Full Paper

Introduction

Demand for skilled professionals with training in science, technology, engineering and mathematics (STEM) is projected to increase significantly in coming years with 75% of the fastest growing occupations requiring STEM skills (Australian Industry Group, 2012). Yet, over the past 20 years, Australia has seen a steep decline in the number of high school students - particularly girls - electing to study science and advanced mathematics (Office of the Chief Scientist, 2014). This has had a flow on effect on the number of young women enrolling in tertiary engineering qualifications.

In 2014 the Chief Scientist released a STEM strategy that included a recommendation to support "high levels of participation and success in STEM [education] for all Australians, including women, Indigenous students and students from disadvantaged and marginalised backgrounds" (Office of the Chief Scientist, 2014). This recommendation resonated with those of a series of national reports on engineering education, including King, 2008 and Godfrey & King, 2011.

Recent research commissioned by a number of engineering multinationals in the UK (Zecharia, Cosgrave, Thomas, & Jones, 2014) builds on previous work in the field (e.g. Fine, Jordan-Young, Kaiser, & Rippon, 2013; Hill, Corbett, & St. Rose, 2010; Lyons et al., 2012; Mills, Ayre, & Gill, 2010; Sikora, 2014).

Zecharia et al take a 'gender lens' to the slow progress in girls' participation in STEM and in women's representation in leadership and in engineering. They identify three key factors considered by students when choosing STEM studies as follows,

1. Relevance of STEM to sense of identity and future aspirations.
2. Perceived actual and relative ability in STEM subjects.
3. 'Science capital' - or experience of STEM, including formal and informal exposure to STEM subjects and careers through the curriculum, schooling, media, culture, family and personal connections' (Zecharia et al., 2014 p.9).

The likelihood of answering 'yes' to the questions arising from these factors, they argue, is mediated by cultural messaging, which includes gender stereotypes and STEM career stereotypes (2014, p.10).

This paper introduces *Collabor8*; an engineering and IT outreach program for female students in Years 8 and 9 attending high schools serving low socio-economic communities. *Collabor8* will test the relative importance of Zecharia et al's three key factors on participants' interest in STEM and intention to select STEM subjects in the senior years of high school and university, and evaluate the impact of the chosen outreach model.

The program is being funded through the Australian Government Department of Education Higher Education Participation Programme (National Priorities Pool) which requires reporting of the evaluation and research findings.

Female participation in STEM study and engineering and IT professions

Our inquiry into the factors contributing to falling STEM subject uptake by girls in Australian secondary education (see Kennedy, Lyons, & Quinn, 2014; Mack & Walsh, 2013) is prompted by a renewed focus on low rates of participation in STEM-based university courses (such as in engineering and IT). Recent statistical information from the engineering and IT sectors shows a decline in the number of girls and young women electing to study STEM subjects at each and every decision point; the first being Year 9 elective subject choice selection (see Engineers Australia, 2012b). This problem is at the intersection of concern about the shortfall of skills at the service of the economy and the recognition of the cost of women's occupational 'segregation' (i.e. representation in fields such as education, health, and under-representation in sciences, technology, engineering) and underemployment - both to their life chances and lifetime savings, to the community and to decision-making for the future.

The annual World Economic Forum's *Global Gender Gap Report* indicates a widening difference between Australia's global ranking for women's educational attainment and women's labour force participation since 2012. While Australia ranks consistently first in the world for women's educational attainment, it's ranking for women's labour force participation fell from 44th (in 2012) to 51st in 2014 (2014).

In line with this, while there has been a low rate of increase in female enrolments in engineering over the past two decades, this has not been reflected in participation rates in the profession, where retention continues to be low (Godfrey & Holland, 2011). While female enrolments in engineering stand at 16%, women represented 11.8% of the engineering workforce in the 2011 census (Engineers Australia, 2012a).

