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TECIS Inclusion and Diversity working group vision

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Abstract: There has been considerable focus on building inclusion and diversity into engineering careers and education, especially in developed countries, but despite this, the percentages for minorities remain unchanged over decades. The multi-cultural interaction of TECIS was a springboard for the launch of a working group to investigate the reasons for this lack of improvement. The genesis of this working group occurred in Sozopol, Bulgaria at the TECIS 2019 conference where twenty-three researchers from over ten countries came together to discuss the lack of women and other marginalized groups in engineering. The objective of this paper is threefold, to outline the future direction of the inclusion and diversity working group in TECIS, to support and foster greater knowledge of gender diversity in engineering education and to outline future research activities that could make a substantial contribution to our understanding of diversity issues in engineering in addition to making best practice recommendations that can be used in the engineering industry. The scope of this paper is limited to women in engineering. Future work will look at other inclusion and diversity issues in STEM.

Keywords: Ethics in Engineering, Multicultural Interaction, Networking, Knowledge Society, Women in Engineering.

1. INTRODUCTION

The inclusion of all members of a society is vital to construction of a fair, diverse and responsible society going forward. Engineering, as a discipline, plays a pivotal role both in innovation and in technological development. Engineers will often work within multi-disciplinary, multi-cultural and multi-site teams on complex engineering projects, so it is imperative that all voices and opinions are heard and inform the decision-making process.

An engineer's impact on communities and society will be more positive when it represents and welcomes diversity, irrespective of their faith, race, ability, country of origin, age, gender or sexual orientation. In the Doyle-Kent et al., (2019) paper titled *"Where are all the Irish woman engineers: a case study"* questions around the importance of gender diversity in engineering and the lack of female participation nationally and internationally was addressed. Because of this paper, a new working group on diversity and inclusion was established by the IFAC technical committee on Technology, Culture and International Stability (TECIS). The purpose of this paper is:

- To outline the future direction of the inclusion and diversity working group in TECIS.
- To support and foster greater knowledge of gender diversity in engineering education.
- To outline future research activities that could make a substantial contribution to our understanding of diversity issues in engineering, as well as making recommendations that could be used in practice in industry.

The paper begins by setting out the importance and need for an inclusion and diversity working group in TECIS. There will be an exploration of gender issues in engineering education and finally, an outline of the future research activities of the working group to understand the issues around poor levels of female participation in engineering.

2. THE IMPORTANCE OF INCLUSION AND DIVERSITY IN TECHNOLOGY AND ENGINEERING

Engineering and technological method approaches, such as human-centered systems (HCS), valorise the human being combining the tacit knowledge of the human with the computing power of technology in a human-machine symbiosis (Polanyi, 2009; Gill, 1996). Professor Michael Cooley, engineer and founding member of the HCS movement, has written a number of books *"Architect or Bee"* (Cooley, 1987), *"Delinquent Genius"* (Cooley, 2018) and his latest work *"The Search for Alternatives"* (Cooley, 2020). Cooley (1987) recognises the potential good of technology; he states that technology must not be regarded as an *"isolated phenomenon but rather as another means of production viewed within the political, ideological and cultural assumptions of the society that has given rise to it"*. In our challenge to tackle gender and diversity issues in engineering and technology, this goes to the heart of scientific inquiry with most of our scientific methodologies being mathematically quantifiable. Cooley suggests that an inability to quantify something is to question its very existence (Cooley, 1987). In this reality, workers will not develop the skills and abilities necessary to play a *"creative and constructive role in society"* (Cooley, 1987) and this will affect underrepresented minorities. This lack of creativity and diversity in engineering will express itself in younger engineers being unable to express their individuality, energy, creativity, and subjective opinions which in turn create a crisis point in the profession (Cooley, 1987).

3. WOMEN IN SCIENCE, TECHNOLOGY, AND ENGINEERING

An Institute of European and Electronics Engineers (IEEE) survey of women working in technology identified issues facing women in technology. In a sample size of 4,579 women; 73% stated they had experienced negative career outcomes due to their gender; lack of trust from male colleagues 34%, management 29% and 18% from female colleagues (Bullo, 2018). A significant number of participants 51% felt the need to speak less about family matters to be taken seriously in the profession (Bullo, 2018).

