## Full Paper


## Abstract

This paper describes a study undertaken to transform existing hands-on laboratory activities into superpracs suitable for marketing to Year 10 to Year 12 students. A survey of global practice in marketing activities identified the best practicals, which were developed into 'superpracs' to appeal more to both boys and girls and present engineering careers as interesting and exciting. Engineering is one of the most male-dominated professions in the western world. Many factors contribute to low numbers of women in STEM, including perceptions of self-efficacy and cultural stereotypes. In a study of US Women in Engineering programs the best programs focused on cultural change in the faculty, while the worst focused on interventions directed at helping girls to cope. In this study first a set of guidelines for design of exciting and inclusive hands-on activities was developed. Each superprac should contain the following elements to appeal to both boys and girls. 'Boy appeal' is enhanced with 'smash and crash', reference to media shows, and mastery appeal. 'Girl appeal' is enhanced by relating the activities to people and society, group interaction, and relating the concepts to the human body (where possible). Existing high quality laboratory activities were then redeveloped into 'superpracs'. These were tested with current students and teacher trainees, then piloted with school age students. Resources for each include teacher training materials, support materials, and resources to run the each prac. Since inception, the superpracs had been run with numerous school groups. Participant feedback showed that the majority of respondents rated the superpracs as good to excellent, much higher than for other STEM programs sessions with normal practical activities. It is recommended that inclusive teaching practices are important to attract more women into engineering, for all learning activities, including marketing of programs. Laboratory activities can be designed to appeal both to boys and girls by including elements that appeal to each. First impressions are important: potential students may change their preferences if they have a bad experience.


## Background

Engineering is one of the most male-dominated professions in the western world. Only 6% of practicing engineers in Australia are women, and only 12% of engineering students (Kaspura 2012). There are slightly higher numbers in some other OECD countries. The US has 20% female engineering students and 18% practicing engineers. Even universities with esteemed Women in Engineering (WIE) programs attract women in only modest numbers. Purdue University 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 had 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 42.5%, University of Pennsylvania 38.7%) (ASEE 2015) but otherwise parity is still a distant goal despite decades of intervention programs.

The numbers for some sciences are also low: 32% female physical science students and only 22% female physics students (Ivie & Ray 2005). Even when women take equal numbers of science classes as men, they are less likely to choose STEM careers (Drury, Siy and Cheryan, 2011).

Low numbers of women in STEM have been attributed to 'gender differences in self-efficacy, differential encouragement to pursue careers in science and mathematics, and cultural stereotypes' (Diekman et al 2010).

A large study funded by the US National Science Foundation compared growth rates in female student numbers over a seventeen year period (1984–2001) for departments that had implemented women in engineering (WIE) programs. The difference between the five best and worst programs was significant – a 10% increase in female engineering student enrolments compared to 2.5% decrease over 5 years. The programs were described as follows (Fox, Sonnert and Nikiforova, 2009).

> *The most successful programs focused to a greater degree upon institutional structures—that is, characteristics and features of the institution and its units—both in perceiving the issues/problems and in addressing them. The least successful programs focused more on addressing women as individuals and on helping women students cope.*

It seems many intervention programs are ineffective while a few are successful. Research is very scarce on what makes particular programs effective or ineffective. Understanding what attracts young people, especially young women, to engineering and science is a critical step in developing more effective marketing for our programs to enhance female participation rates in these programs.

Key influences on female undergraduates in their choice of engineering or science were previously reported as influence of role models, parents, teachers, achievement in maths, alignment of career with personal goals, and people-oriented careers (Woolnough, 1994, Hobart et al 2006,Henman, 2010, Tully & Jacobs 2010, Cherney and Campbell, 2011, Drury, et al. 2011).The first phase of this research project compared male and female students in three different disciplines, civil, environmental and chemical engineering, and has been previously reported (Gravina, Jollands, Woon 2011, Jollands, Gravina, Latham, Brodie 2013). We found some distinctive differences between the disciplines. While students from different disciplines and both boys and girls identified many common factors in their career choice (family, teachers, and career perceptions) 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.

This paper describes the second phase of the research project, undertaken to transform existing hands-on laboratory activities into superpracs suitable for marketing to Year 10 to Year 12 students. A survey of global practice in marketing  activities identified the best practical activities, then these were developed into ‘superpracs’ that appeal more to both boys and girls and present engineering careers as interesting and exciting.

## Aims

This phase of the study had two aims:.

- To identify the best laboratory activities for marketing of STEM disciplines
- To describe how to develop 'superpracs' that appeal to both boys and girls and make engineering a more interesting career option.

## Approach

The project was informed by a broad literature review as well as a survey of websites for marketing programs that include hands on activities.

The current approach to marketing STEM programs generally assumes the target market is homogeneous, that is, girls and boys have the same interests and motivations. As engineering academics are predominately men, the role models, project case studies, and images provided by academic staff to marketing staff are dominated by male interests. A perusal of marketing information for engineering faculties demonstrates this point: the predominance of ‘formula SAE’ images for mechanical engineering and the absence of girls in photos of their award winning design teams.

This portrayal of engineering in marketing information neglects gender differences in student motivation. A better approach is to assume that the market is segmented, and to be inclusive of the different needs and motivations of each segment when advertising, resources, and activities are designed. In addition to inclusive marketing images, inclusive in-reach and out-reach programs are needed.