The contributing factors to this low rate of retention have been flagged by female engineers in a number of professional surveys since 2002, and they are now the subject of reporting required of private sector companies with more than 100 employees, by the national Workplace Gender Equality Agency. This strategy to reform the workplace, together with the deep contemporary analysis by Mills, Franzway, Gill and Sharp (2014) of the questions 'Why so few women engineers?' and 'Why has engineering been so resistant to change?', are a contextual frame for *Collabor8*. Mills et al reviewed the large scale project of advocacy for women in engineering - to which UTS WiE&IT has contributed since 1981 - and attributes the lack of change in the profile of engineering to enduring and unexamined beliefs arising from the interaction of knowledge, power and gender politics. Our experience in advocacy and outreach and in the professional and personal outcomes for female graduates, strengthens this project with respect to the disruption of stereotypes (Zecharia et al factors 1 & 2) and the building of 'science capital' (factor 3).

Our interest lies in identifying the factors that influence girls' decisions about whether to select STEM subjects from the very first point at which they can make a selection choice (Year 8) in order to determine factors that policy makers, educators, and others designing STEM interventions can use. It was therefore our intention to draw on key literature in the design of *Collabor8*, so that our findings can better inform coordinated outreach to young people about STEM choices and opportunities (Gale & Parker, 2013, p. 65).

The *Collabor8* Program: Objectives and approach

The overarching aim of the *Collabor8* Program is to address the decline in female enrolment in STEM subjects (and STEM enabling subjects such as Design and Technology, Engineering Studies, etc.) as girls move through high school. It is our assumption that higher interest and enrolment levels in these subjects in junior years (i.e. Years 9 and 10) is necessary for increased enrolments in STEM subjects in Years 11 and 12 and subsequent enrolment in tertiary engineering and IT courses. We are committed to a rigorous evaluation of the effectiveness of the program in achieving its objectives and undertaking a study of the factors that influence participants' subject selection.

In 2015 the program will engage up to 400 female students in Years 8 and 9 from seven government schools serving low-socioeconomic (low SES) communities in Sydney and regional NSW in a program of activities across the school year. Each student will attend four separate *Collabor8* program sessions that include problem-based learning activities.

The objectives of the *Collabor8* program are threefold:

1. **1.** To broaden the awareness of girls in targeted low SES high schools about engineering and information technology and increase their overall interest in studying STEM/engineering and IT in senior high school and at university.
2. **2.** To evaluate the impact of the *Collabor8* program against its intended outcomes; and,
3. **3.** To identify and investigate the following through a rigorous evaluation and research program:
    - Self-reported factors that influence subject selection,
    - How these factors differ among the cohort i.e. are they impacted by type of school, year group, ethnic background, personal acquaintance with engineers, etc.
    - The number of touch points needed to influence subject selection intentions.

Our approach to designing the *Collabor8* Program of activities, the evaluation framework and complementary research study on factors that influence subject selection, was inspired by the work of Zecharia et al. Following a stakeholder consultation to review approaches to engaging girls in STEM study and careers in the UK they found a lack of engagement with relevant literature (by high schools, universities, career advisors employers, Government) when designing their approaches (2014, p. 8). It was therefore our intention to draw on key literature and lessons from others in the design of *Collabor8* so that our findings can better inform coordinated outreach to young people about STEM choices and opportunities (Gale & Parker 2013, p65).

Zecharia et al propose that three factors are necessary for an individual (male or female) to pursue study or a career in STEM or STEM related field. The three factors are all underpinned by a single factor: ‘the cultural messages that people receive from a very young age’ about their identities (including their gender identities), their abilities and about STEM in general – in other words the stereotypes our culture uses to make sense of what it is to be a man or woman; who is good at/does what; and what science, technology, engineering and mathematics (and related careers) entail.

<u>Zecharia et al’s 3 factors in the pursuit of STEM</u>

1. Relevance of STEM to sense of identity and future aspirations.
2. Perceived actual and relative ability in STEM subjects.
3. `Science capital' - or experience of STEM, including formal and informal exposure to STEM subjects and careers in the curriculum, at school, in the media, culture and via family and personal connections (Zecharia et al., 2014, p. 9).

Zecharia et al translate the three factors outlined above into a ‘mental checklist’ that is a useful tool for applying their approach as the underpinning evaluation framework for the *Collabor8* Program. The correlations between the three factors above and Zecharia et al’s ‘mental checklist’ is explained below.