This is a significant study and aid to understanding the potential impact on women's confidence in the male dominated workforce. It is also notable working in a male dominated workforce can put pressure on women to work harder and longer to prove themselves resulting in poor work life balance. Athena Swan Charter is embedded into higher education and encourages role models by recognising the advancement of gender equality, representation, progression and success for all (Ovseiko, 2017). The European Commission has developed a *"Gender in EU-funded research and innovation toolkit"* to provide practical advice on the integration and importance of gender in research; to understand the "gender and science" nexus and make scientists more sensitive to gender in research (European Commission, 2014). This toolkit forms part of a wider strategy to ensure female participation in science by addressing male and female needs and understanding the gender dimension in science (European Commission, 2014). The tool kit recognises an important issue that the TECIS working group on inclusion and diversity embraces. Gender in research requires action in both the participation of women in science and gender as a dimension of research studies (European Commission, 2014).

It is important to direct female attention to STEM careers at a young age. According to the World Economic Forum "There is an increased awareness of the role model problem that children's rights activist Marian Wright Edleman articulated so well: *"You can't be what you can't see*". Edleman goes on to say that when asked to draw a scientist most students draw a man in a lab coat and that portrayals of scientists and engineers in movies and on television has been men. But the good news is that awareness of this issue is now causing it to change (The World Economic Forum, 2020).

Clearly there is a need to collaborate with social scientists who study these issues. Ciupercă et al in 2020 states that *"According to the literature of social psychology regarding the social influence determined by the active minorities, the STEM women do not represent active minorities in the true sense of the word, because they do not militate actively to impose their point of view. But this social group can be included in the category of active catalytic minorities because, through their daily professional activity, the society became aware of the need to involve them more actively in social life."*

Recently, in an article published in the journal *Psychological Science*, written by two psychologists Stoet and Geary (2018), it is shown that in many countries with high levels of gender equality, fewer women choose STEM fields as compared to countries with much lower levels of gender equality. This is termed the "Gender Equality Paradox". Elaborating on this seemingly counter-intuitive result, an article in *The Atlantic* (2018) says: "Just 18 percent of American computer-science college degrees go to women. This is in the United States, where many college men proudly describe themselves as "male feminists" and girls are taught that they can be anything they want to be. Meanwhile, in Algeria, 41 percent of college graduates in the fields of science, technology, engineering, and math or "STEM," as it's known—are female" (Khazan, 2018). There is also a need to understand how national-level policies influence the dynamics of participation and progress of various groups in the nation's science and technology activities.

Another example of study in gender issues is one undertaken by Johansson et al., (2018). They state that "Factors that contributed to enhancing the learning opportunities men enjoy, such as horizontal and vertical manager mobility, senior manager support, strategic networks, career system, freedom of action and gender stereotypes, constituted barriers to learning and career development for women". These differences in the workplace affect the career path of women in the workplace.

In the absence of explicit discrimination, there are many socio-cultural factors that determine whether certain populations will choose certain educational and career paths. Nielsen et al., (2019) undertook a comprehensive study on gender diversity and management aspiration in Denmark. They state that "In

today's Western welfare states, women are statistically equally or better educated than their male peers. Therefore, when women do not take equal part in the management and leadership, it can lead to underutilization of women's competencies and knowledge resources". At the same time, they note that males are more likely to aspire to management level in a company than women. Societal gender stereotyping associate's different qualities to men and women pushing men into management whilst holding women back. Ultimately, they deduce that there are many factors involved "individual preferences and/or macro-structural factors, but of factors at the organizational level". For this international working group, "understanding the current situation" includes understanding all these issues.

In professional bodies, a code of ethics is an important instrument against unethical behaviour. It is a set of guiding principles or a system that people can use to help them ensure they behave well and in a professional manner. According to Harris et al (1996) *"It is an essential part of professional education because it helps students deal with issues they will face in professional practice"*. A code of ethics can influence how we treat others in our day to day work practices. Stewart (2011) investigated, from a stakeholder perspective, the effects of ethics on the relationship between diversity, climate and voluntary turnovers. The results *"suggest that the diversity climate-turnover intentions relationship is strongest when ethical climate perceptions are high rather than low"* (Stewart, 2011).

The IEEE has an ethical code with principles that commits its members to high ethical and professional standards. One of those principles is respect and dignity and commits its members not to discriminate based on race, religion, gender, disability, age or sexual orientation (IEEE, 2019). In Ireland, the national body for engineering, Engineers Ireland, has established ethical guidelines to ensure members act with honesty and respect in their relationships with colleagues, clients, and society at large. Bitay et al., (2015) discussed the development of a universal code of ethics in engineering and technological development encompassing environmental consciousness; human-centredness in technology development working towards the development of next-generation socially responsible technologies.

