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Can engineering education be altered to improve gender equality within STEM workplaces?

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ABSTRACT

CONTEXT
The STEM field suffers from a lack of gender equality. Engineering is among the poorer performing STEM fields, both in enrolments of women in engineering and attracting and retaining women in the industry sector. Graduates of women in engineering have tripled since 1993; however, of these graduates, only 36% choose to join the engineering profession (Okrent & Burke, 2021). The field has a reasonably stagnant gender ratio globally, with women making up 16% of the workforce in Australia (Okrent & Burke, 2021) and just 13% in the United Kingdom and the USA (Ayre et al., 2013; NSF, 2021).

PURPOSE OR GOAL
Suppose we are to improve both the proportion of women studying engineering and the proportion of women in the industry. In that case, we need to attract more women to the field while retaining women in engineering to improve overall gender equality. This paper reviews the literature on the gender gap in engineering with a particular focus on why women leave the engineering sector to develop a better understanding of factors that lead to the loss of women and identify areas of improvement to improve retention. Furthermore, this paper aims to establish how education can be a valuable tool to promote gender equality, particularly in engineering.

APPROACH OR METHODOLOGY/METHODS
This paper takes a literature review approach to why women exit the engineering industry and what factors might contribute to the retention of women. A review of literature indexed by Google Scholar and the university library's online catalogue was conducted to achieve such an outcome. Returned literature was examined for inclusion in the review, and a thematic qualitative analysis was done to develop themes emerging from the literature.

ACTUAL OR ANTICIPATED OUTCOMES
The main reasons for females departing the engineering discipline are diversity barriers, the toxic masculine culture, societal expectations, and the resulting lack of support. Education is an effective tool that should be incorporated within the engineering workplace to promote diversity and reduce gender disparity. Tertiary educators can support studying female engineers by incorporating professional role models. Inclusive teaching models can be adopted at tertiary and organisational levels to promote inclusivity and diversity as a method for problem-solving and to enable social change within the workforce culture.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY
Education must be incorporated at tertiary and organisational levels within engineering to enhance gender diversity. It is proposed that educators administer an inclusive teaching model that relies on diversity to reach the most practical solutions. Integrating engineering role models into high school and tertiary education systems will combat the influence of societal expectations and teach females about their role in engineering. Organisational policies and specific teaching modules must be introduced to create awareness of sexist workplace behaviours and reduce the toxicity of the masculine culture.

KEYWORDS
gender equality, equity and diversity, engineering profession.

Introduction

A distinct gender disparity is evident in the STEM (Science, Technology, Engineering and Mathematics) workforces; however, engineering maintains the highest degree of female attrition. With authorities providing ongoing funding to encourage gender equality within the STEM field, there has been an increase in tertiary qualified female engineers; however, the percentage of women practising in the field has remained relatively stagnant. Research highlights the potential for education to be an effective tool to encourage female retention within male-dominated fields.

The Nation Science Board (2021) revealed that the number of women who graduated with a tertiary degree in the science and engineering field has almost tripled between 1993 and 2019 (Table 1). Of these qualified females, only 36% choose to practice in the field, a figure which remained stable between 1993 and 2019. Although more women are entering the science and engineering workforce, a substantially more significant number are choosing to depart the occupation after completing years of tertiary education.

Table 1 - Statistics of Women who are qualified and or practising in the STEM field for the years: 1993, 2003, and 2019 (Okrent & Burke, 2021)

Occupation and Tertiary Qualification	Thousands			Percent		
	1993	2003	2019	1993	2003	2019
Female workforce with a bachelor's degree or above	3,064	7,585	26,341	31	42	52
STEM Occupations						
STEM workforce	755	1,269	2,193	23	26	29
STEM-related workforce	NA	2,948	5,109	NA	55	57
STEM Highest Degree						
STEM Degree	2,025	3,426	6,132	31	36	40
STEM-related Degree	NA	2,462	4,747	NA	56	64

NA = not available

STEM = science, technology, engineering, and mathematics

Despite ongoing government initiatives to encourage women into engineering, the gender disproportion is stressed by many women selecting to depart the profession shortly after graduating. National Science Board (2019) statistics indicate that in the STEM workforce, the representation of women within engineering continues to remain the lowest at 16% (Figure 1) (Okrent & Burke, 2021). Female professional engineers within Australia leave the occupation at a projected rate of 40% larger than their male counterparts (Ayre et al., 2011).