1. Relevance of STEM = Is it for people like me?
2. Perceived actual and relative ability = Do I feel confident?
3. Science capital = Can I see the possibilities and pathways?’

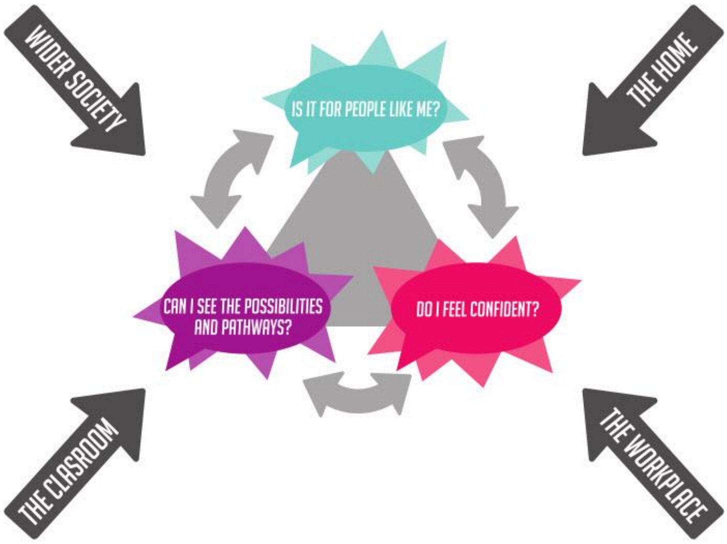

Figure 1: The 'mental checklist' interactions with cultural messaging that give rise to YES or NO answers that influence decisions about studying STEM (Zecharia et al., 2014, p.10).

It is also the view of Zecharia et al that many of the solutions that are employed to address the underrepresentation of women in STEM fields try (unsuccessfully) to conflate stereotypes of femininity with stereotypes of STEM careers. WiE&IT has taken on board the ideas in Zecharia et al's paper as well as their recommendation for an increase in the amount of project-based creative, real world learning in designing the *Collabor8* Program. We aim to disrupt stereotypes at two levels: 1. Self-perception and 2. science capital. We wish to disrupt the perception that being male and studying/working in STEM go together (and that being female does not) as well as breaking down stereotypes of what STEM subjects and careers entail and what the people who pursue them are like.

The *Collabor8* Program: Intended outcomes

It is intended that the Year 8 and 9 program participants benefit including by increased knowledge and understanding of engineering and IT as study paths and careers; increased awareness of the importance of STEM skills for an engineering or IT study path or career; and, increased interest in STEM enabling subjects (in this case Year 8 and 9 Science, Mathematics, Design and Technology and Digital Technologies/Information and Communication Technology) and relevant skills and possible future pathways – 'science capital'. We hope that through the program the girls develop a sense of ease and belonging in STEM teaching environments and confidence in their own capacity to learn and apply concepts related to STEM skills - 'perceived ability' and 'relevance of STEM'.

We plan to produce a project report that outlines findings and recommendations that:

- Provides WiE&IT, and STEM outreach advocates in universities and the community and teachers with a case study and practical guidelines for a new approach to working with girls in junior high school years;
- Provides the Australian Government Department of Education (project funder) further programmatic and research evidence of best practice in university led STEM outreach to girls and young women.

Why junior high school? Why low SES?

The *Collabor8* Program is working with students from junior years of high school in order to stimulate interest in STEM early - before girls have already opted out of the subjects that prepare them for senior high school, tertiary STEM study and careers in STEM related fields such as engineering. Across the country, students are given their first opportunity to independently select the subjects they will study in Year 8 (i.e. they select a number of elective subjects for study in Year 9 during their Year 8 year). While maths and science are compulsory until Year 10, a student's enjoyment of the subject in junior years is a solid predictor of their choosing it in senior years when it is no longer mandatory (Ainley & Ainley, 2011; Watt, Eccles, & Durik, 2006). In addition schools offer electives such as Design and Technology, Information and Communications Technology, Engineering Studies, etc. that can extend students awareness of the everyday application of STEM concepts and can be considered STEM enabling subject areas. Relevant to - but beyond the scope of - this project is accessibility of these subjects which are not uniformly available, including for single sex schools, where demand may be low.

