Girls in STEM: why do they choose their discipline?

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Structured abstract

BACKGROUND
Engineering has remained one of the most male-dominated professions worldwide. In Australia, the engineering profession has traditionally attracted few women, with women accounting for only 6% of practicing and professional engineers and 14% of enrolments in engineering courses nationally. Many initiatives to encourage girls to enrol in engineering programs have been implemented, but few have delivered lasting results. This indicates there is a poor understanding of what attracts women to engineering. Although some STEM disciplines consistently attract more girls there have been very few studies on what influences girls to select their discipline of engineering or science and no directions for more effective marketing of programs.

PURPOSE
The research objectives of this study were to determine what factors influence undergraduates in their choice of engineering or science as a program, and to analyse whether the factors are different between gender and discipline.

DESIGN/METHOD
Cohorts of students were recruited from programs with higher (chemistry and chemical engineering) and lower (civil engineering and physics) numbers of female students. Both male and female students participated in the study. Data were collected by survey and focus groups. Students were asked questions about what influenced them to select their field of study. The focus groups were recorded then transcribed, and the data analysed thematically using a framework developed from the literature.

RESULTS
The literature suggests key issues for girls are influence of role models, parents, teachers, achievement in maths, alignment of career with personal goals, and people-oriented careers. Our study also found these were factors identified by many of our students. However, the extent of the influence varied significantly with gender and discipline. In particular, girls were more strongly influenced by their family and were more likely to have a family member as an engineer. Boys were more influenced by engineering programs on TV. Engineering students were motivated by salary and were keen to enter management more than science students. Physics and civil engineers expressed a strong desire to leave a mark on the world, which was absent in the discussion with the other disciplines.

CONCLUSIONS
The engineering and science market is segmented, and this should be considered when promotional materials and activities are designed. In particular, emphasis should be placed on promoting STEM careers to the whole of the prospective student's family, salary level, hands-on nature of engineering, management prospects and making a tangible impact on the world.

KEYWORDS
Discipline choice, gender, marketing

Introduction

The Australian National Commission for UNESCO's Women in Science and Engineering Summit (WiSE) held at Parliament House in Canberra on 11 April 2011 acknowledged the low participation rates of women in science and engineering and highlighted the vision:

> *to help realise the potential in science, technology and innovation, widening the talent pool of scientists and engineers in public and private domains through engaging more girls and women in science, engineering and technology*

Engineering has remained one of the most male-dominated professions in the western world. There is some variation, for example, women represent 18% of practicing engineers in the US, and only 6% in Australia (Little & Barra 2009; Tully & Jacobs 2010), but generally the number is far from parity. Student numbers are slightly higher, with 20% female students studying engineering in Canada and 14% in Australia (Baker *et al*. 2009, King and Godfrey 2011). The numbers for physical sciences are also low: only 32% of Physical science students are female (UNESCO WISE summit 11 Apr 2011) and only 22% of physics students are female (Ivie & Ray 2005). Even when women take equal numbers of science classes as men, they are less likely to chose STEM careers (Drury *et al.* 2011).

Even universities with esteemed WIE programs attract women in only modest numbers. Purdue was awarded the prestigious Bernard M. Gordon Prize in 2005 for its EPICS program designed to attract female students (Coyle, Jameison, Oakes 2006), but in 2013 it still has only 27% female students in its first year of engineering programs and 22% overall (Purdue 2013). Some high ranking universities in the US have much higher numbers of female engineering graduates (MIT 39%, Princeton 32%) but otherwise parity is still a distant a goal despite decades of intervention programs.

Background

Many programs have been implemented to increase women in engineering and science but few have delivered lasting results. This indicates there is a poor understanding of what attracts women to engineering. Prior to 2001, the increase in women enrolling in engineering courses in Australia was attributed to the period of maximum state and federal funding for gender related intervention programmes in the education sectors from 1986 to 1990 (Lewis, Harris & Cox 2000). Public awareness of participation of women in mathematics and physical sciences was raised. However, as the participation rate never approached parity these programs were considered ineffective and were discontinued.

Research is very scarce on what makes particular programs effective or ineffective. According to King and Godfrey (2011) female participation rates are now declining in engineering. Understanding what attracts young people, especially young women, to engineering and science is a critical step in developing more effective programs and enhancing female participation rates in these programs.