In relation to the software engineering discipline, in the wake of the Cambridge Analytica scandal Christopher Wylie calls for a code of ethics for software engineering (Wylie, 2019). He argues that if the software engineer can revert to a code of ethics in his/her refusal to develop the software in the first place then the unscrupulous manipulation of large datasets as occurred with Cambridge Analytica may be prevented from happening again. In Michael Cooley's (2020) book "The Search For Alternatives" when speaking about defining the future he states: *"One of the major contributions would be for more women to come into science and technology. Not as imitation men, or as honorary men, but to begin to question the value systems being built into our science and technology and show how it can be structured differently"* (Cooley, 2020). Through his work valuable lessons on valuing the human being and appreciating diversity can be learned. It is the opinion of Cooley that there is a lack of the young, and creative in the engineering workplace and this is expected to reach a crisis point in the 21st century with a shortage of over 500,000 engineers and scientists in the USA. The lack of young people can be attributed to the lack of a space that allows them to express their energy, creativity, individuality and facilitates their emotional expression and subjective opinions. Cooley says that he finds it very sad that some of our most able, creative, constructive and sensitive young people will no longer study science and technology as "*They see it as repressive or running counter to the very best in the human essence*" (Cooley, 2020). Has the scientific/reductionist method gone too far?

4. DIVERSITY IN TECHNOLOGY AND ENGINEERING EDUCATION

Most studies of attitudes towards Science, Technology Engineering and Mathematics (STEM) careers have focused on adolescents and young adults. Few have examined the attitudes of younger children to stereotypical career choices. In a study of 141 children (aged 3 to 8) Mulvey and Irvin (2018) identified important insights around the judgements of counter-stereotypical STEM career choices. Whilst students supported counter-stereotypical career choices and articulated the unacceptability of exclusion from careers based on gender, parental attitudes towards science and mathematics were a strong influencing factor.

In an earlier study Whitehead (1996) stated that *"results from cross-cultural studies tend to indicate that differences in the perception of subjects and achievement appear to be linked to sex-stereotyped attitudes within a particular society rather than to innate sex differences in ability"*. Her study of 1,200 students aged between 15-17 years old in England and Wales resulted in the following findings. Girls that were taking either the perceived 'masculine' or perceived 'feminine' subjects for A level didn't link this to the stereotypical view to either 'masculinity' or 'femininity'. Both groups tended to rate themselves highly on the competence trait and reject the traditional female role for themselves. 'The two extreme groups, those doing 'feminine' only subjects and those doing 'masculine' only subjects, showed no significant differences, suggesting that perception of subjects as 'masculine' or 'feminine' is not strongly related to subject choice at A-level in girls, a conclusion that is reinforced by looking at actual subject choice". The same cannot be said about the boys in the study.

According to Griffith (2010), the female student experiences of STEM in universities is an important factor in female attrition in the Sciences. Students attending universities that focus on teaching and research for undergraduate students are more likely to complete STEM courses. This compares favourably to those institutions that focus on graduate studies. The female's experience of university can have an impact on her identity as a competent scientist, therefore, universities must be welcoming and inclusive (Griffith, 2010). A less hostile environment where women can feel engaged is key to

their success in their STEM courses (Jensen and Deemer, 2018). Griffith (2010) found evidence that role models can influence a student's decision in choosing STEM courses. Bettinger et al (2005) also investigated and proved the importance of faculty role models in STEM stating *"One focus has been to increase mentoring opportunities for female students by hiring more women faculty members. Theory and evidence suggest that female instructors may be instrumental in encouraging women to enrol and excel in subjects in which they are underrepresented."* Female students tend not to choose third level programmes that are male dominated but having female role models as faculty members helps improve the percentages. Their findings give an insight into the results of policy decisions in faculties stating *"The results suggest that female instructors do positively influence course selection and major choice in some disciplines, thus supporting a possible role-model effect"*. (Bettinger et al, 2005)

In addition, they continue to state that unfortunately women are underrepresented on university faculties and this shortage of role models may be one of the reasons for a reduced number of females in the STEM fields. Šaras et al., (2018) also argues that the proportion of women in the faculty may benefit women STEM students and positively influence woman's chances of obtaining STEM degrees, especially at male-dominated research institutions. Encouraging a collaborative environment and peer support within STEM departments may also enhance women's participation in STEM. Interestingly though Griffith (2010) states that having a high proportion of females in STEM does not increase the persistence of women in STEM.