Research and authority involvement is yet to uncover why females choose to leave engineering in search of alternate careers. To better understand why many women leave the profession, evaluating the discriminatory barriers and impediments causing such career dissatisfaction is imperative. Understanding such barriers enable educators at tertiary and organisational levels to design and implement teaching modules that alter the workplace culture to enhance female retention.

Available literature provides valuable perceptions into the motives for women considering departing the engineering profession; however, there remains minimal information regarding the actual reasons for such attritions. Similarly to exit interviews, understanding the experiences and reasoning for women leaving engineering is essential to comprehend the organisational factors that were instrumental in such a decision to leave. Recognising the rationale for females departing STEM workforces will enable the profession to incorporate learnings as the foundation for an inclusive and equal culture. Education is a powerful tool that can be harnessed to support females in male-dominated fields, providing them equal opportunities in an equitable workplace.

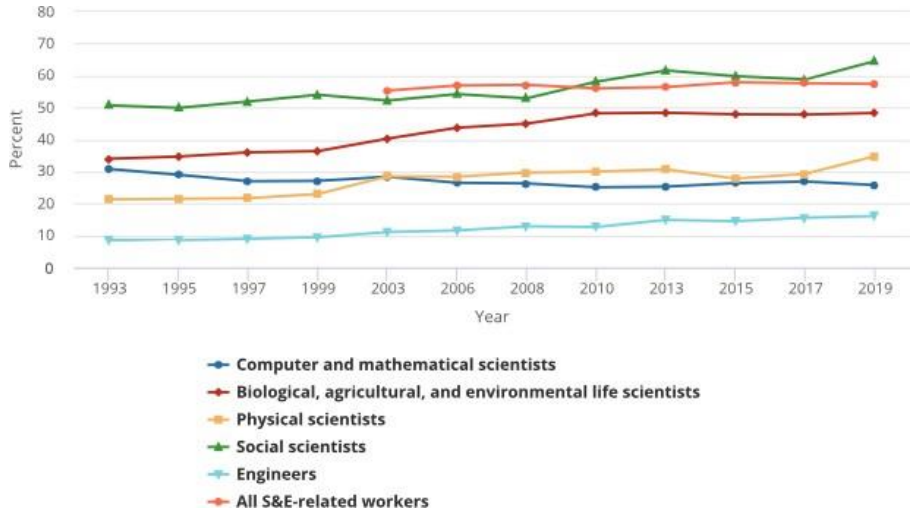

Figure 1: Women who are tertiary qualified within STEM between the years 1993 and 2019 (Okrent & Burke, 2021)

This report analyses the reasons for women exiting the engineering profession as depicted within the relevant and peer-reviewed literature. It then incorporates ways in which education can be used to enhance female retention within STEM workplaces. Although there is an increase in tertiary-educated female graduates, only 16% are practising engineers (Okrent & Burke, 2021). Despite their initial attraction to the profession, a high majority are selecting alternate careers after completing a rigorous program of studies to become qualified engineers. Something is occurring which deters women from the engineering workforce or encourages them to leave the field shortly after entry. Research highlights ways in which education can remould the engineering culture at both an organisational and tertiary level to reduce the current levels of gender disparity.

Methodology

The methodology of this project involves reviewing available and peer-reviewed studies to produce a thematic literature review. Such review will be achieved by collecting evidence on females leaving the engineering profession to understand the reasoning and workplace factors instrumental to such decisions. A specific criterion has been established to determine what available literature will be included or excluded from this review, as discussed in section 2.2.

This literature review aims to provide valuable contributions that will assist in raising awareness as to why females are deterred from the engineering profession. Such understanding will enable organisations to implement the necessary actions to improve the gender disparity within engineering. This outcome will be achieved by employing a qualitative analysis approach when reviewing available literature to paint a detailed image of the experiences encountered by practising female engineers, which inevitably entail their departure from the profession. A complex array of workplace themes will be explored which contribute to a female engineer's decision to persist or depart from the occupation. Education methods will then be proposed as a solution to overcome such barriers.

