Strategies to encourage and retain women in engineering: A case study approach

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Structured Abstract

BACKGROUND
It has long been identified in Australia that the number of women enrolled in engineering degree courses is far below that of their male counterparts. Many studies have endeavoured to address this frustrating, ongoing imbalance. Studies show that there is a significant lack of awareness among female secondary students of what engineers actually do. Therefore, it is not surprising that many students entering the tertiary sector have little appreciation of what is involved in studying engineering. Furthermore, factors such as the identification of engineering as a male pursuit, poor academic self-confidence and feelings of intimidation continue to contribute to the inequality of female participation and retention in engineering studies.

PURPOSE
Our aim in this study was to gain a deeper understanding of the influential factors that could be addressed within a university's engineering school to encourage and improve the retention of women in engineering pathways.

DESIGN
We followed a two-staged case study approach. During stage one, we investigated quantitatively the extent of the perceived problem using student profiles. The statistical data collected over a period of four years (2008 – 2011) revealed a low progression rate of female students to the Masters of Engineering from a Bachelor of Science. In order to understand the reasons for such a low progression rate, in stage two, qualitative data were drawn from focus group interviews with twenty-three (23) female students from differing year and course stages. Participants were asked about their thoughts and expectations prior to entering university and their subsequent study experiences including, likes and dislikes of their engineering subjects.

RESULTS
Based on our findings, we propose various strategies for encouraging and retaining female students in engineering pathways broadly classified under two categories: (1) Teaching approaches and (2) Engagement. Key factors related to teaching approaches included attitude, language and approachability of teaching staff, awareness of gender composition and workload balance in teams as well as the importance of explaining the usefulness of content in the real-world. Other pertinent factors related to engagement included networking with industry professionals, female role models both within the university and in industry and fostering peer-support events.

CONCLUSIONS
Based on this study we have proposed a framework with recommendations that address the factors voiced by the experiences of our participants. While we have limited capability to change uninformed perceptions before students, female and male, enter university studies, this proposed framework may well be a guide to impact on the way we engage our teaching and learning practices in engineering.

KEYWORDS
Student retention, teaching approaches, engagement

Introduction

Despite the research and interventions, women continue to be underrepresented in engineering programs in Australia. Ongoing studies and dialogue must continue, and this case study is a small contribution to that collective effort. While studies have investigated barriers to women entering engineering, our particular focus concerns factors that influence women's retention within a particular engineering education model.

Our case study was undertaken in an engineering school in an Australian university that recently adopted a new model for engineering degrees; a three-year specialised bachelor's degree in science, followed by a Master's degree in engineering. Through this model, students are able to 'try out' engineering subjects during their undergraduate years before committing to pursue a postgraduate engineering pathway. Although our expectation was that this would result in more female students taking up engineering, early results do not show a trend in this direction. However, this degree structure has offered a unique opportunity to identify factors, within the teaching and learning domain that had impact on female students' later subject and course decisions. By talking with female students who decided to continue with engineering, as well as those women who chose to withdraw, we hoped to identify influential factors that could be practically addressed within university engineering schools to improve the retention of women.

Related work

Students enter university, each with a unique set of perceptions and expectations about themselves and their course (Sacre, Atman & Shuman, 1998; Li, Hariharan & Tang, 2009). Female students' self-efficacy, a belief that one can succeed (Bandura, 1997; Marra, Rodgers, Shen & Bogue 2009), can be exasperated when women experience the persistently masculine culture inherent in engineering education (Godfrey, 2009; Mills, 2011; Peterson, 2011) despite Male, Bush and Murray's (2009) finding that stereotypical female competencies are valued by the engineering workplace.

Studies have also investigated the problem of women dropping out of engineering courses or switching degree programs during their first two years (Godfrey, 2008; Hill, Corbett & Rose, 2010). Reasons include, lack of academic self-confidence in a competitive environment, poor advising, inability to help others and not being accepted, feeling intimidated and anxious when they become the target of derogatory behaviours (Male et al, 2009). Faulkner's (2009) "in/visibility paradox", where female engineering students are invisible as students yet visible as women, contributes to our understanding of the female engineering student experience.

