Evaluating the Impact of the YoWIE Summer School on Girls' Perception of Engineering

CONTEXT
Women are a minority in engineering studies nationally and internationally, and there are many programs working to increase the participation of women in engineering. However, the participation rate over the last 10 years has shown very little change. In Australia, on average, women make up 17% of engineering students at university, and around 12% of professional engineers. Girls are also underrepresented in high school mathematics and physics classes, important enablers for engineering at university. Further, about 25% of girls choose not to study mathematics in their last year of high school.

PURPOSE
This paper presents the design and evaluation of a three-day engineering summer school program for girls in their third and fourth years of secondary education. The program aims to increase girls' confidence that they can succeed at engineering, and to increase their awareness of the importance of studying mathematics and science to prepare for university level engineering studies.

APPROACH
The summer school was designed to give female students in years 9 and 10 an introduction to university level engineering activities and a better understanding of the role of engineers. Girls participated in a variety of hands-on activities and were introduced to female engineers and engineering students to make them part of a broader engineering community. The program was evaluated to better understand the needs of the participants, and to improve future iterations. Evaluation of the summer school used and uses anonymous surveys:
Pre-survey: This survey collected baseline information on the girls' perception of, and preparedness for, an engineering career before the summer school. It was conducted on the first morning girls arrived.
Immediate post- survey: This survey collected information on girls' perception of and preparedness for an engineering career and their experience at the event during the last session on the last day.
Follow up surveys: The students will be surveyed 6 months after the summer school. This allows us to see whether there has been lasting change from the program. In addition, we stay in contact with the participants through a social network of peers, IEEE YoWIEnet.

RESULTS
Results indicated that girls who participated in the program left with a better understanding of the role of engineers, increased interest in engineering, and increased confidence in their ability to be engineers.

CONCLUSIONS
As a result of the three-day program, the young women who participated in the YoWIE program at the School of Engineering and IT (SEIT) at UNSW Canberra were in a better position to make decisions about their potential future as engineers. Their understanding of the breadth of engineering and the role of engineers was improved. They had increased interest in engineering and confidence in their ability to be engineers. They also had increased knowledge of the subject choices they would need to make if they intended to pursue engineering. Follow up surveys and informal contact through IEEE YoWIEnet will allow us to track the lasting change of the program.

Introduction

A 2015 study showed fewer than 25% of Australian engineering researchers are women, and fewer than 15% of Australian inventors are women (The Economist, 2017). Women are a minority in engineering studies nationally and internationally, and there are many programs working to increase the participation of women in engineering. However, the participation rate over the last 10 years has shown very little change (Engineers Australia, 2017 and 2012). In Australia, on average, women make up 17% of engineering students at university, and around 12% of professional engineers. Girls are also underrepresented in high school mathematics and physics classes, important enablers for engineering at university. Further, about 25% of girls choose not to study mathematics in their last year of high school (AMSI, 2013). This makes it very difficult for them to gain entry to an engineering program at university, should they wish to do so.

It is likely that cultural issues within engineering, and society more broadly, where engineering and other mathematics-based disciplines are seen as more suited to boys, contribute to this low participation rate. Stereotype threat has been demonstrated to affect girls' performance in traditionally male dominated disciplines (Good, 2008). Pittman (2008) notes that the lack of female role models, and a peer group, for girls interested in engineering is also likely to be a problem, as sense of belonging is an important aspect of the learning experience.

Activities such as summer schools introduce girls to engineering, provide an opportunity for girls to meet with other like-minded peers, and allow tertiary educators to pass on information to help the girls prepare for a career in engineering. Such programs can help overcome problems such as stereotype threat and lack of peers and mentors for girls who are interested in engineering. In Australia, such programs need to target girls in their third and fourth years of secondary education, before they make the decision at the end of their fourth year to discontinue with important foundational subjects such as maths and physics.

The purpose of this research is to gather data on the impact that a summer school has on girls' perception of, and preparedness for, engineering studies. The contributions of this paper are:

- The design of a three day summer school program that appeals to girls in their third and fourth years of secondary education.
- Results demonstrating that participation in this summer school has a significant impact on girls' perception of their ability to undertake engineering studies.

The remainder of the paper is organized as follows: Section II reviews literature on women in engineering and programs to increase enrolments of women in engineering degrees. Section III presents the design of our summer school program. Section IV describes the evaluation of the program, in which data were gathered from summer school participants before and after participation to determine the change in girls' perception of engineering and of themselves as potential engineers. Section V discusses the results of this evaluation. We conclude in Section VI with a discussion of future work in this area.