Development of a Research Question

The research question was formulated to highlight what will be answered by reviewing the available literature. The author thoroughly understood such a question to attain relevant results. Greenhalgh has constructed a paper on the “Well-Built Clinical Question,” which was adopted to formulate a strong research question. Such a question was achieved by utilising the PICO framework: population, intervention, comparison, and outcome (Greenhalgh, 2019).

- Population: Female engineers who have completed years of rigorous engineering studies before abandoning the profession.
- Intervention: Entered the engineering profession as a qualified engineer but soon chose to pursue a career in a different field.
- Comparison: The rate of females leaving engineering compared to their male counterparts. Additionally, the number of tertiary qualified female engineers compared to the number of practising female engineers.
- Outcome: Despite being initially attracted to the profession, what is occurring that is deterring women from entering the profession or encouraging them to leave after entry? How can this deterrent be minimised through education?

Data Analysis

Qualitative and quantitative data concerning the subject of diversity and inclusion, along with women's likelihood of abandoning the engineering profession at a higher rate than males, were evaluated through existing studies. A literature review was employed as it offered the opportunity to investigate available studies on the topic and understand variances and sensitivities in the literature.

The review will mainly incorporate literature from the university's online collection and Google Scholar. The authenticity of the literature will be evaluated before being incorporated into the review to ensure the information source is valid. Peer-reviewed articles will be favoured. Grey literature will also be incorporated to include information outside of the regular academic publishing model. It is essential to search for such information as grey literature is more likely to include negative data, which impacts the reliability of the discoveries.

Literature Review and Outcomes

The global shortage of practising female engineers is encountered in Australia despite organisational and government involvements such as the Workplace Gender Equality Act 2012. The act aims to stimulate and progress gender equality by obliging relevant employers to submit annual reports comprising data on gender equality indicators. The number of qualified female engineers significantly increased by 112.4% between 2006 and 2016; however, there was a proportionally minuscule 3% increase of women in the engineering labour force (Kaspura, 2019). Such data reveals that the number of women engineers has boosted, yet the advancement towards equity within the engineering profession remains very slow. It can be said that the progression of current gender initiatives could be further endorsed through education at school, tertiary and organisational levels. To adequately administer education that addresses the gender disparity within engineering, one must first understand the key contributors to female attrition. The main barriers preventing gender equality in engineering have been explored through published literature.

Barriers to Inclusion and Diversity

It is uncertain whether organisations are oblivious to the immense benefits women bring to the overall performance of engineering teams or if they are at a loss as to how to enhance diversity within the workplace. Engineers Canada defines diversity as "engaging the profession's best minds, which includes women, Indigenous peoples, and internationally educated professionals (Nelson & Brennan, 2019)." The European Institute for Gender Equality (EIGE) has conducted many studies on the economic influence of gender equality within STEM (science, technology, maths, and engineering). Closing the gender gap would create an additional 1.2 million employment opportunities. From a monetary perspective, it would improve the gross domestic product by 610-820 billion in 2050 (Economic Benefits of Gender Equality in the EU, 2020). The 2017 World Economic forum emphasises that reducing such gender disparity by a mere 25% will increase the global gross domestic product by US$5.3 trillion (The Global Gender Gap Report 2017 Insight Report, 2017). Such information indicates the immense economic benefits which result from enhanced diversity, specifically the involvement of women. The Australian

Government's Department of Industry, Science, Energy and Resources reveal that in 2020, women employed within STEM workplaces did receive a salary 19% lower than their male counterparts (Australian government, 2020). Despite the benefits obtained from female engineers, their contribution continues to be welcomed with severe pay disparities and disproportional promotional opportunities. Such behaviour suggests that the engineering profession is stuck in tradition and is opposed to diversity. Although the inclusion of women in engineering increases the range of talent, essential to strengthening the economic value of the profession, the pay discrepancy promotes misogynistic values and ultimately discourages women from the job.