Course material that is predominantly theoretical with lack of real-world practical applications has been found to generate disinterest (Besterfield-Sacre, Atman, & Shuman, 1998). On the other hand, strategies that have been shown to have a positive effect on student learning and retention include: supportive peer interaction within friendship groups (Harvey, Drew & Smith, 2006); participation in extra-curricular activities and mentoring (Godfrey 2008); peer networks because of women's preference for social coping characteristics and positive interaction between the teaching academics and the student, both within classes and out (Morganson. Jones & Major, 2010). Studies suggest that women value working in groups because collaboration offers mutual help and personal interaction (Felder et al, 1995; Marra et al, 2009; Morganson et al., 2010). While providing role models and mentoring networks in out-reach programs have been established to promote and generate a positive atmosphere about science and engineering (Wee, Cordova-Wentling, Korte, Larson & Michael, 2010; Morganson et al., 2010), one of the drawbacks of such initiatives is their short lifespan (Godfrey 2008).

Research methodology

The research approach we followed was a two-stage process. During stage one, we investigated quantitatively the extent of the perceived problem of low female retention numbers using student profile data. The statistical data collected over a period of four years

(2008 – 2011) revealed that of the female students entering the Bachelor of Science (who are all eligible to study engineering if they chose to), only around 10% enrolled in first year engineering subjects compared to around 35% enrolling in first year mathematics subjects. Of the female students who enrolled in first year engineering subjects, only around 25% progressed into the Master of Engineering (M. Eng) program. Furthermore, from the total student population who entered the M. Eng. from the B.Sc., only 14% were female. The statistical data emerging from this new course structure prompted some concern and demanded that focused attention be given to understanding qualitatively, why women were making their particular career choices. Were there any influential factors at play that discouraged women from continuing with engineering and might there be some practical factors that could be implemented to foster engineering as a desirable career path for women?

In order to understand the reasons for such low progression rates to the M. Eng. from the B.Sc., in stage two, qualitative data were drawn from audio-recordings of six focus group interviews with 23 female students from differing year and course stages. Twenty-two out of the 23 participants were local Australian students. We interviewed participants that fell into four categories: (1) six students who attempted two first year engineering subjects and then decided not continue to pursue engineering pathways because they failed the subject; (2) nine students who were in the engineering pathways, that is, doing a few engineering subjects in their second and third year of under-graduation; (3) two students who completed their undergraduate degrees in an engineering related major but decided not pursue a Masters in Engineering and (4) six students presently enrolled in the M. Eng.

Semi-structured focus group interviews were conducted on campus by the researchers. Participants were asked about their expectations prior to entering university and their subsequent study experiences. Focus was given to factors that students reported sustaining or impeding their progress with engineering subjects. With the participants' written and verbal permission, interviews were audio-recorded and transcripts prepared. Notes were also taken during each session by the researchers. Following distribution of the transcripts, the researchers met to identify repeated and persistent experiences and issues that helped to explain the quantitative data. Key themes were eventually captured and considered.

Findings

In this section, we describe our findings by organizing the data broadly into two categories namely: (1) external influences prior to university entry; and (2) experiences during university study.

Influences prior to university entry

Although our research focuses on the students' university experiences, we were keen to find out what female students knew about engineering, when they entered university, and the impact of such expectations. In this regard we heard participants admitting that their knowledge of engineering was extremely limited, *"I didn't really know what to expect I think that was part of the reason why I ended up leaving my major in engineering it wasn't what I expected and I didn't like it".* The perception of engineering as a career for men is still strong, *"I have no idea what engineering was… I thought it's such a guy kind of subject so I just did science".* We noted that for some women, engineering is envisaged as a socially valuable career, *"I went into engineering because I wanted to be able to make effects on the world".* Being able to see oneself, as an engineer, was revealed as influential, "*I could imagine myself doing engineering".* Family was also a major source of encouragement, whether coming from a *"science-oriented family"* or having a "*mum who encouraged me so it didn't deter me when people said there's only boys in engineering"* or "*being tutored by a family friend who is an engineer and it always seemed like a really exciting job*".

Experiences during study

Our main focus, however, was identifying factors, during their university studies, that provoked women to either continue or discontinue their engineering pathways. Below we present our findings classified into four broad categories.