Background

A. Participation of women in engineering

In 1975, the IEEE published a special issue of Transactions on Education on women in engineering. At that time, fewer than 2% of engineers in the United States were women in spite of the fact that women had been enrolling in, and completing, engineering degrees for more than 90 years (Sloan, 1975). In that issue, various articles discussed the difficulties of pursuing an engineering career for women, including negative stereotypes (Sloan, 1975 and Brown, 1975), poor choice of subjects in junior high school (Burks, 1975) and difficulty in obtaining employment as an engineer [(Sloan, 1975 and Davis, 1975)—all issues still being discussed. Other articles described ways to increase the number of women enrolling in engineering (Frohreich, 1975 and Medalen, 1975). One article describes a summer program for high school girls, the "Girls Engineering Institute", that increased the number of women enrolling in engineering at the University of North Dakota from 1% to 10% over four years (Medalen, 1975).

So, more than 40 years ago, many of the difficulties in increasing the enrolment of women in engineering, as well as some successful strategies for doing so, had been identified.

Ten years later, in 1985, women made up 16% of university engineering enrolments, and 6% of the engineering workforce (Estrin,1985). Since then, the increase in participation rate has been modest,

with women still making up only around 20% of university engineering enrolments in the United States and a slightly smaller fraction in Australia (Engineers Australia, 2017).

However, while the numbers have not improved dramatically in the last 30 years, our understanding of the factors that contribute to the underrepresentation of women in engineering has.

Important factors include socio-cultural effects such as the different expectations of girls by family and peers, and the societal pressure to fill a role that is in keeping with one's gender (Powell, 2009) and avoiding the social cost of taking on a non-traditional role (Baglihole,2002). While many young men with a talent for mathematics are encouraged to study engineering, particularly when they have relatives who are engineers, this is not the case for many young women.

For those women that begin an engineering degree, lower self-efficacy is a factor in the higher attrition rates of women compared to men (Marra, 2009). This lower self-efficacy arises from various sources, including a sense of isolation. As long as women are a small minority in engineering degrees, and the profession, this sense of isolation is likely to continue.

One important factor is stereotype threat. While there is little evidence that men are superior at mathematics to women, and there is no difference in mathematics performance at high school there is still a common belief that boys are better at mathematics than girls. This belief is enough to affect the performance of girls on mathematics tests (Good, 2008 and Spencer, 1999). This stereotype acts to discourage girls from taking mathematics at high school. Gender differences in self-confidence in mathematics emerge even before high school (Pajares, 2005). Self-confidence, and the belief that one can succeed, is an important factor in motivation toward a career (Hill, 2010). So the incorrect stereotype that girls are poor at mathematics has an impact on girls' subject choices at high school, and hence on their ability later to pursue an engineering degree and career.

A lack of understanding of what an engineering degree entails, or what an engineering career might look like, is an issue for all students, but particularly for young women (Eccles, 2007). It is often not clear to young women that careers in science and engineering align with their values, which may involve helping people (Low, 2005 and Weisgram, 2006)

B. Improving participation through outreach

There have been many programs and initiatives that aim to increase the participation of women in engineering. Many universities run outreach programs. Increasingly, there are outreach programs targeted at encouraging girls to study science and engineering. An Australian study of what aspects of such programs girls most appreciated found that working collaboratively in groups, and doing practical activities were important (Little, 2009). Other studies found that highlighting the value of engineering as an altruistic profession, one that improves people's lives, also encourages girls to consider engineering as a profession (Colvin, 2012).

Increasing women's confidence in their ability to undertake an engineering degree is an important factor in increasing numbers of women studying engineering. Interventions which involve bringing high school girls onto university campuses for engineering experiences have been shown to do this (Heller, 1997).

One way of encouraging young women to consider an engineering degree is through summer schools targeted at high school girls. As noted earlier, it is important that this happens before the girls have made subject choice decisions that are difficult or impossible to reverse. This occurs at the transition to year 11 in Australia, as choosing low-level maths at year 11 makes it very difficult to choose higher level maths at year 12.