The *Collabor8* Program's focus on female students from low-SES schools is supported by evidence indicating that female students from low SES backgrounds are more motivated to continue to higher education than their male peers (see Curtis, Drummond, Halsey, & Lawson, 2012) and the declining rate at which female students select STEM enabling subjects that increase their options for tertiary study. Research by Godfrey & King has found that if women persist in engineering courses they have higher rates of graduation (2011). Secondly, Godfrey and King found that in a faculty of engineering and IT with a high rate of low SES participation, there was found to be no difference in average pass rates or retention between low SES students of engineering and their peers (2011).

In 2015 the schools participating in *Collabor8* are required to be government schools serving a low SES community due to the nature of the funding, the intended impact of the *Collabor8* program of activities and the nature of the research inquiry. Only schools that have been identified on the Universities Admissions Centre (UAC) Educational Access Schemes lists of schools are eligible.

We note, from considerable experience of women in engineering advocacy in a university context, that students who do not study advanced mathematics, senior sciences or technology and information technology can, and do enrol in tertiary engineering and IT courses by compensating for their lack of prior STEM knowledge, for example, by repeating their senior year or enrolling in a similar qualification at TAFE or by taking maths and science bridging courses.

The *Collabor8* Program: Collaboration with teachers

The *Collabor8* Program is intended to catalyse a community of practice for high school science, maths, design and technology (and other interested) teachers keen to improve their engagement of girls in STEM subjects throughout junior and senior high school. The first meeting of the '*Collabor8*: Teaching STEM to female students' community of practice was held in September 2015 and a second is planned for November 2015. The sessions are led by a *Collabor8* teacher and are well subscribed by teachers from both low- and non-low SES, public and private high schools.

The *Collabor8* Program: Program structure and learning model

The *Collabor8* Program extends the existing WiE&IT hands-on learning outreach model to girls in Years 8 and 9 from low SES backgrounds in a four 'touch point' program that spans the course of a single school year. Each touch point is designed to stimulate interest in engineering, IT and STEM concepts; demystify the fields of engineering and IT and increase awareness about what these professions do; disrupt stereotypes that engineering and IT are exclusively careers for men; demonstrate that concepts learnt in STEM subjects are applicable in solving real world problems; and expose students to female engineering and IT students and industry professionals.

The same cohort of students will attend:

- Touch point #1: An in-school visit featuring presentations by current female UTS engineering and IT undergraduates who share their own experience of choosing engineering and IT at university and lead the students in a hands-on activity that demonstrates how structural engineering concepts can solve real world problems and improve people's' living conditions in the developing world. Delivered in the students' schools (July 2015).
- Touch point #2: A full day of hands-on problem solving activities that demonstrate how skills learned through engineering and IT degrees (i.e. problem solving, critical thinking, teamwork, etc.) can be applied to everyday problems and situations and in a career, with a focus on disrupting common gender stereotypes (i.e. 'girls aren't good at...'.). Delivered on campus (July 2015).
- Touch point #3: An in-school visit featuring presentations from women currently working in engineering and IT coupled with a problem solving activity linking coding and software engineering concepts to everyday applications. Delivered in the students' schools (September - October 2015).
- Touch point #4: A full day of hands-on learning activities that relate to the work of an industry host company and tour of their workplaces and projects. This activity will be civil engineering focused. Delivered at the host company's locations (November - December 2015).

In total each student participant in the *Collabor8* Program will have completed a total of 14 hours of activities across the four touch points.

The *Collabor8* Program's four touch points are a combination of the existing programs run by the WiE&IT with the opportunity to trial a combined intensive program for a designated cohort. WiE&IT's high school outreach activities have been delivered to Years 7 to 12 and participants would not be expressly invited to return, although they may do so. They have included:

- The Sydney Women in Engineering and IT (SWiEIT) Speakers Program – in which female UTS engineering and IT students visit high schools to present to female students about their own stories of choosing to study engineering or IT at university.
- Engineering and IT Hands-On Day for Girls – in which high school girls from Years 7 to 12 attend UTS campus to take part in a full day of hands-on engineering and IT related problem solving activities.