Perceptions/experiences during early study: Experiencing difficulty with the course content was often exacerbated by not having the self-confidence to seek assistance; *"I was really bad at asking for help I don't know why I'm so scared to say 'I don't get this'\.* Experiencing difficulties transitioned into a sense of diminished self-efficacy from which one student did not recover; *"I feel so dumb…and that was the main reason why I quit because I did not like feeling I couldn't do something".*

For one female student, actually seeking assistance contributed to her low self-esteem. She admitted that asking questions made her feel "stupid". Although she reports that the male students she was studying with also did not understand the content, they claimed they would work it out "after class". And yet, even after she passed the subject, unlike half of her male peers, this female student's sense of self-worth and practice in seeking assistance still was not validated; *"looking back… I couldn't have been that dumb, but I felt very weak… I was so humiliated".* Another participant reported that a lecturer would avert his eyes when she raised her hand. When the student believed she was being treated differently; the male students agreed with her.

We uncovered feelings of being the 'outsider' generated by earlier stereotypes: *"I guess, from when you're a kid… that maths and science are for boys… so you already feel like a bit of an outsider going into those classes".* Were their perceptions ever verified? One student recalled being stunned by a tutor's comment: *"the tutor asked everyone what stream they were going down and me and my friend said we were doing civil and he said 'but you're girls'*

Experiences of being predominantly in a male dominated environment varied. One female student commented; *"I'm not comfortable in that blokey environment... a girlfriend absolutely adores the environment… but I'm not okay with that"*. Another student felt annoyed with the use of male pronouns such as 'he' during lectures and tutorials; "*somewhere out there*, *there has to be a female project manager surely… and it particularly annoys me when I hear my female classmates also referring to people as 'he'… don't you want to be that engineer?"* When students do make a connection with a female engineer in the faculty the consequences can be powerful; *"they were the most encouraging people throughout my course (they) said don't give up and they're probably one of the major reasons why I'm still holding onto the Masters of Engineering"*.

Teaching and learning influences: The students were not at all hesitant in responding to questions concerning the impact of teaching and learning. Lecturers and tutors were described in positive terms when they: *"acknowledged that it was a difficult problem… when they helped you frame your mind to be able to start… broke down the steps for you".* On the other hand, teaching also provoked negative experiences; *"it's almost like because they (tutors) understand it… they can't comprehend how you couldn't understand it"*. In a similar vein another student reflected: "*they didn't understand why we didn't understand… which made me feel even dumber"*. The students also expressed frustration with the teaching when they could not understand the concepts; *"that's not explaining it… that's just telling me the answer".*

The importance of knowing the reason for the content was raised during interview: *"I love it when you can actually do something really cool with this later on… a lot of stuff we did just seemed a bit pointless".* Understanding the content, itself, emphasized one female, was not the issue – it was that she did not understand: *"why we are learning it".* Another student could see the practical application ahead but during her first year found the content too distant; *"…nothing felt relevant that's why I eventually dropped out of engineering… it just seemed like I was wasting time".* One student asked her college tutor for help and was told: *"'no… the moment I finished the subject I forgot all about that because you'll never use it again", so then it's… why am I learning this?"* One student summed it up*: "I think without the whys it's very difficult for us to move along… we just need to know why".*

Students admitted being disappointed with classes because they had expected engineering was going to be a *"real world" and "hands-on'* course". Another student felt much the same: *"I think it's more fulfilling if you actually get your hands dirty"*. One comment reflected a less than optimistic experience; *"it doesn't seem like a dream anymore, it's just high school again"*. When female students were offered experiences that were both practical and purposeful, these students described the impact: *"it was all practical, we were in groups of three and… we got to try it all it was really interesting and that's kind of what made me decide to do (engineering)".*

During one focus group the female students talked about the crucial importance of experiencing a curriculum that was described as "interesting". When asked what that meant, one participant said: *"something that makes you think... like I'm not just waiting for the lecturer to say the answer… I'm thinking about it".* The participants' emphases on the influence of 'interesting' with 'practical applications' were illustrated by one description: *"I designed a heat exchanger for one of my assignments… we did it on the Visio and it was very satisfying"* and *"I loved that subject and that just gave me a purpose as to what I want to do in engineering I felt like for the first time I was properly understanding something".*

Working in groups: Female students generally expressed very positive attitudes to working in groups: "*I like actually working in teams… bouncing off ideas with each other"*. Did experiences change depending on the gender composition of the group? When a student who transferred out of engineering participated in a predominantly female populated course she became more acutely aware of what she did not experience in engineering. In an all female group, she reflected; *"…everybody takes responsibility for their own work and gets it done".* Another student added that: *"when there's other girls in the group… you've got somebody else that's making things happen".* Working only with males intensified some females' negative perceptions: *"if you're the only female in the group, you feel like you're being judged, even if you're not"*.