One such program, the "Discover Engineering" summer camp (Zywno, 1999), focused on informing girls about engineering career options while engaging them in interesting hands-on activities. The result was more than half of attendees continuing to engineering degrees. The results from the "Girls Engineering Institute" program were similarly impressive, and this program also had an emphasis on hands-on activities (Medalen, 1975)

These programs were both summer camps, taking place over several days or a few weeks. A single "exposure day" to electrical engineering in Israel (Hazzan, 2005) increased students' understanding of what electrical engineering is, and they were more likely to consider electrical engineering as a degree option as a result. An important aspect of the exposure day was the presentation of female electrical engineers and electrical engineering students, engaging in discussion of their experiences: they acted as role models, and helped normalize the idea of women in the engineering profession. The high school girls attending the exposure day had the opportunity to discuss their views of the pros and cons of an engineering career, in an open and collaborative environment, with these female role models.

A review of the literature on female-only engineering workshops has found that important aspects of successful programs include providing girls with a genuine understanding and knowledge of the profession and its relevance to their own goals, and building a network of support (Sinkele, 2011).

The next section discusses the design of a Young Women in Engineering (YoWIE) summer school program at UNSW Canberra (located in the Australian Defence Force Academy), based on these principles.

Summer School Program Design

The YoWIE program is a three day, non-residential event. It is open to girls in the middle of their secondary education, three to four years from the beginning of high school, where they are still able to make subject decisions that will enable them to pursue engineering. They participate in a range of hands-on activities, hear talks by female practicing engineers and get information on what subjects are required, and what subjects are recommended, for engineering degrees at university. This is explained in detail in the remainder of this section.

A. Activities

Activities are divided into themes based on common engineering disciplines and sub-disciplines. Days 1 and 2 are electrical and mechanical engineering as well as some computer science. The activities are:

- Microcontrollers: assembling a circuit board and programming in Python.
- Computer aided design (CAD): designing a personalized case to house the microcontroller unit. This is then printed on a 3D printer.
- Lego Mindstorms: using the Lego programming language to control wheeled robots to solve problems.
- Lawnmowers: disassembling and reassembling a lawnmower engine.

Day 3 covers aeronautical, civil and chemical engineering. The activities are:

- Concrete: learn about the properties of concrete; mix and pour concrete and observe concrete stress tests.
- Silly putty: learn about polymers and mix silly putty.
- Rockets: do the maths to calculate rocket trajectories then assemble and fire simple rockets.

The tasks in each activity are designed to be practical and hands-on. They engage the girls and show them the fun and relevant nature of engineering, while developing their confidence and self-efficacy as they succeed at these tasks. The tasks are designed to be interesting and relevant—for example the rebuilding of a lawn mower—so that the girls can link the activities to everyday life, as well as future engineering careers. The activities span a range of engineering disciplines to highlight the breadth of engineering and give the girls an idea of what different types of engineering might entail. The activities are ‘real’ as well as fun: for example, in the rocket activity, the participants were required to use trigonometry to solve the trajectory of an air pressure rocket.

The girls work in teams during the activities, and the collaborative nature of engineering is emphasized. There is no explicit competitive element.

Following the program the girls are invited to continue to build their network with peers and with practicing engineers via the online IEEE YoWIEnet network.

B. Guest speakers and visitors

Several female engineers from industry spoke at the summer school, including a mechanical engineer talking about building heating and cooling and two civil engineers working on Canberra’s new light rail system.

The guest lecturers and facilitators spoke candidly about their experiences as engineers and as engineering students. The girls were encouraged to discuss the challenges and benefits of an engineering career, and the reality of an engineering workplace with the speakers. Hence, they were able to get an accurate impression of the reality of an engineering career.

Women academic staff and students were well represented among the facilitators of the program. The summer school was facilitated by 27 staff, including PhD students, postdoctoral researchers and academic staff from SEIT, UNSW Canberra. Ten of these staff (37%) were females. This is three times greater female representation than currently exists among engineering academics at SEIT and was specifically orchestrated so girls could meet female engineering academics at a variety of stages in their

careers. In addition, other female students and academics attended the meal breaks each day and met with the girls in an informal setting. The girls also had opportunities for casual conversation with the facilitators during activities and breaks.

The morning and afternoon tea breaks were unstructured time for the girls to socialize. The lunch breaks included about 45 minutes unstructured time and 45 minutes of tours, including a lab tour and a campus tour.

Evaluation

Evaluation of the summer school used two surveys. They were anonymous, but each participant added their own secret code on their surveys. This permitted the investigator to match up an individual's responses to the two surveys, without identifying that individual.