The decision to have four touch points in the 2015 Collabor8 Program was informed by the reception and feedback from past programs and by consultation with UTS's student equity and outreach unit whose focus is widening participation and access to university for students from low-SES backgrounds. Also influential is the work of Gemici, Bernarz, Karmel and Lim (2014), who have found that the likelihood of a high school student from a low-SES background aspiring to, and gaining a tertiary place, can be predicted by the number of times they have engaged with a tertiary study institution.

Collabor8: Evaluation and research component

Collabor8 will be evaluated against intended outcomes which relate directly to the program's stated objectives. The intended outcomes are categorised into four outcome categories, three of which are inspired by Zecharia et al's three factors in an individual's pursuit of STEM study or a STEM related career. The intended outcomes also align with a set of outcome indicators against which data will be collected. The intended outcomes are shown in Table 1.

Table 1**:** The intended outcomes of the *Collabor8* Program.

Outcome category	Outcomes
Relevance of STEM	1. *Participant can see the relevance of STEM skills to their own sense of identity.* 2. *Participant can see the relevance of STEM to their future aspirations.*
Perceived actual and relative ability	3. *Participants feel increased confidence in the skills needed for success in STEM subjects* 4. *Participants feel increased confidence in own abilities in STEM subjects*
Science Capital	5. *Participant has a better understanding of engineering and IT as a study path and career.* 6. *Participant reports increased interest in STEM subjects at school.*
Behaviour	7. *Increased uptake of STEM enabling subjects among Year 8 students selecting Year 9 subjects*

The research design involves collecting data from student participants at each of the four touch points. Self-reporting surveys were chosen for data collection in this project for reason of the size of the cohort (400) and the age and status of participants – minors aged 13-15 years in Years 8 and 9. Human Research Ethics approval was obtained from the university and the NSW Department of Education and Communities (via the SERAP State Education Research Applications Process).

Student participants will be asked to complete the same self-report 'event survey' answering questions against each of the outcome indicators at each touch point, in addition to completing a more in-depth 'baseline survey' at the beginning of the program and an 'end-of-program' survey.

At this stage, there is no scope to collect data longitudinally so as to test the impact of the *Collabor8* Program on the cohort as they progress through their schooling, however this is a desirable development of this research which will guide further funding proposals.

Conclusion and recommendations

This paper has introduced a research project that seeks to identify the key factors that influence subject selection in secondary school by female students in low SES schools in NSW in Years 8 and 9 and particularly on the choices for STEM enabling subjects that can be the basis for senior studies and for increased choices at university. It seeks to test the proposition that, necessary conditions for a student's choice of STEM studies are the relevance of STEM to their self-identity; their perceived and actual ability, and their accumulated 'science capital' of exposure and experiences familiarising them with pathways into STEM studies and careers, and which are all subject to messaging and gender stereotypes and STEM career stereotypes (Zecharia et al., 2014).

It has been facilitated by federal funding that was secured in part by leveraging the UTS Women in Engineering and IT Program's reputation for consistent and sustained communications with female school students about opportunities for fulfilment through service to society, as well as economic independence, by choosing to study engineering and IT. It is backgrounded by valuable work which has reviewed the project of women in engineering advocacy over decades and attributes the lack of change in the profile of engineering to enduring and unexamined beliefs arising from the interaction of knowledge, power and gender politics (Mills et al., 2014).

It is hoped that the findings from *Collabor8* can better inform co-ordinated outreach strategies to engage with young people about choices for their future. This is in parallel with the efforts of universities to reform curricula to engender design thinking, problem solving and critical analysis skills for lifelong learning and with the efforts of many employers to transform their enterprises to better value and develop their workforce to promote diversity, retention and well-being, as the life of society and the conduct of research and economic activity confront significant change in every aspect.

References

Ainley, M., & Ainley, J. (2011). Student engagement with science in early adolescence: The contribution of enjoyment to students' continuing interest in learning about science. *Contemporary Educational Psychology*, *36*(1), 4–12.