One perspective that was made frequently by participants was that in some groups the males did not take the females seriously: *"I was the only female and they didn't listen to me… do I have to prove something?"* Another student reported that: *"when with the boys they just did it for me".* One female verified that experience by saying that in the first year, from her experience, male students: *"definitely don't acknowledge you at all or care about your opinion or care if you're behind and need some help or something".* When questioned, one participant was adamant that the gender cards were definitely in play: *"the guys always think that girls aren't smart enough so you have to prove yourself".*

One quandary that some of the women students struggled with was how to behave in a mixed gender group – particularly when it came to roles of leadership, *"if there's another woman on board it feels a lot more comfortable whereas if it's all guys you're not quite sure if they get it or if you're just being pushy and it doesn't feel as bossy".* Then when probed into whether she thought male students don't like taking direction from a female, her quandary was revealed: *"when I ask them where they're at… I don't know how much of it is me sort of worrying that I'm being bossy".* Another student described it this way: *"you don't want to take over and be too assertive but if you sit there in a corner and sort of, step back, you're being a pushover, so in your own head you're thinking… how do I come up with a good mix?"*

Role models: The presence of female academics, tutors and visitors from industry was valued. As one student observed: *"there are other women doing this… I can do this"*. Another participant reflected; *"I think on a subconscious level… when you're surrounded by so many men, it's reassuring to have professors who are women that make you think yeah, I can be that… I can get there too".* Some comments placed the women 'inside'; "*when female academic staff were present you didn't feel like you wouldn't be taken seriously".*

Across all female participants, peer friendships were identified as vital to successful; *"if I have an issue with an assignment I can ask all my friends like hey what is with this question and we'll sit down and we'll figure it out ourselves".* One female thought back to her time in first year when she didn't know anyone in her classes: *"you had to do all your assignments independently which was so much more work".* Friendships offer other benefits; *"you look forward to meeting everyone going to classes".* When asked whether it mattered having female friends, one student agreed;

"the first thing you do when you walk into room the most obvious is are you a girl or are you a boy and if there's going to be less girls in a room then (the girls) will drift towards each other… whereas the boys are all like already buddies".

The impact of having a female friend, specifically, was raised; *"once you have one female friend it doesn't matter who the rest of your friends are"* when *"surrounded by a big bunch of blokes".* While acknowledging females can also be difficult, females, *"get it done instead of wanting to put things off until the last minute".* Not having any friends in first year made life very difficult for one student: *"I found first year really hard I didn't know anyone and it took me a really long time to make friends".*

Discussion

In this discussion we have considered our findings against the existing literature and offer some observations and recommendations. We are not making claims here that every, or most, females experience all these situations and own all these perspectives. What we are trying to do particularly, is identify factors to explain why some women who have come so close to undertaking engineering choose another pathway.

The interview data suggest that during late secondary school there are girls who are able to envisage themselves as engineers. For some women, their 'seeing' was embedded, not in the technology or the science of engineering, but rather in its application and in particular engineering's socially valuable practicality. A value that is commensurate with the work of Faulkner (2006). When at university, the women were not content just to learn *about* engineering, they expected and wanted to *feel like* an engineer.

During the interviews we encountered experiences of feeling "judged" in classes; leading to the kind of anxiety referred to by Male et al., (2009). There were examples of being reluctant to seek help or feeling embarrassed when they did ask questions. The actual facts of each encounter can never be known, yet what is real is the way these women perceived and responded to such situations. What might explain these perceptions, for example, of feeling like an outsider? Faulkner's (2009) in/visibility paradox shines much insight here. When one of our participants admitted feeling "scared" because she could not bring herself to seek assistance in class it may have been that publicly asking for help not only made publicly evident that she was struggling but also raised her visibility as a female needing help: a double hit.