Some studies have found no differences between what attracted female students to different disciplines. Hobart *et al*. (2006)'s extensive study of engineering undergraduates surveyed cohorts from civil, mechanical, electrical and mining engineering. They found no differences between student's influences in the different disciplines, except that more civil engineers enjoyed the outdoors, and more mechanical and electrical engineers liked playing with gadgets. It is unclear if this applied equally to male and female students. One of the limitations of the study is it focused on male dominated disciplines. Other studies have reported significant differences. One found significant differences among the influences on program choices of civil, environmental and chemical engineering students (Gravina, Jollands & Woon 2011). All the students cited favourite subjects as an influence, but only environmental engineering students cited family as an influence and only civils cited teachers as an influence. The authors concluded that a segmented marketing approach should be adopted.

Hence more work is needed to understand how students choose different engineering and science disciplines, and how to design more effective marketing strategies.

Literature review

The gender ratio in engineering and science depends very much on the discipline. While females represent approximately half the commencing undergraduate students in the natural and physical sciences, only 22% of physics students are female (Ivie & Ray 2005). In Australia, women account for only 15% of enrolments in engineering courses (Little & Barra 2009; Tully & Jacobs 2010). Chemical engineering is significantly more popular choice than other fields, for example, in Canada 40% of chemical engineering students are female (Anderson & Gilbride 2003). At the other end of the spectrum, programs such as automotive, maritime and mechanical engineering attract few women, typically 10% or less of students are female. There are several factors that are recognised as influencing not only the choice of an individual to undertake further studies in engineering and science, but also their selection of a particular discipline.

Influence of role models

Engineers and scientists as role models

In the United States, girls take as many classes in Science, maths and technology as boys, and receive higher grades than boys in these classes. Despite this, however, girls remain less likely to choose to pursue a career in this field than their male counterparts (Drury, Siy and Cheryan 2011). Hence more effort is needed to recruit women and girls into STEM related higher education programs and careers than boys. One effective strategy involves the use of role models, in which successful engineers or scientists are showcased. Empirical data suggests that such role models are effective in influencing girls' career aspirations, regardless of whether the role models are male or female. However, role models may reinforce stereotypes, which may deter women from pursuing a career in STEM, as well as influence their choice of discipline. Drury discusses how girls can be put off studying computer science by the current stereotype of people working in the discipline – "as unsociable and preoccupied with technology" (Drury, Siy & Cheryan 2011, 266).

Parents as role models

Along with professionals working in the field, family members and teachers may also act as role models and influence a student's career decision (Hobart *et al.*, 2006). Many factors, including family background, family income, parental level of education and career affect a young person's preference for area of study. Woolnough (1994) found that 34% of the engineering students surveyed had at least one parent who was an engineer. In a study conducted at the Technical University of Norway (NTH), the students were asked to assess how much their parents had affected their decision to study at university. Results showed that women said they were very much encouraged by both their parents to attend university: mothers in particular talked of the importance of education for women, while fathers had a greater influence on the type of education their daughters should choose. Both parents directly supported and acted as role models for their child (Kvande 1986). Another study found that parents and teachers had the most influence on students' perceptions of science (Henman 2010).

Influence of education and extracurricular activities

Research frequently cites the importance of educational environment and programs as well as extra-curricular activities in influencing students to pursue further studies in STEM and their choice of discipline.

Influence of single gender schools

Approximately 22% of all the female secondary students in the state of New South Wales (NSW) attend an all-girls high school (Australian Bureau of Statistics 2007). Girls who attend single-gender schools carry less gender-based stereotypical views with them into their university years. A US study of over 500 boys and girls completing high school at both single

sex and coeducational schools revealed that girls in single sex schools had higher motivation and self-esteem in their mathematics and science classes (Cherney & Campbell 2011). A survey of female engineering students at Sydney University of Technology found that 40% attended a single-sex secondary school: the authors argued this indicates girls from single sex schools are more likely to enrol in engineering (Tully & Jacobs 2010). However, Cherney & Campbell (2011) found that even though girls at single-sex schools outperformed their counterparts at coeducational schools in maths ability, they did not appear to express more interest in continuing study in the areas of maths or science.

Influence of teaching practice

The influence of science teachers on higher education and career choices of both boys and girls was found in a UK survey. Career advisors highlighted that the student experience in science classrooms and extracurricular activities run by science departments were major influences in the future career choices of high school students (Munro and Elcom, 2000). Daly (2009) reported that a teaching style that incorporates more group work, presentations and class discussions improved girls' engagement with the physical sciences.

Influence of career perceptions

A career choice is governed by "the intersection of people's goals and their preconceptions of the goals afforded by different careers" (Diekman *et al*. 2010, 1051). In a large study of high school and college students as well as parents, school personnel and teachers it was found that the four biggest influences on their career choice were personal influence, parents, earning potential and teachers. Parents and teachers were the major source informing their perception and understanding of STEM careers (Hall *et al*. 2011). No analysis was reported of impact of gender.

