, Acoustic and Telecommunication Research Unit and in 2005 she joined the research Unit of System Integration and Process Automation (UISPA) within the Associated Laboratory of Energy, Transports and Aeronautics (LAETA), and became UISPA coordinator in December 2007. She is a member of the Scientific Council at FEUP. Her activity has been related with measurements and sensors development and applications, online experimentation, development of sensorized devices and is presently focused in e-health and e-rehabilitation and ageing. She is also examining the use of online experimentation as a part of the Internet of Things (IoT) and the integration of emergent technologies in training and education (remote monitoring and actuation, virtual and augmented reality and interaction with haptic devices). She received the international qualification of ING-PAED IGIP – International Engineering Educator (PT003). She is both an individual and institutional (FEUP) Member of the VIT@LIS network and of ELTF – EUNIS and Institutional Member of the Global Online Consortium (GOLC). She was President of SPEE - Portuguese Society for Engineering Education (Feb. 2010 – May 2012). She was Vice-President of IEEE Education Society, Portuguese Chapter (2011 - 2014). She is Executive Committee member of GIP - International Society for Engineering Education, from Sep. 2010 to Sep. 2016, then elected President and now Past President and she is Executive Committee member of the International Association of Online Engineering (IAOE).

Thinking and deciding freely is a tremendous privilege provided by the opportunity of being part of the academic community in the scientific environment at the University of Porto. This has given her a strong feeling of debt and she is now eager to give something back to society. During her career she is keen to continue as the academic Teresa Restivo, always curious, and maintaining a strong sense of purpose and ethical standards. She has found that her academic career has been nurtured by the challenges, cooperation and initiatives around her, at the University; across the wider set of Portuguese and international organizations she works with; and internationally with existing friends everywhere but also always open to new ones.

Despite the different challenges and bias experienced by participants, they all find the STEM careers they have chosen rewarding and would still pursue their chosen career in retrospect.

# Our Own Unconscious Bias and Levels of Trust

Unconscious bias occurs when our brains make quick judgements and assessments of people without us realizing it. These biases are influenced by our background, cultural environment and personal experience [10] and can lead to us stereotyping and having automatic preferences that influence our decision making and opinions, particularly when we are under pressure or having to make quick decisions. It is easier to identify other people’s bias than our own bias [17] particularly unconscious or inherent bias. Recognizing our own internal biases and challenging them is an important step in breaking down stereotypes, and our own implicit assumptions, and through this, we can challenge the status quo and develop a more inclusive and open environment.

Unconscious bias is particularly evident when under pressure, and/or making quick decisions. Therefore, in recruitment, promotion and other areas of career development, it is important that people take time to make the correct decisions and are encouraged to address and remove any unconscious bias they may have. For example, playing a short video on unconscious bias to an interview panel at the start has been shown to result in focusing on who has the best skills, expertise and characteristics for the role, helping remove unconscious bias and resulting in a more diverse set of appointments.

There is growing evidence that heterogeneous (diverse) teams are more creative and innovative than homogeneous ones (teams where all members are of the same race, gender, background, etc.) and that organizations that are more diverse tend to outperform and are more successful than less diverse organizations [12, 27]. Therefore, creating better diversity in physical sciences, engineering and technology and collaborating across race, nationality, gender, age, physical abilities and other backgrounds and characteristics is important. This requires mutual respect and trust.

However, if we examine our own ‘circle of trust’, that is, those people we trust most in our lives, we often find they have similar characteristics to ourselves. If we use our natural ‘circle of trust’ in the workplace, the tendency is to work with colleagues with similar characteristics to ourselves [45] and this can propagate homogeneous teams. We need to be much more conscious about the way we build teams, delegate and empower others to ensure we are creating an inclusive and diverse organization. Differing backgrounds and perspectives offer the chance for varying viewpoints to be heard and to tap into the wealth of experience and expertise across the organization and wider community. This cultivates innovation and the ability to think ‘outside the box’ and outside one’s own ‘comfort zone’ and provides the opportunity for everyone to reach their full potential, make valuable contributions and have their voice heard.

# Summary and Conclusions

An environment of diversity and inclusion is very important at every stage of a female’s life from childhood up until they enter the workforce and through their career and industry experience. If females do not feel welcome or included in STEM careers, they cannot identify with ‘people like me’ and thus do not have good experiences about STEM interactions and the STEM career pipeline will continue to leak. This will perpetuate the low proportion of females and loss of potential female talent in STEM. This is particularly true in the physical sciences, engineering and technology disciplines where females are particularly under-represented and are more likely to leave than enter the disciplines.

Just as different factors impact on the representation of females in STEM roles, different solutions are required to reduce the gender gap [18]. These include awareness of one’s own bias and ‘circle of trust’ and taking active action to mitigate these, thus providing educational and workplace environments that are welcoming and value each and every one of us. Gender and other stereotypes will not just disappear overnight but can be systematically changed over time. For example, even though females are under-represented in engineering, the females that are in the discipline are breaking the stereotypes and can be STEM ambassadors that other females wanting to enter the disciplines or at an early stage of their career can identify with.

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