The visibility of women as females rather than as students is particularly enhanced when in a "*blokey*" environment, unless the females adopt 'the boys' behaviours in order to be on the 'inside'. The occasional yet sexist comment by people in positions of authority such as "*civil engineering is for boys*" and the continual use of male pronouns or references to exclusively male engineers can only reinforce gender stereotypes.

Despite comments from the women interviewed who claimed to *"enjoy"* and *"value"* working in groups, when in mixed gender teams, some women reported confusion about identity. As Faulkner (2009) would have it, as the only female in a group, she is visible as a female but invisible as engineering student. Adopting a position of leadership exacerbates that situation. Therein lies the dilemma. If she is *"assertive"* then she may be thought of as *"bossy"* (the visible female). If not assertive then she may be considered a 'pushover' (the invisible student). It is not surprising that one participant uttered the rhetorical query; *"how do I come up with a good mix?"* Having another female in the group appeared to make a positive difference. In that case, visibility would likely be shared and diminished.

As we noted from our findings, students will go to lectures and tutes to meet up with friends as well as seeking mutual academic support. Whatever the gender mix or ostensible purpose of the group, female students acknowledged the significant role that their peers play in sustaining them through difficult times. Being in a female group offers relief from the constant visibility and therefore increased risk-taking is a likely beneficial outcome.

The *"if she can do it – I can too"* mantra was give to us albeit in a range of guises. The presence of female engineers, both academics and women from industry, clearly offers encouraging and supportive influence: one that might be better exploited.

In the next section we present a model we have developed that captures our findings and encapsulates our recommendations. The influential factors and their recommended strategies have been fused within a multi-pronged approach as we have briefly discussed below.

Recommendations

Based on our findings, we have developed a model as shown in Figure 1 that captures our findings and encapsulates our recommendations. Recommended strategies for encouraging and retaining female students in engineering pathways are broadly classified under two categories: (1) Teaching; and (2) Engagement.