Stereotyping within the profession depicts the poor diversity of engineering workers and the ill-treatment of minorities. Such behaviour counteracts the efforts dedicated to supporting minorities within STEM education systems. The emergence of a relatively new data stream, online social networks, brings to light the social behaviours and attitudes of the public. Platforms such as Facebook, Instagram and Twitter can be effectively used to attract voices and unite minority groups within STEM. Malik (2018) explores the activism campaign #ILookLikeAnEngineer which was initiated by female platform engineer Isis Wenger, who was pictured on a billboard recruitment advertisement. Her image attracted significant online attention with excessive degrading criticism stating that she was “too attractive” for a “real engineer” (Malik et al., 2018). Such literature highlights the segregated opinions that continue to fuel the sexist engineering culture. Wenger’s hashtag enabled other minorities to express their ideas on the problem, which identifies how the use of social media can provide education and support for STEM diversity. Although this literature fails to address the backlash minorities would encounter through social media, it remains a sturdy platform to provide education on diversity.

Engineering education strongly influences the values and culture of the workforce; therefore, the lack of diversity reflects inadequacies that begin in STEM education. Literature reveals that diversity, specifically the inclusion of women, provides significant benefits to the engineering profession; however, such knowledge has limited practical effects because it has not been expressed within the workforce or education systems. The Royal Academy of Engineering studied the inclusivity of engineering culture and determined that evident tensions obstruct diversity (Atkins et al., 2018). Such obstructions include:

- A polite yet unwelcoming environment
- An unbroken tie to tradition.
- Minimal support for career progression.

Nelson and Brennan (2019) identify the presence of 'inclusion privilege,' whereby those who do not experience exclusion are unlikely to act, remaining ignorant to such diversity issues. Although these pieces of literature provide critical information, they are limited in application as they indicate such barriers can be removed through education but fail to specify how organisations should give such education. Peters (2018) has proposed the Integrated Engineering Programme (IEP), which presents a model for teaching inclusion and diversity within engineering education. This approach addresses teaching methods, focusing on content, delivery, and application. This inclusive education model establishes a receptive culture for all students and promotes diversity to resolve problems. To achieve the practical benefits of such education, it is evident that active participation will be essential for all stages of engineering, including students, teachers, and those within the workforce.

Societal Expectation and Lack of Support

There are prevalent misconceptions about engineering among high school girls and about the role of practising female engineers. Such misinformation contributes to the gender gap in engineering due to fewer females partaking in STEM subjects compared to their male counterparts. As a result, fewer women become technically skilled and experienced within the engineering profession. Within Australia, 18% of graduates in engineering and technology subjects are female (Husband Benita, 2020). Inevitably, the small proportion of women graduates is mirrored throughout the workplace, with 12.4% of female engineers hired in Australia in 2016 (Snapshot of Disparity in STEM |

Department of Industry, Science, Energy and Resources, 2020). This small percentage ultimately poses a technical barrier to women's contribution to engineering. Literature suggests that knowledge development could overcome this technological barrier by enhancing the approach to engineering during the early learning stages. Salas-Morera (2019) conducted an extensive survey on final-year high school students (834) and students in their first year of tertiary education studying: engineering (319) and science (209). Such qualitative research determines that girls perceive the engineering profession as highly valuable, yet they understand it to be for males. Females are subject to educational barriers from a young age which inevitably deters them from pursuing engineering.

The dominant misconception is that engineering does not enable one to meet their communal purpose, something often perceived as necessary to women when selecting a career. To appeal to young women, educators must give engineering the sense of communal utility it holds in society. Additionally, there remains a solid societal misconception that engineering is deemed a more appropriate career path for men than women (Salas- Morera et al., 2019; Diekman et al., 2010). Such belief suggests that the engineering curriculum needs to be remodelled to allow all students to understand their purpose within the social role of engineering and the contribution they will have to the community. This misconception is further reinforced by Madara and Namango (2016), who determined that many people understand an engineer to be someone who does 'manual work with machinery.' High school students and the people who influence them - teachers, parents, and school counsellors - primarily do not understand what an engineer is, therefore creating a barrier around public awareness of STEM minorities and recruiting young engineers.