A. Pre-YoWIE survey

This survey collected baseline information on the girls' perception of, and preparedness for, an engineering career before the summer school. It was conducted on the first morning girls arrived . The survey was voluntary, but the response rate was near 100%. The questions in this part of the survey are shown in Table 1.

B. Immediate post-YoWIE survey

This survey collected information on girls' perception of and preparedness for an engineering career during the last session on the last day. Data on girls' experience at the event were also collected. The questions in this part of the survey are shown in Table 2.

Results

Pre- and post- YoWIE surveys with matching codes were collected from 27 of the 34 participants. The following sections discuss the results under the headings of student background (Part A); student perception (Part B) and student experience (Part C). Question numbers in the sections below refer to the pre-event survey, unless otherwise indicated.

Table 1: Pre-event survey questions and response type

Question	Response type
1. I am interested in engineering	5 point scale
2. The kind of engineering I am interested in is:	Closed (check boxes)
3. I would like to pursue a career in engineering	5 point scale
4. I would like to pursue a career in an area related to or similar to engineering, eg: science, computing, technology, other	5 point scale
5. I feel confident in my ability to succeed in engineering or a related/similar area	0-100%
6. I know what subjects I need to take to study engineering at university	5 point scale
7. The subjects I am planning to take in year 11/12 are:	List requested
8. I have hobbies that are engineering related	Yes/no
9. I have been to an engineering event before	Yes/no
10. The people who are most supportive in encouraging my interest in engineering are	Closed (check boxes)
11. The thing I am most looking forward to at YoWIE is:	Open

Table 2: Post-event survey questions and response type.

Question	Response type
1. I am interested in engineering	5 point scale
2. The kind of engineering I am interested in is:	Closed (check boxes)

3. I would like to pursue a career in engineering	5 point scale
4. I would like to pursue a career in an area related to or similar to engineering, eg: science, computing, technology, other	5 point scale
5. I have a better idea of what a career in engineering would be like now	4 point scale
6. I feel confident in my ability to succeed in engineering or a related/similar area	0-100%
7. I have a better idea of what subjects I would study if I did engineering at university	4 point scale
8. I know what subjects I need to take to study engineering at university	5 point scale
9. The subjects I am planning to take in year 11/12 are:	List requested
10. What was your favourite part of YoWIE?	Open
11. What was your least favourite part of YoWIE?	Open
12. If there was one thing you would change for YoWIE 2019, what would it be?	Open
13. Would you recommend YoWIE to your friends/family in the right age group? If so, what would you tell them?	Open
14. Overall I enjoyed the YoWIE program	5 point scale
15. Any other comments or feedback?	Open

A. Student background

When we recruited girls for the summer school, we asked their science and mathematics teachers to select girls they thought might have some interest in engineering. Several questions in the pre-survey (Q1 and Q8–10) explore this interest. When asked if they were interested in engineering the average response was 4.1 on a 5 point scale (where 5 was ‘a lot’ and 1 was ‘not at all’).

41% of girls indicated they already had an engineering-related hobby (Q8). These included robotics, astronomy, problem solving and logic, flying, and pulling things apart. 33% of girls indicated they had attended an engineering or science related event before (Q9).

Parents emerged as the most common source of support and encouragement for girls’ interest in engineering (63% of respondents indicated their parents supported their interest). High school teachers are also important sources of encouragement—41% of respondents indicated their teachers supported their interest in engineering.

B. Student perception results

This section describes students’ perception of engineering before and after YoWIE 2018. Responses to Q1 (see Figure 1) indicate that students had an interest in engineering before coming to YoWIE. The girls remain interested immediately after YoWIE, and their interest increased. A one-tailed paired t test showed a statistically significant increase in interest ($p < 0.025$). Their interest in a career in engineering or a related field (Q3&4) also increased (Figure 2.)

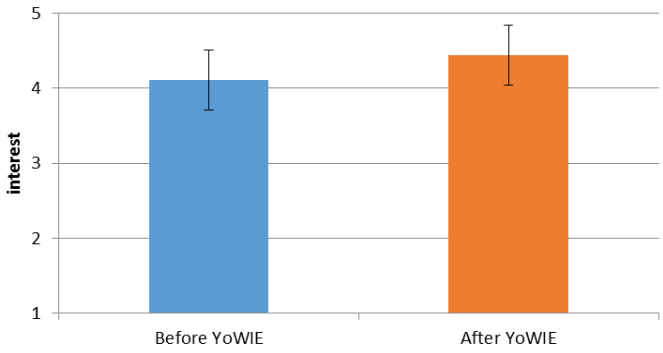

Figure 1. Q1: Student interest in engineering immediately before and immediately after YoWIE 2018, 5 point Likert scale; 1 = no interest, 5 = very interested. 95% confidence intervals are shown.