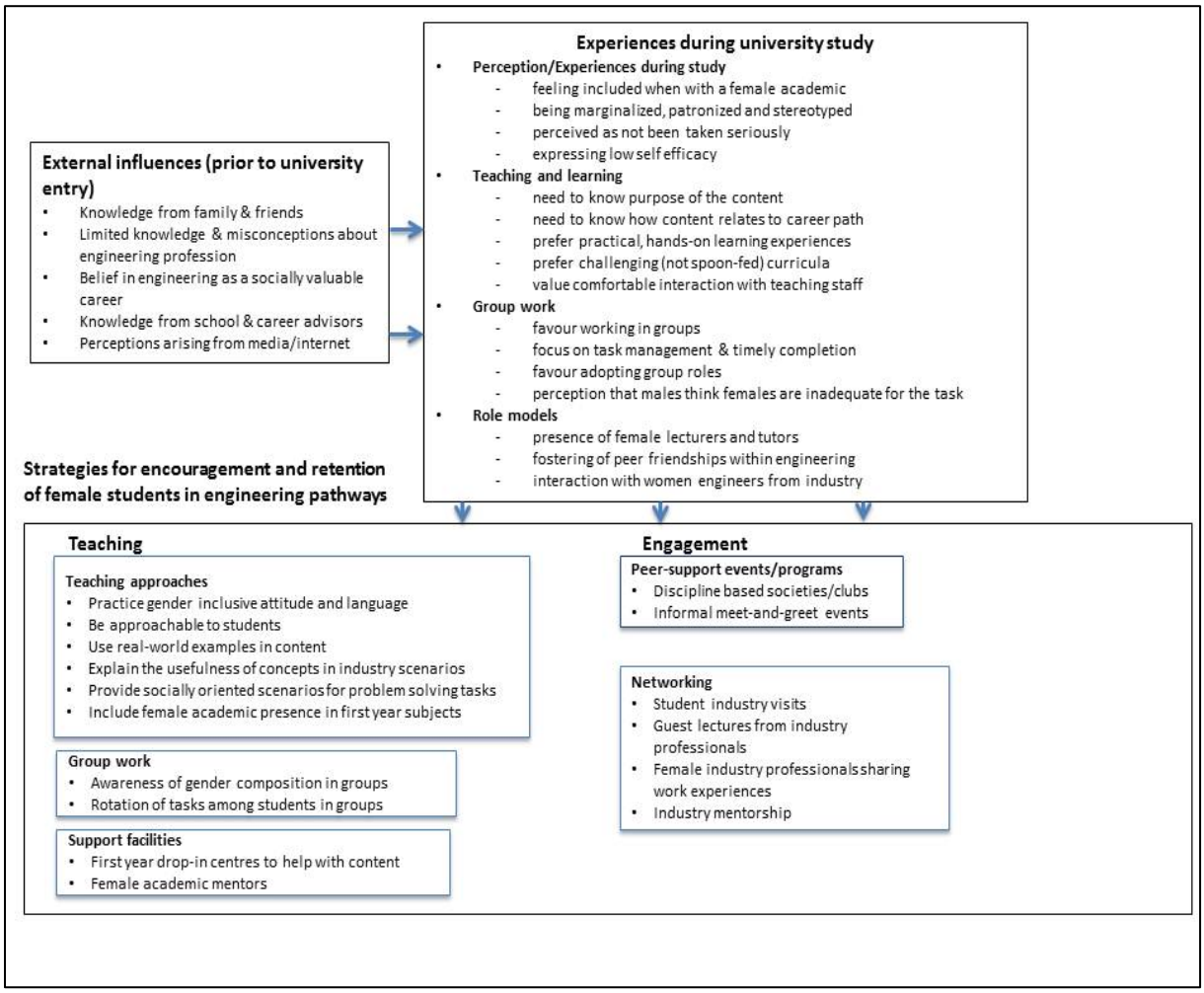

Figure1: Strategies for encouraging and retaining female students in engineering pathways

Teaching approaches: Implementing gender-inclusive examples (women active in industry) and using gender-inclusive language would help address the frustration of female students who report feeling like 'outsiders'. This focus might well be addressed by women themselves to teaching academics and included within any academic/tutor training program. Staff development opportunities might raise the paradox of visibility/invisibility within student groups and offer strategies for communicating inclusively and positively with students.

Addressing the need for purposeful content is another aspect recommended for staff development. Developing curricula where the industry application of content is clearly

described would foster motivation. Of benefit also would be opportunities for students to engage in practical tasks, in authentic contexts, where they come away with a developing sense of what it is to do the work of an engineer. And where possible, link the content being taught to social development programs or projects. The presence of female academics especially in first year classes is evidently of value to new female students.

Group work: Working in groups is an acquired skill and one that causes most students angst. We recommend that all students be taught, explicitly, how to adopt roles and responsibilities within groups in order that tasks are undertaken in an equitable and timely manner. As with all students from minority backgrounds, we suggest that such students are given the opportunity to pair with another before larger groups are formed.

Support facilities: We believe that a first response is to address the perceptions and misconceptions owned by the women themselves – particularly during first year (ACER, 2010). A mentor program with female academics who have previously received some training, would enable informal interaction in a non-judgemental environment to discuss issues such as in/visibility, seeking assistance, leadership in peer groups and arising quandaries. This strategy would not only allow for comfortable interaction with an experienced female academic but would also foster friendships between the participating women. Furthermore, providing industry visits from women engineers would also offer prompt that *"if she can do it – so can I"* mindset.

Peer support events/programs: The first year experience is evidently a key time when universities can organize events in order that female students can 'meet and greet' other students, within the discipline, with the basic outcome of forging friendship. Furthermore, we suggest organizing events that are discipline-specific, 'hands-on' problem solving activities that foster interest, passion and a socially beneficial reason for solving them. We also support peer mentoring programs where students who require extra assistance can get the help they need in a supportive one-on-one environment either from informed peers.

Networking: Engagement with industry, in particular female engineers, through guest lectures, networking events, and mentoring programs could help improving the awareness of engineering and its application and would portray female role models.

Rather than considering these recommendations as 'initiatives for female engineers' most may be considered gender inclusive because if we teach well – we teach well for all students. Being without friends for support, feeling intimidated can just as easily be ascribed to males. If there is to be sustained change in the numbers of women graduating from engineering programs, then both females and males, students and academics, must be actively receptive and inclusive.

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