Engineering role models (professionals visiting schools and universities) significantly influence teenagers and young adults by providing real insight into engineering careers. Role models are essential to changing students' perceptions of employment, particularly those male or female dominated. The study by Madara and Namango (2016) employs a qualitative approach to analyse teenage girls' perception of engineering as a potential career path, determining that 53% of the students had never interacted with an engineer. This literature states that seeing successful female STEM professionals enables young women to disconnect from the societal constraints of their abilities. Research shows that young girls are primarily influenced by role models and mentors (González-Pérez et al., 2020). González-Pérez highlights that regular interactions with females working in STEM drive the relationship between female students' confidence in maths and their choice of STEM as a career path. These findings are supported by Eccles' (2013) model of achievement-related options, which predicts the correlation between one's expectations of succeeding and the value of the task. This literature highlights the importance of integrating engineering role models into education to encourage younger females to pursue careers.

The Systematic Bias and Male-Orientated Practices of Engineering

Research conducted on females within the engineering profession continues to uncover how masculine workplace culture depreciates and segregates women. While enduring the conventional challenges everyone encounters to excel within a selected career; female engineers are also faced with this detrimental culture and having to continuously prove their worth (Ayre et al., 2013; Faulkner, 2009). These themes suggest that women abandoning the engineering profession stems from job dissatisfaction due to the workplace culture, not the nature of the engineering work. It can be further proposed that women who remain in engineering must portray higher amounts of persistence and perseverance, which arises from one's personality characteristics (Ayre et al., 2013). This notion is highlighted in Buse's survey of 630 qualified tertiary engineers who are currently or were recently employed in an engineering position. The results determined that women who remained in engineering displayed high amounts of persistence, driven by independence and confidence, combined with their strength to mediate challenging situations to their benefit (Buse, 2011). A research paper produced by Jennifer Hunt shows that the exit rate of women in engineering is driven by dissatisfaction with inadequate promotional opportunities and the resulting lack of financial development (Hunt, 2010). Several different social barriers are preventing women from remaining in the engineering field. Wegner's #ILookLikeAnEngineer campaign sparkes

awareness of the discrimination encountered by non-stereotypical engineers such as women. It further reinforces the misogynist traits of engineering, which contribute to the high rates of female attrition.

For male-dominated fields to embrace progressive social change, education must begin with the majority who benefit from the status quo. Such a majority refers to the stereotyped engineer: privileged men. Flood (2018) states that Australian and international studies reveal that men hold a conservative perspective toward gender equality. Men also have a substandard ability to recognise discrimination towards women, mainly if the sexism is obscure (Drury & Kaiser, 2014). Flood (2018) further explores the notion that structural inequality goes unnoticed by the privileged because they become familiar with the benefits, experiencing it as usual. Such literature suggests that the foundations of social change must commence in early education and require organisational participation to be eradicated. On a corporate level, the gender equality business case has sparked gender initiatives by presenting the economic benefits of gender equality (Workplace Gender Equality Agency, 2018). Educational strategies have been proposed by Flood (2018), which respond to and provide education surrounding the gender disparity within male-dominated fields.

1. *Organisational policies:* address leadership and workforce cultures that significantly influence gender equality within engineering corporations. If leaders support gender equality initiatives, individuals are likely to promote such actions.
2. *Delivery and content strategy:* provide methods to address the issue of gender inequality through content, how to manage backlash and how to dispute reactions of avoidance.
3. *Teaching diversity:* promotes ways in which educators should present diversity training.

Conclusion and Recommendations

Of the STEM workforces, engineering maintains the highest amount of female attrition despite ongoing funding and input from authorities. Available literature reveals three crucial barriers preventing females from persisting in engineering. Such obstacles are; inadequate inclusion and diversity, societal expectations and the resulting lack of support, and the systemic bias due to the male-dominated culture. Education is critical in eradicating these themes to improve gender equality in engineering. It is recommended that tertiary educators introduce a teaching model that focuses on the need for diversity to resolve problems and produce the most effective solution, to enhance the inclusion of women. School systems can combat societal expectations by integrating engineering role models - professional female engineers - into high school education. Such an approach will teach girls about the role of women in engineering and increase their confidence in STEM subjects. Education will enable male engineers to understand and rectify their actions to reduce the toxicity of the masculine culture. The profession can achieve this result by introducing organisational policies and teaching models throughout tertiary education. Published literature depicts that education at all levels, high school students, tertiary organisations and the workforce, can enhance the preservation of practising female engineers. The workforce and culture of a profession reflect the education curricula. As such, adapting the delivery and content of education can improve the engineering workforce and the number of women.

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