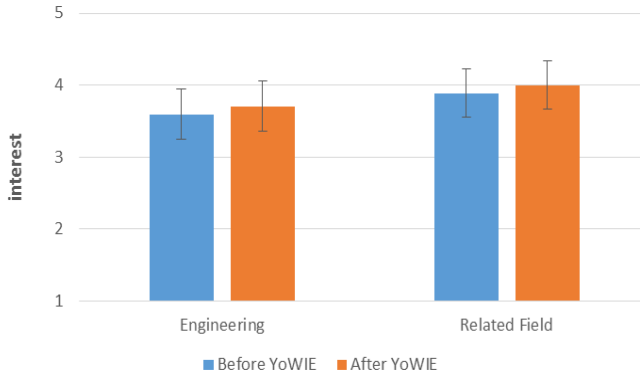

Figure 2. Q3-4: Student interest in a career in engineering or a related field immediately before and immediately after YoWIE 2018.

Figure 3 shows which kinds of engineering the girls were interested in (Q2). Girls changed their responses to this question after the event, showing a decrease in interest in civil engineering and increased interest in other types of engineering, including electrical. Further, the girls indicated they had a much better idea of what a career in engineering would be like after the event (Q5 post; 3.8 average on a 4 point scale).

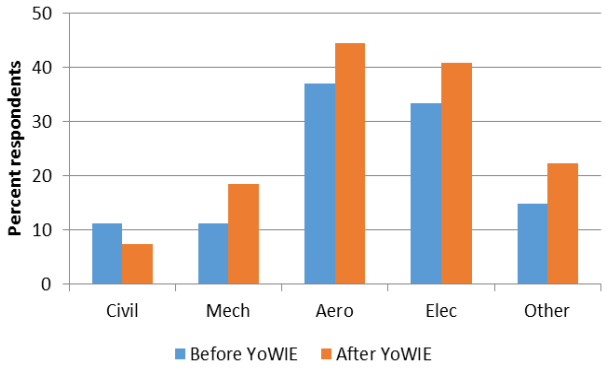

Figure 3. Q2: Percent of respondents showing interest in each kind of engineering. Note they could select more than one type.

Figure 4 shows that girls' confidence in their ability to succeed in engineering (Q5(Q6 post)) increased dramatically after the event (one-tailed paired *t*-test, $p < 0.0005$). In addition, girls had a significantly improved understanding of what subjects they need to take in their last two years of school to be able

to do engineering. This was indicated both by differences in their response to the question “I know what subjects I need to take to study engineering at university” (Q6(Q8 post); one-tailed paired *t*-test, $p < 0.001$, Figure 5) and their subject choices (Q7 (Q9 post)). Hence, not only did the girls have more interest in engineering and increased confidence in their ability to undertake engineering, they were also now able to make appropriate subject choices to enable them to pursue engineering.

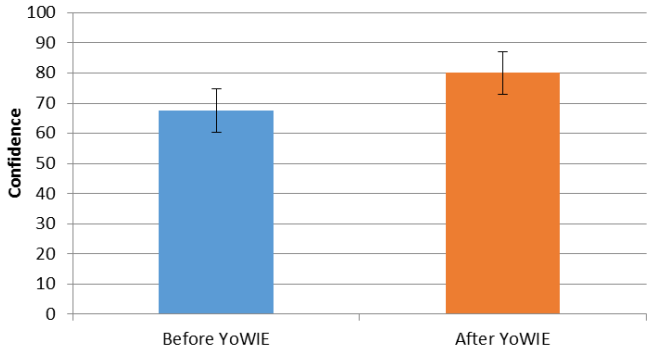

Figure 4. Q5(Q6 in post): Confidence in ability to succeed at engineering. 95% confidence intervals are shown. Continuous scale from 0 = no confidence to 100% confident.

The girls also left the summer school feeling they had a better idea of what university level engineering studies would entail (Q7 post, average of 3.3 on a 4 point scale, where 4 was ‘a lot better’).

