

Where do New Zealand Female Engineers come from? Insights from a quantitative analysis

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STRUCTURED ABSTRACT

CONTEXT

Females are under-represented in the New Zealand engineering student cohort. Increased female engagement in engineering subjects is a target of many tertiary education providers. The lack of diversity in engineering graduates has ramifications for engineering industry and limits productivity. It also contradicts the Critical theory, which promotes equity of opportunity across different people groups.

PURPOSE

This research determines the rate of all-girls high school attendance from female students that progress to enrolment in tertiary engineering training

APPROACH

The high schools attended by each student that enrolled in engineering at the University of Canterbury between 2005 and 2017 were recorded. The rate of single sex high-school attendance of this group of students was compared to the national rate of single sex attendance (~13%)

RESULTS

A total of 1147 female records were analysed and 847 females recorded a New Zealand high school. Female students enrolled in engineering over the time period went to single sex schools in 56% of cases. In contrast, 4845 male records were analysed and 4441 recorded New Zealand High schools. In contrast to females, males went to single sex high schools at a rate of only 35%.

CONCLUSIONS

This rate of attendance at single sex high schools in the female engineering cohort is significantly higher than the nation average. This may be due to some cultural differences at single sex girls' high schools. However, it may also be due to the parental ambition that may correlate with selection of single sex education for the children. Further investigation of the causes for this outcome may provide significant insight that could ameliorate the lack of diversity of the engineering cohort

KEYWORDS

Engineering education, Quantitative analysis, Females in STEM.

Introduction

The lack of female participation in science, technology engineering and mathematics (STEM) is a well-known problem (Tellhed, Bäckström, & Björklund, 2017; Wang & Degol, 2017). It has been noted to contribute to the gender pay gap (World Economic Forum, 2014) and increased equality and diversity in STEM has been recognised as a goal for many government agencies (Ministry for Women, 2018b; Ministry of Business Innovation and Employment, 2016), professional bodies (Institute for Professional Engineers New Zealand (IPENZ), 2013) and education providers in New Zealand (University of Auckland, 2018) and across much of the western world (OECD, 2014; UNESCO, 2018). However, there is strong evidence from the Islamic world that the lack of equality is a cultural phenomenon. In particular, much of the Islamic world has very high rates of female participation in STEM and engineering in particular (Huyer, 2015). Hence, to remediate the STEM inequality in New Zealand, it is imperative to determine the cultural factors that contribute to the problem.

While there remains inconsistencies in the representation of the Critical theory, most sociologists maintain that it is concerned with the gap between society's current and ideal states (Cohen, Manion, & Morrison, 2011). The theory generally expounds the importance of liberation, freedom of expression, and symmetry of opportunity across people groups (Cohen et al., 2011; Held, 1980). Hence, the lack of female participation in STEM observed in much of the western world could be addressed within the context of the Critical theory. Importantly, the Critical theory is a somewhat unique philosophy in that it aims to not only explain the current state of society, but to also instigate positive changes in society (Cohen et al., 2011). Hence, it also provides a context in which changes in STEM enrolment may take place.

This present research empirically considers the high school environments attended by engineering students at the University of Canterbury between the 2005 and 2017.

Methods

Scambler (2001) notes that the Critical theory is concerned with understanding the context in which some change is desired. Hence, a data audit of the students that entered into the College of Engineering during their second year at the University of Canterbury between 2005 and 2017 was undertaken. The audit considered whether the high schools attended by the engineering students who enrolled during this period were single sex or co-educational.

Cohorts

Students must complete an 'intermediate year' as a prerequisite for admittance into the College of Engineering. Entrance to the intermediate year is based on satisfactory performance in year 13 maths, physics and chemistry as well as year 12 English. The intermediate year contains foundational courses in science, mathematics and engineering mechanics. Students must pass all of their courses to be eligible for entry into the professional programmes within the College of Engineering. There are nine programmes within the College of Engineering: Chemical and Process Engineering, Civil Engineering, Computer Engineering, Electrical and Electronic Engineering, Forestry Engineering, Mechanical Engineering, Mechatronic Engineering, Natural Resource Engineering, and Software Engineering. In some cases, yearly enrolment numbers are capped and entrance is competitive on the student's grade point average.

Upon enrolment with the University of Canterbury, the students' prior high school and their gender is recorded. The schools were categorized as single-sex schools or co-educational based on information available on their websites, or in some cases of school closure, via Wikipedia or Newspaper articles. The gender recorded at enrolment was used. Students who went to an international high school, and those who were home schooled were discounted from the analysis. Omitting these records from analysis was deemed appropriate as this

research hopes to determine the factors behind enrolment in engineering that may be addressed and potentially optimised in a New Zealand context.

Analysis

The rate of attendance at single sex schools was evaluated for both male and female students. This rate was compared to the national average of single sex attendance in New Zealand. In particular The New Zealand government working group 'Education counts', estimate that the rate of male single sex high school attendance is 11.3% and the female rate of single sex high school attendance is 11.8% (Education Counts, 2017).

Results

In total 5992 student records were analysed. Of those, 5288 records indicated a New Zealand high school. There were 4441 qualifying male records and 847 qualifying female records. In total, 474 females went to girls'-only high schools. This rate of 56% exceeds the national average of 13% by a factor of 4.3. In contrast, 1576 males went to a boys'-only school. This represents a rate of 35% which is a 2.9 times more than the national average. Table 1 summarises these findings

Table 1 rate of attendance in single sex and coeducational high schools for students in the College of Engineering at the University of Canterbury 2005-2017.