Whilst women consider the salary potential of STEM careers to be higher than non-STEM careers, a low level of ability to combine work and family obligations decreases the value of the job for women more than men changing this perception might increase the value of STEM jobs (Friedmann, 2018). Kelly et al., (2019) states that female undergraduates in Ireland feel social bias, balancing work and family life. They suggest that a lack of role models is the main cause of fewer women in STEM professions which supports previously cited research (Kelly et al., 2019).

5. THE ROLE OF TECIS IN GENDER, INCLUSION AND DIVERSITY

The Inclusion and Diversity working group itself is composed from a diverse community; 10 countries, female and male, academics and industrialists. Specialities range from Sociologists, Scientists, Engineers to Information Technologists. The age profile ranges from young student researchers to the retired.

The aims of the working group are to provide a future direction, provide greater knowledge to support and foster diversity in engineering education and provide best practice recommendations for the engineering industry itself, in addition to publishing findings in academic papers with a view to disseminating this information to the public in general.

5.1 To initiate the group work

To initiate the gathering of primary data ***Figure 1*** was proposed by the working group. This structure of the working group is a proposal and it is anticipated it will change over time. The rationale behind it is to break down the work into manageable tasks.

Each member of the working group is requested to select an area of interest/subgroup. The purpose of the sub-groups is to work together to generate research outputs which will drive the future direction of the working group, to acquire greater knowledge and to support and foster diversity in engineering education and in the industry.

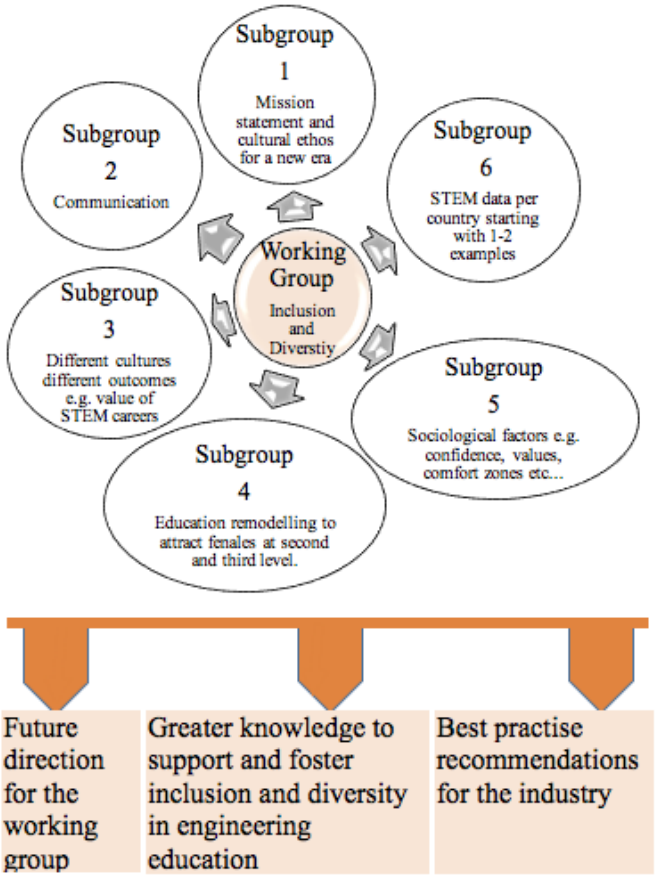

Figure 1. IFAC TECIS Inclusion and Diversity Working Group Structure, October 2019**.**

5.2 To disseminate results

The findings of the work of the members of the technical committee will be shared amongst IFAC TECIS members, presented at TECIS members respective institutions and finally distributed to participant communities, professional bodies and industrial partners. A good example of other outreach activities is a "Women in Engineering" coffee morning which provides a good opportunity to disseminate the work of the TECIS working group. The recordings of any papers presented could be made available online (subject to copyright) and opportunities in relation to other media outlets be pursued e.g. podcasts.