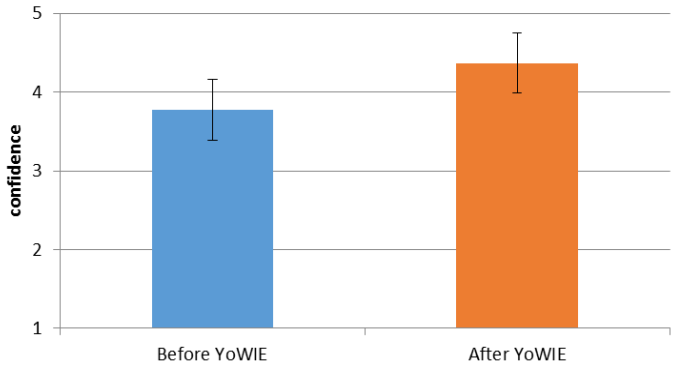

Figure 5. Q6 (Q8 in post): Confidence in knowledge of what subjects to take to study engineering. 5 point Likert scale, 1 = no idea to 5 = I definitely know. 95% confidence intervals are shown.

Student experience results

All students surveyed enjoyed the summer school (Q15: 5.0 average on a 5 point scale where 5 was ‘a lot’ and 1 was ‘not at all’). Figure 6 shows girls’ favourite and least favourite parts of YoWIE (Q10-11). These were open-ended questions, with results analysed by identifying the names of each activity in their responses. The most commonly identified favourite activities were the lawnmower disassembly and microcontrollers. The most common least favourites were the CAD and concrete. Several students simply responded that they liked everything or that there was nothing they disliked. These responses are not included in Figure 6.

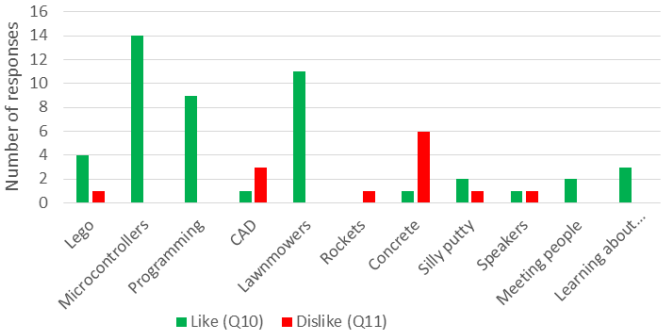

Figure 6. Q10-11: Favourite and least favourite parts of YoWIE.

All girls who answered Q14 would recommend YoWIE to their friends. Responses to this question included:

- *"yes, I'd tell them it's a fun, hands-on program for people who like engineering and problem solving"*
- *"I would tell them that it is an extremely enjoyable program that gives a good hands-on experience"*
- *"definitely – it was awesome fun and clarified what areas of engineering I liked and wanted to do more"*
- *"yes, because it gives you a proper understanding of uni engineering and the people you meet are amazing"*
- *"yes, I would tell them about how there is a lot practical work and lots of information where you can get a lot of experience"*
- *"Yes, I'd tell them it's really fun and we get to socialise with other nerds"*

These open comments indicate that the aspects appreciated by the girls are indeed those highlighted in Section II as being aspects of best-practice program design: hands-on practical activities, information about engineering as a career and the building of a social network.

The YoWIE acronym also spells out the word "YOWIE". At the start of the summer school we explain to the girls that Yowies are also rare, but that one of our aims is to build a community for them. Anecdotally, we believe we are going some way to achieving this. The girls appeared to enjoy themselves throughout the event. During the closing ceremony there was still significant energy in the room and interest in attending future events.

While the girls were recruited from many schools, with only 2–3 girls on average from each school, several larger social groups formed at the meal breaks. They took photos of themselves throughout the event, and shared social media information. At the end they organized a spontaneous group photo wearing their UNSW Canberra shirts and sunglasses.

Conclusion

As a result of the three day program, the young women who participated were in a better position to make decisions about their potential future as engineers. Their understanding of the breadth of engineering and the role of engineers was improved. They had increased interest in engineering and confidence in their ability to be engineers. They also had increased knowledge of the subject choices they would need to make if they intended to pursue engineering.

While we may expect that they will retain (at least some of) the knowledge and understanding gained, it is possible that the increase in interest and confidence will fade in the months and years following the program. Hence, we intend to follow the group, and subsequent cohorts, and collect further survey data after some months and again a year or two after the program. This will let us determine if the positive effects of the program are lasting.

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Acknowledgment

We are grateful for the support of an IEEE New Initiative Committee Grant to fund the program.