Altruistic career goals

This concept of alignment between perceptions of career outcomes and personal career goals has been explored in several studies. Diekman hypothesised that women are more likely to choose a career which endorses communal or altruistic goals (working with or helping people), while certain STEM pathways like certain disciplines of engineering are "perceived as inhibiting communal goals". This misalignment of personal goals and career perceptions explains why women may choose not to enter STEM pathways even if they are proficient in science and maths (Diekman *et al*. 2010). Similarly, girls were found to be more engaged and interested in science-related tasks, if they were convinced of the altruistic value of science. The relatively high proportion of women in professions such as environmental engineering may then be attributed to the perception of such disciplines as being more "other-oriented" than others, such as mechanical engineering (Weisgram & Bigler 2006). The influx of women to the science disciplines that are most obviously related to helping people such as biomedicine and psychology can be similarly explained (Diekman *et al*. 2010). Given that "STEM fields hold the key to helping people", dispersing the idea that careers in science and engineering do in fact endorse communal and altruistic goals may encourage more women to pursue a wider variety of STEM careers (Weisgram & Bigler 2006).

Personal interest and preferences

Some studies have found that an individual's ability and personality are significant factors in their choice to embark on further studies in STEM (Woolnough 1992, Hobart *et al*. 2006). A recent meta-analysis found that the biggest gender difference related to interests is men prefer 'thing-oriented' careers and women prefer 'people-oriented' careers (Su, Round and Armstrong, 2009). In a similar study students were asked which personal trait influenced their choice of engineering as a career. The key difference between girls and boys was that boys reported "playing with gadgets" and the desire for a "hands-on" course as being the most significant influences, while girls ranked "did well at maths" as the highest (Hobart *et al.* 2006). Barnes *et al*. (2005) found there is a considerable correlation between the "Investigative personality factor" and interest in the physical sciences. As this personality trait

appears to be more common in males, this further explains why physics appeals more to male students.

Purpose

This study had two main research objectives:

1) To determine what are the factors that influence RMIT undergraduates in their choice of engineering or science as a program
2) To analyse whether the factors are different between gender and discipline.

Methods

Participants in this study were RMIT University undergraduate students recruited from four programs: civil and chemical engineering, and chemistry and physics. Both male and female students were recruited, so the similarities and differences in the motivations for choice of programs could be distinguished between gender as well as discipline.

The call for volunteers for focus groups was sent by email to a second year class in the selected discipline. The desired sample size was 10 students per focus group. The actual sample size ranged from 4 to 8 students. The ratio of male to female was 1:1 in three of the disciplines. Five focus groups were run in total, one or two per discipline. A second focus group was run in one case, when the first focus group was small and didn't contain any girls. In Physics, there were no female volunteers, despite two attempts at recruiting students. The only suitable focus group time clashed with another Physics class, hence the number of students in the focus groups was smaller than the other disciplines.

Each focus group had a duration of 60 minutes. Focus groups were scheduled at lunch time directly after a lecture, with lunch provided. Each focus group had students from one discipline only.

The focus groups explored the causal thinking that led to the student's choice of program. The research assistant (RA) adopted a semi-structured approach using a framework developed in our previous study (Gravina, Jollands & Woon 2011). The questions were framed around three themes: role models, education and extra-curricula activities, and career perceptions.

Focus groups were recorded and then transcribed verbatim. The transcripts were analysed thematically using nVivo. The themes were based on the framework from our previous study with sub-themes (common factors) of altruism, broad career paths, family, management roles, salary prospects, and so on. A clarificative approach was adopted in the analysis of data, in which outcomes (intentional and incidental) are related to the objectives (Owens 2007). This means that transcript data is coded to one or more sub-themes where there is evidence that the sub-theme has had some influence on a student's thinking. The findings of the study were compared with the literature.

A survey was also undertaken. It was emailed to each class in each discipline. It contained a similar set of questions to the focus groups. The questions were framed around the same three themes as the focus groups, and there were some additional demographic questions such as respondent age/language spoken at home. The response rate for the survey was too low to draw firm conclusions. However, when the data from the survey was compared with the focus group, it supported the conclusions from the focus groups.

Results

In all of the focus groups, it emerged that all the participants were influenced by a number of common factors including family, teachers, and certain aspects of their perception of their intended career. Generally these factors align to those identified in the literature – this suggests that although it was a small sample, the sample was representative of a broader

body of students. However, the extent to which these factors influenced their decisions depended on both gender and discipline.