5.3 Inspiring future generations

Preliminary work has begun in subgroup 2 to showcase successful women and those marginalised in STEM. The purpose is to provide role models that other women and those marginalised women in STEM can follow. Irish sport provides a good example of this in a campaign being run currently by the Federation of Irish Sport to encourage more women/girls to participate, called *"If she can't see it she can't be it"*. (IrishSport.ie, 2020).

The participants in the showcases include a young female engineering student, a female engineer from industry, a female with an engineering management background and a female engineer who has worked in the engineering industry and has a significant amount of international professional exposure. This initial project will act as a testbed to identify issues to be addressed prior to further expansion of the project. These testimonials, with the permission of participants, will be used to promote greater participation in STEM e.g. during International Women's Day. Whilst the working group is an international body It is very important to note that the initial promotional materials will have an Irish focus.

Participants in the video testimonials will be asked to answer the following questions:

- What attracted you to science and technology?
- Share your positive and negative experiences in STEM?
- Why do you feel greater female participation in STEM is important?
- What impact does your discipline have on the world?
- Who are your role models and why?

This promotional material will be posted on a dedicated website or other media channels. This is a means of creating initial interest in the activities of the working group in order to connect and engage with a wider population for future data gathering.

6.0 CONCLUSIONS

Working as a cohesive multicultural group on the areas highlighted in template (Figure 1) will greatly aid in understanding the current status. There will be many questions to be answered.

Data gathering is an essential element of this process as understanding sociological, cultural and educational influences are key to unlocking trends and paradoxes.

How can we redefine the role of an engineer in modern society so as to attract young females into modern techno-engineering fields? They need to be part of the future global decision-making process, which moulds future society.

It is strongly felt that engineering education needs to be remodelled to attract young women at third level. How can the core values of our youth be incorporated into engineering disciplines so that the value of this education is more highly appreciated in a modern setting? Networking and mentoring are key here with strong mentoring models. This working group, as a whole, can promote careers and education in engineering by highlighting positive role models and communicating the good news stories through diverse digital mediums and through IFAC and TECIS.

In order to gain clarity on what its' own core values are a possible future direction for the working group could be to adopt/adapt or create its own Manifesto. Definition of an ethos leads on to engagement within and between the subgroups and is vital for the work to co-evolve.

Women and minority communities need to feel safe and comfortable in their working environment to thrive. To this end, TECIS and IFAC assist greatly by the provision of a platform that is a supportive and a safe environment from where a set of guiding principles can be discussed, interpreted, reinterpreted and produced on how to respectfully and tenderly treat everyone in the engineering workplace. This research provides future research directions for the IFAC community and addresses important issues directly relating to the remodelling of STEM education and the opening up of the engineering industry to a wider diversity of people.

REFERENCES

Bettinger, E. P. and Long, B. T. (2005) 'Do Faculty Serve as Role Models? The Impact of Instructor Gender on Female Students', *The American Economic Review,* 95(2), pp. 152-157.

Bitay, B., Brandt, D. and Savelsberg, E. (2005) 'The Global Validity of Ethics: Applying Ethics To Engineering And Technology Development', *IFAC Proceedings Volumes,* 38(1), pp. 19-24.

Bullo, F. (2018) 'Nurturing Diversity and Reducing Implicit Evaluation Bias [President's Message]', *IEEE Control Systems Magazine,* 38(4), pp. 8-13.

Ciuperca, E. M., Stanciu, A (2020) 'Variables of STEM women in Romania'. Paper accepted for *9th International Conference Redefining Community in Intercultural Context RCIC'20.* European Cultural Community, 07-09 May 2020, Cluj, Romania.

Cooley, M. (1987) *Architect or Bee? The Human Price of Technology.* Nottingham: Spokesman.

Cooley, M. (2018) *Delinquent genius: the strange affair of man and his technology.* Nottingham: Spokesman.

Cooley, M. (2020) *The Search for Alternatives: Liberating Human Imagination.* Nottingham: Spokesman.

Doyle Kent, M., Costello, O. and Kopacek, P. (2019) 'Where are all the Irish women engineers: a case study', *IFAC-PapersOnLine,* 52(25), pp. 136-141.

Engineers Ireland (2018) '*Code of Ethics*'. [Online] Available at: https://www.engineersireland.ie/Professionals/News-Insights/Resource-centre/Regulations-and-governance/Code-of-ethics (Accessed 16/03/2020).