How to engage both girls and boys in science and engineering hands-on laboratory activities was developed based on our previous findings (Gravina, Jollands, Woon 2011, Jollands, Gravina, Latham, Brodie 2013). The critical elements to design inclusive hands-on activities are summarised in Table 1.

Table 1: Elements of hands-on laboratory activities that appeal to both girls and boys

| **Appeal to girls** | **Appeals to boys** |
|---|---|
| Social interaction e.g. by setting groupwork | “smash and crash” |
| Discussion and reflection on applications that help people and society | Engage with science in the media e.g. “Mythbusters” |
| Applications related to the human body | Mastery appeal – the desire to control and shape the environment |

Final year undergraduate engineering students were recruited to develop the superpracs; they were considered key to developing exciting and impactful teacher and student resources at the ‘right’ level. Part of the redevelopment was undertaken as a final year Research Project, and part as paid casual work. To close the loop on the design cycle, the same undergraduates had an opportunity to run their superprac with school groups, in an authentic marketing activity with real customers. They then refined the superprac resources in line with their experience.

First the students created a short-list of high quality laboratory activities for three disciplines; civil and chemical engineering and physics. They discussed their findings with the authors, and the most suitable was chosen for further development. The students then developed the existing activity into a superprac according to the guidelines (Table 1). They also developed resources. Teacher resources were designed to assist a new demonstrator to learn how to run the activity successfully. They included materials and ideas about how to make the activity exciting and interesting. This would help even experienced demonstrators to make the activity more interesting. A list of the resources developed for each superprac is shown in Table 2.

Table 2: Resources developed for each superprac

| **Teachers/demonstrators** | **For Students** |
|---|---|
| Teacher outline<br>Video to help the teacher learn how to run the activity<br>Short powerpoint presentations about the activity and applications to show before and during the activity<br>Background materials on applications of the underlying science<br>Worksheet with ideal answers | Student outline<br>Background materials on applications<br>Video of applications<br>Worksheet/proforma with questions for discussion in groups<br>Worksheet with extension activity for a longer session |

These superpracs were trialled with current students and teacher trainees during development, then piloted with school age students. The resources were revised at each step. Once polished, the practicals were run with numerous school groups.

## Results

The following practicals were found to best fit the criteria identified in Table 1 and to have the most portential to develop into superpracs:

Table 3: Superprac laboratory activities that appeal to both girls and boys

| Discipline | Superprac title |
|---|---|
| Chemical engineering | Imploding can of coke |
| Civil engineering | Build a bridge from paper |
| Physics | Refraction of light through jelly lenses |

Brainstorming was used to add the any missing elements to each existing practical activity, in a way that would promote student engagement. The amount of time and effort needed to develop existing practical activities was unexpected. The comprehensive set of teacher and student resources took many days to develop. It was surprisingly difficult to find any existing physics practicals that had potential to be developed in line with the guidelines. This may be because the project failed to attract physics students to work on developing the practicals; so they were developed by engineering undergraduates who had studied physics at high school. The practical that was chosen for development (on refraction of light) met some but not all of the guideline criteria: it lacks a “smash and crash” element.

The superpracs have been run in various in-reach and out-reach programs with over 500 students during 2013 to 2015. Events included a Power of Engineering Day, a local school visit, the RMIT LEAP program, RMIT Science Experience, and RMIT Engineering Experience Day. Feedback has been very positive. Participants in the RMIT Science Experience 2014 rated the chemical engineering superprac as good to excellent (28 out of 30 respondents, from 139 participants). This was significantly higher satisfaction rating than for other program sessions with normal practical activities. Student feedback from the other sessions was similarly good.

Data on conversion rate from of marketing events participants into enrolments in engineering is not currently available. The long lead time makes collecting such data difficult. In addition, these activities are designed to encourage high school students to consider STEM as a career, rather than RMIT as a tertiary destination.

## Discussion and conclusions

The project has developed a much clearer understanding of how to engage both girls and boys in science and engineering marketing activities. Existing in- and out-reach activities assume that the market is homogeneous, but it is well known that there are differences between motivations for girls and boys in terms of STEM career choices. All students identify family, teachers, and career perceptions, as influences on their choice of program. However, girls are more strongly influenced by their family and boys are more influenced by engineering programs on TV. If marketing activities are to appeal to both boys and girls, they need to be designed to do so.

To enhance appeal to girls, the practical activity should include social interaction by setting group work, discussion and reflection on applications that help people and society, and relate the practical to applications related to the human body. To enhance appeal to boys, the practical activity should contain an element of “Smash and crash”, engage with science in the media, and have mastery appeal. Good quality resources for teachers, demonstrators and participants are needed to enhance participants’ interest in STEM careers.

The set of resources for teachers must be suitably detailed, so new teachers can easily learn how to set up the superprac and supervise it confidently. This is particularly important when the practical activity might be done in an out-reach session, where the staff involved might be casuals rather than discipline staff. Resources should include a video of how the superprac is done. To ensure competent explanation of links between the practical and the discipline, a good quality powerpoint presentation is needed that includes video links to real world applications. The set of resources for students should be very engaging, with questions designed to stimulate thinking about the fundamentals underpinning the practical, and answers requiring group work.

A well-designed and validated questionnaire should be used to collect feedback from participants. This is vital to assess at least the short-term impact of marketing activities. Over time this feedback can be used to improve the overall effectiveness of the superpracs.

Trends over time in female participation rates are not yet available, but in future, RMIT programs will be compared with national trends to identify if the superpracs have contributed to attracting more female students.

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