Common factors of influence

The common factors of influence include 'teaching practice' and 'broad career options'. It was recognised by all students that a good teacher can play an integral role in making science interesting and accessible to students, ultimately encouraging them to continue to study in the STEM field. Students believed that experiments and hands-on activities are a crucial part of the science curriculum and play an integral role in their enjoyment of subjects such as physics and chemistry. Furthermore, all students tended to agree that part of their motivation for studying engineering or science was the fact that they could foresee that it would open up a breadth of career options. A typical comment was "I still sort of don't know what a lot of scientists do, there's quite a large variety of jobs." Although some of the engineering students stated that they were not aware of how broad engineering was until they started studying, they recognised that it was an aspect of the profession that appealed to them.

Differences between males and females

Two key differences emerged between the motivating factors of males and females across the various groups. These were the extent to which family influenced their career decision and the perceptions that they gained from the media. Although family was recognisably a factor in each of the students' decision, for the girls, especially those studying engineering, it emerged as a much stronger influence than for the boys. 5 of the 7 girls studying engineering stated that they had family members who were engineers or scientists, and that it was from these familial connections that they gained the insight into the profession that engaged their interest in pursuing STEM careers. One female engineering commented "my whole family are engineers so I kind of understood what it meant". Although some of the male students also had family members who worked in the industry, they did not identify them as having influenced their decision in a significant way. On the other hand, it emerged that the perceptions of science and engineering projected by the media had a much larger influence on the male participants than the female, as, while only civil engineering girls mentioned media, the boys from all four disciplines identified TV shows and documentaries as engaging their interest in STEM. A typical comment was: "So it's amazing. You're getting enjoyment from that, but also learning. So you're like, yeah, science is cool".

Differences between science and engineering

Science and engineering students were differentiated by two aspects of their career expectations: expected salary and aspiration to move into management roles. For the engineering students, the prospect of a large salary upon graduation was a significant motivating factor behind their choice to study engineering. On the other end of the spectrum, the science students expressed that their expected salary played only a minor role (if any) in their career decision, similarly, the desire to move into management roles was largely absent for science students.

There was also a slight variation in how the engineering and the science students articulated their preference for hands-on activities. For science students, this took the form of an expressed interest in 'doing experiments', as the chemistry and physics students stated that they enjoyed experiments in high school science classes and this practical experience influences their career choice. One science student commented "I find it a lot more fun to touch things and go, oh that's really dangerous". On the other hand, the impact of 'doing experiments' was not discussed in detail by the engineering students, but rather they stated that they had a desire to have a 'hands-on job'. For 9 of the 18 engineering students, this included preference for a job that incorporated outdoors or on-site work. A typical comment from an engineering student was "I wanted to do something hands on and outdoors so that was the engineering aspect".

Differences between chemical and physical disciplines

Whether a student preferred chemistry or physics in high school was a key determinant of whether they entered into the chemical disciplines (chemical engineering or chemistry) or the physical disciplines (civil engineering or physics). Aside from this, another key difference emerged between the two groups: the desire to make a 'tangible impact' was expressed as a motivating factor for those in the physical discipline (by both male and female students), but not in the chemical discipline. Unlike the chemistry or chemical engineering students, the physics and especially the civil engineering students expressed that their aim to leave their own mark on the world, through a physical building or construction, an invention or a discovery. One civil engineering student commented "I think what appealed most was the fact that when you build something, you kind of leave your own mark on the world, literally". Especially civil engineering students extended this idea as they explored the idea that engineers make a great contribution to the advancement of society and that this influenced them in their career choice: "So I picked structural [engineering] because that's one way that I thought was helping civilisation move forward."

Conclusions

This study aimed to find what influences male and female undergraduates in their choice of engineering or science. Both engineering and physical sciences are male-dominated disciplines. Women account for 6% of practicing engineers, 16% of undergraduate engineering students, and 22% of physics undergraduates. Many initiatives have been undertaken but have failed to make an impact on enrolments in Australia. The literature suggests key issues for girls are influence of role models, parents, teachers, achievement in maths, alignment of career with personal goals, and people-oriented careers.

Our study also found many factors were common to students, including family, teachers, and career perceptions. However, the extent of the influence varied significantly with gender and discipline. In particular, girls were more strongly influenced by their family and were more likely to have a family member as an engineer. Boys were more influenced by engineering programs on TV. Engineering students were motivated by salary and were keen to enter management more than science students. Physics and civil engineers expressed a strong desire to leave a mark on the world, which was absent in the discussion with the other disciplines.

The current approach to marketing STEM programs is to assume the market is homogeneous. This approach does not reflect the research on student motivation. There are clear differences between motivations of girls and boys. So a better approach would be to assume that the market is segmented, and to consider the different groups when materials, activities and promotions are designed.

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Acknowledgements

The authors gratefully acknowledge the financial support of the RMIT University College of Science, Engineering and Health *STeLR* grant scheme.

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