Friedmann, E. (2018) 'Increasing women's participation in the STEM industry: A first step for developing a social marketing strategy', *Journal of Social Marketing,* 8(4), pp. 442-460.

Gill, K. S. (1996) *Human Machine Symbiosis: The Foundations of Human-centred Systems Design.* London: Springer-Verlag

Griffith, A. L. (2010) 'Persistence of women and minorities in STEM field majors: Is it the school that matters?', *Economics of Education Review,* 29(6), pp. 911-922.

Harris Jr., C. E., Davis, M., Pritchard, M. S. and Rabins, M. J. (1996) 'Engineering Ethics: What? Why? How? And When?', *Journal of Engineering Education,* 85(2), pp. 93-96.

IEEE (2019) '*IEEE Code of Ethics*'. [Online] Available at: https://www.ieee.org/about/corporate/governance/p7-8.html (Accessed 16/03/2020).

Irish Sport, *'20X20 Goes Live for Women in Sport'* (2020) [Online] Available at: https://www.irishsport.ie/20x20-goes-live-for-women-in-sport/ (Accessed 20/02/20)

Jensen, L. E. and Deemer, E. D. (2019) 'Identity, Campus Climate, and Burnout Among Undergraduate Women in STEM Fields', *The Career Development Quarterly,* 67(2), pp. 96-109.

Johansson, K. and Abrahamsson, L., 2018. Gender-equal organizations as a prerequisite for workplace learning. *The Learning Organization*.

Kelly, R., McGarr, O., Lehane, L. and Erduran, S. (2019) 'STEM and gender at university: focusing on Irish undergraduate female students' perceptions', *Journal of Applied Research in Higher Education,* 11(4), pp. 770-787.

Khazan, O. (2018) '*The More Gender Equality, the Fewer Women in STEM"*. [Online] Available at: https://www.theatlantic.com/science/archive/2018/02/the-more-gender-equality-the-fewer-women-in-stem/553592/ (Accessed 16/03/2020).

Kwak, N. and Ramirez Francisco, O. (2019) 'Is Engineering Harder to Crack Than Science? A Cross-National Analysis of Women's Participation in Male-Dominated Fields of Study in Higher Education', in Alexander, W. W., (ed.) *Annual Review of Comparative and International Education 2018.* Emerald Publishing Limited, pp. 159-183.

Mulvey, K. L. and Irvin, M. J. (2018) 'Judgments and reasoning about exclusion from counter-stereotypic STEM career choices in early childhood', *Early Childhood Research Quarterly,* 44, pp. 220-230.

Nielsen, V.L. and Madsen, M.B., 2019. Gender diversity and management aspirations in public sector workplaces in Denmark. Gender in Management: *An International Journal*.

Ovseiko, P.V., Chapple, A., Edmunds, L.D. and Ziebland, S., 2017. Advancing gender equality through the Athena SWAN Charter for Women in Science: an exploratory study of women's and men's perceptions. *Health research policy and systems*, *15*(1), p.12.

Polanyi, M. and Sen, A. (2009) *The Tacit Dimension.* Chicago University of Chicago Press.

Šaras, E. D., Perez-Felkner, L. and Nix, S. (2018) 'Warming the Chill: Insights for Institutions and Researchers to Keep Women in STEM', *New Directions for Institutional Research,* 2018(179), pp. 115-137.

Stewart, R. W. (2011) 'You Support Diversity, But Are You Ethical? Examining the Interactive Effects of Diversity and Ethical Climate Perceptions on Turnover Intentions', *Journal of Business Ethics,* 99(3), pp. 453-465.

Stoet, G. and Geary, D. C. (2018) 'The Gender-Equality Paradox in Science, Technology, Engineering, and Mathematics Education', *Psychological Science,* 29(4), pp. 581-593.

The World Economic Forum: '*Why we need more women in tech by 2030 - and how to do it*', Article part of the Annual Meeting of the Global Future Councils [Online] Available at: https://www.weforum.org/agenda/2017/11/women-in-tech-engineering-ellen-stofan/ (Accessed 16/03/2020)

Thorson, K. R., Forbes, C. E., Magerman, A. B. and West, T. V. (2019) 'Under threat but engaged: Stereotype threat leads women to engage with female but not male partners in math', *Contemporary Educational Psychology,* 58, pp. 243-259.

Wylie, C. (2019) *Mindf*ck: Inside Cambridge Analytica's Plot to Break the World.* Profile Books.