	Eligible students	Single sex	Coeducational	Ratio of single sex
Females	847	474	373	56.0%
Males	4441	1576	2865	35.5%
Female ratio	16.0%	23.1%	11.5%	

Of interest, some engineering disciplines exhibited distinct rates of prior single sex attendance for female students. In particular, 71% of females in computer engineering went to a single sex high school. In contrast, 52% of females enrolled in chemical and process engineering went to a single sex high school.

Of interest, seven females enrolled in engineering between 2005 and 2017 went to boys only schools, but no males went to girls only schools in this same period.

Discussion

The low rate of female participation in STEM has been noted as a barrier to diversity in engineering practice and contradicts the Critical theory which supports equality (Cohen et al., 2011; Held, 1980). As well as the social ramifications, the lack of females in STEM has been implicated in the gender pay gap (Ministry for Women, 2018b; World Economic Forum, 2014), and has significant economic ramifications. However, in certain parts of the world, and Islamic countries in particular, the gender bias is negligible, or reversed (Huyer, 2015). This is evidence that cultural changes in New Zealand could potentially mitigate or even reverse this gender bias. However, prior to implementation of successful implementation of remediation, the contributing factors for this lack of diversity in New Zealand must be identified.

This research shows a clear bias towards single sex high school attendance in engineering students. However, this bias is considerably stronger among female students. In particular, females in engineering were 4.3 times more likely to come from a single sex school than a typical female in New Zealand. This is significantly greater than the rate of single sex

attendance for males in the same cohort (2.9 times). This strong indicator shows that there is some cultural element in single sex girls' high schools that causes improved rates of female participation in engineering at the University of Canterbury. This research also provides an empirical evaluation of the efficacy of single-sex schools which was noted as lacking by US policy makers (Mael, Alonso, Gibson, Rogers, & Smith, 2005).

This analysis considered data from 5288 eligible students over 12 years of enrolments at the University of Canterbury. Hence, the statistical analysis was extremely robust, and it could be reasonably safely assumed that there are some cultural differences occurring across co-educational and girls' only high school that are leading to distinct rates of enrolment in engineering. This research did not consider what the cultural differences may have been. However, one may hypothesise that conforming to historical gender norms may be more encouraged at co-educational schools. However, there may also be differential parental expectations from girls sent to girls' only schools which influence enrolment. Determining specific causes of improved enrolments from single sex schools is important future work that will be driven, in part, by the present research.

The findings of this study should also be considered across genders, and not simply within genders. In particular, girls' only high schools generated only 23% of the enrolments in engineering from single sex schools (Table 1). While this is certainly much better than the coeducational ratio of 11.5%, it still represents a ratio that can be much improved.

This analysis did not consider the high school enrolments of international students, and omitted those who were home schooled. This choice was driven by the goal of determining how New Zealand high school culture contributes to enrolment in engineering. Furthermore, the gender of students at enrolment was used. While the gender of some students changed over their enrolment the various factors that may have influenced them during high school would most likely have been associated with the gender recorded at their initial enrolment.

This research did not consider the general rate of university enrolment across students who went to single sex and co-educational high schools. However, to determine the factors that affect enrolment in engineering across genders, it was only necessary to consider the relative behaviour across male and female students enrolled in engineering. In particular, the increased rate of boys' only high school attendance in those that enrolled in engineering implies that single sex schools have improved rates of engineering career selection. However, the effect of single sex education on female career selection was enhanced significantly.

To the authors' knowledge, the outcomes of this research have not been confirmed in any other cohort. However, the strength of the effect of single sex school attendance on enrolment in other STEM subjects should be considered. Research may be undertaken across other universities and polytechnic providers in New Zealand. New Zealand has a uniquely high rate of single sex high school participation. Hence, there may be limited scope to repeat these findings internationally. This gives New Zealand unique potential to lead research into female STEM participation.

In simple terms, the Critical theory considers how to remediate undesirable aspects of society. The lack of female participation in STEM careers and education is an instance of inequity that many organisations have been interested in addressing. For example, the government ministry for women notes that the gender pay gap is partially driven by the lack of female participation in STEM (Ministry for Women, 2018b; World Economic Forum, 2014) and advocates a series of outlets to support female participation in STEM training (Ministry for Women, 2018a). Similar goals were addressed recently in the US (Obama, 2013). Furthermore, UNESCO note that the issue is initiated at a high school level and may be ameliorated via appropriate training and encouragement (UNESCO, 2018).

Conclusions and recommendations

The analysis used enrolment data from 5992 students at the College of Engineering, and thus provides strong empirical evidence positive impact of girls' only high schools on female participation in engineering training at the University of Canterbury. The reasons for this impact are not known. Future research should ascertain the strength of this effect on other STEM enrolments, and at other universities in New Zealand. Furthermore, the relative affect sizes of the various influences should also be determined in order to target effective intervention. In particular, the relative strength of personal perceptions of STEM education or careers; peer influence; teacher influence; parental advise; bias among careers advisor; marketing from tertiary sectors are unknown. This research has shown that a possible domain to compare and contrast these influences may be across the coeducational and single sex high schools. Once such influences can be established, targeted remediation can occur, both in single sex and coeducational high schools (Wang & Degol, 2017).

The high rate of single sex education in New Zealand is unique. Hence, New Zealand may have a unique educational environment in which gender bias in education could be researched.

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