Australian Industry Group. (2012). *Lifting our Science, Technology, Engineering and Maths (STEM) Skills*. Retrieved from http://www.aigroup.com.au/portal/binary/com.epicentric.contentmanagement.servlet.ContentDeliveryServlet/LIVE_CONTENT/Publications/Reports/2013/Ai_Group_Skills_Survey_2012-STEM_FINAL_PRINTED.pdf

Curtis, D., Drummond, A., Halsey, J., & Lawson, M. (2012). *Peer-Mentoring of Students in Rural and Low-Socioeconomic Status Schools: Increasing aspirations for higher education.* Canberra: National Vocational Education and Training Research Program.

Engineers Australia. (2012a). *The Engineers Australia survey of working environment and engineering careers, 2012*. Retrieved from www.engineersaustralia.org.au

Engineers Australia. (2012b). *Women in engineering: A statistical update*. Retrieved from www.engineersaustralia.org.au

Fine, C., Jordan-Young, R., Kaiser, A., & Rippon, G. (2013). Plasticity, plasticity, plasticity…and the rigid problem of sex. *Trends in Cognitive Sciences*, *17*(11), 550–1.

Gale, T., & Parker, S. (2013). *Widening Participation in Australian Higher Education*. CFE Research. Retrieved from https://www.ncsehe.edu.au/publications/widening-participation-australian-higher-education/

Gemici, S., Bernarz, A., Karmel, T., & Lim, P. (2014). *The Factors Affecting the Educational and Occupational Aspirations of Young Australians*. *Longitudinal Surveys of Australian Youth*. National Centre for Vocational Education Research.

Godfrey, E., & Holland, B. (2011). System thinking: How universities can boost the retention of a higher proportion of women engineers in the engineering workforce. Proceedings of the 2011 AAEE Conference, Fremantle, Western Australia.

Godfrey, E., & King, R. (2011). *Curriculum specification and support for engineering education: understanding attrition, academic support, revised competencies, pathways and access. Final Report*. Australian Learning and Teaching Council.

Godfrey, E., & Robin, K. (2011). *Women in Engineering Education: Recommendations for curriculum change and support to aid recruitment and retention*.

Hill, C., Corbett, C., & St. Rose, A. (2010). *Why So Few? Women in Science, Technology, Engineering and Mathematics*. Washington DC: American Association of University Women (AAUW).

Kennedy, J., Lyons, T., & Quinn, F. (2014). The continuing decline of science and mathematics enrolments in Australian high schools. *Teaching Science*. Retrieved from http://eprints.qut.edu.au/73153

King, R. (2008). *Engineers for the Future: Addressing the supply and quality of Australian engineering graduates for the 21st century*. Australian Council of Engineering Deans.

Lyons, T., Quinn, F., Rizk, N., Anderson, N., Hubber, P., Kenny, J., Sparrow, L. West, J., & Wilson, S. (2012). *Starting out in STEM: A study of young men and women in first year science, technology, engineering and mathematics courses.* Armidale: SiMERR National Research Centre.

Mack, J., & Walsh, B. (2013). Mathematics and Science Combinations NSW HSC 2001-2011 by Gender.

Mills, J., Ayre, M. E., & Gill, J. (2010). *Gender Inclusive Engineering Education*. Routledge.

Mills, J., Franzway, S., Gill, J., & Sharp, R. (2013). *Challenging Knowledge, Sex and Power: Gender, Work and Engineering*. New York: Routledge.

Office of the Chief Scientist. (2014). *Science, technology, engineering and mathematics: Australia's future*. Canberra: Australian Government.

Sikora, J. (2014). Gender Gap in School Science: Are Single-Sex Schools Important? *Sex Roles*, *70*(9-10), 400–415.

Watt, H., Eccles, J., & Durik, A. (2006). The leaky mathematics pipeline for girls: A motivational analysis of high school enrolments in Australia and the USA. *Equal Opportunities International*, *25*(8), 642–659.

World Economic Forum. (2014). *The Global Gender Gap Report 2014*. Retrieved from http://www3.weforum.org/docs/GGGR14/GGGR_CompleteReport_2014.pdf

Zecharia, A., Cosgrave, E., Thomas, L., & Jones, R. (2014). *Through Both Eyes: The case for a gender lens in STEM*.

Copyright