Collabor8 and disrupt: Identifying influencers on STEM subject choices

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CONTEXT
The decreasing rate at which Australian high school students are studying advanced mathematics and science compounds the significantly lower rate of female enrolment, and representation in some STEM (science, technology, engineering and maths) professional fields (EA 2012)(OCS 2014). It continues the distinctive occupational segregation by gender of the Australian workforce with consequent inequities and under capacity in skills considered necessary for economic transformation. Since the gender advocacy in education interventions of the 1980's, there's been a dramatic rise in female participation and success in secondary and tertiary education and in fields *other* than STEM. The stand out example of low female enrolments (17%) is in the field of engineering (target 40%) and the evident lack of attraction of these fields for girls has prompted inquiry into the significant influencers of subject choices and courses of study. Further, persistently poor retention of women professionals, particularly in engineering, has seen significant scholarly investigation (Mills et al 2013) and policy response (WGEA 2014). Any credible strategy for significant change needs to be informed by research on decision making by girls and women at both entry into, and exit from, these fields.

PURPOSE
This study was an opportunity to investigate influencers on Year 8 and 9 girls from 7 metropolitan and regional schools serving low SES communities for choice of subjects and future courses of study, via a purpose-designed program, *Collabor8*. In four touch point events over eight months, *Collabor8* sought to inquire as to what effect a best practice program could have on the perceptions of a junior cohort about studying engineering/IT at university; on their confidence that they could achieve in such studies and courses, and on their familiarity with what engineers and IT professionals do.

APPROACH
Collabor8 drew on the extensive experience of the WIEIT Program UTS and evidence of what works to engage girls in STEM, such as practical hands-on and applied problem-solving, and demonstrable social benefit. It's theory of change, intended outcomes and evaluation framework were influenced by Zecharia et al 2014 who propose a 'gender lens' is necessary to comprehend the challenge and to assess diverse efforts to increase interest of high school girls in STEM (p.8). They found the influences at play for a young person to choose STEM to be: relevance; perceived ability and 'science capital', prompting the questions: *Is it relevant to me?*; *Do I feel confident?* and *Can I see the possibilities and pathways?* (p.10) *Collabor8* conducted a pre- and post- Program survey, and an event survey evaluation at each of four touch points.

RESULTS
Participation in *Collabor8* was found to significantly improve the cohorts' perceptions of the relevance of STEM study, confidence in their abilities, and 'science capital'. Notably, 77% of students attending all 4 touch points report being interested or very interested in study of engineering/IT at university in the future, compared with 25.8% reporting they were interested or very interested prior to the program.

CONCLUSIONS
The finding that female perceptions of STEM subjects and their prospects in STEM careers can be significantly shifted by an intensive program of experience and interaction with STEM peers and professionals, aligns with Justman and Mendez' study of STEM subject choices by 58,000 high school students (2016): that gendered patterns of specialisation in STEM subjects are likely shaped by 'social norms and perceived economic incentives' (p. 23). There's a strong case for *Collabor8* follow-up; for investing in strategies to disrupt gendered stereotyping of courses and careers, and for dismantling features of STEM workplaces and cultures known to deter women's retention, continuity and success.

KEYWORDS gender, STEM subjects, influences, social norms, stereotypes, retention

Introduction

A phenomenon of concern in Australia is the decreasing rate at which high school students are studying advanced mathematics and science and also how this compounds the significantly lower rate of female enrolment, and representation in some STEM (science, technology, engineering and maths) fields (EA 2012) (OCS 2014). This continues the distinctive occupational segregation by gender of the Australian workforce; wage differentials by gender, and under capacity in skills considered requisite for the nation's future. Since the 1980's beginnings of advocacy to girls and young women to choose to study and qualify in science and engineering, there has been a dramatic rise in female participation and success in secondary and tertiary education and in fields *other* than STEM. The stand out example of persistently low female enrolments (17% 2016) is in the non-traditional field of engineering (non-traditional fields equity target 40%).

The evident lack of attraction of these fields for girls has prompted inquiry into the factors that are significant influencers of subject choices and courses of tertiary study. At the same time, persistently poor retention of women professionals, particularly in engineering (WGEA 2014), has been the subject of significant scholarly investigation (Mills et al 2013) (Male in Bilimoria & Lloyd 2014) and recent policy response (WGEA 2014, Australian Government 2015 and 2016). It is clear that any credible strategy for significant change needs to be informed by research into influencers on decision making at points of both entry and exit from these fields.

Female participation in STEM study

A rich picture has been compiled of trends in subject selection in secondary schools and particularly with respect to declining enrolments in STEM 'enabling subjects' of physics and chemistry and intermediate and advanced mathematics that equip students for success in courses such as engineering, since 2000 (EA 2015 p.4). These trends are occurring against a backdrop of increased participation at all levels of education pursuant to the widening participation policy targets set by the Bradley Review of Higher Education in 2008. Clear evidence of declining enrolments in senior secondary STEM studies and especially in intermediate and advanced maths, and especially by females, has sharpened priorities for government and the Office of the Chief Scientist, in concert with the academies, education, universities, professional organisations and industry.

Kennedy, Lyons and Quinn (2014) analysed raw enrolment data for upper secondary science and mathematics courses from the education departments of each Australian state and territory from 1992 to 2012 and found that the participation rates for most science and mathematics subjects fell (Kennedy et al, 2014). Of the sciences the most significant declines were seen in Biology (-10%) and Physics (-7%). In the same period, intermediate level Mathematics saw an 11% decline and advanced level Mathematics a 7% decline in participation while entry level Mathematics saw increased participation (+11%) demonstrating the trend towards lower levels of mathematical study.

An example relevant to this paper, is that, when framed as a proportion of the entire Year 12 cohort, Kennedy et al (2014) found the proportion of Year 12 students studying Physics has declined each year from 21% in 1992 to just 14% in 2012; and female numbers have fallen more significantly than male with there being just one female student studying Year 12 Physics for every 3 male students in 2012 (a sex ratio of 0.25). Further, in 2012, advanced level Mathematics had a sex ratio of 0.35 or 14 female students for every 25 males. (Kennedy et al, 2014). While many universities no longer have mandatory prerequisites of study, including for engineering, such subjects attract entry points; prior exposure and achievement in secondary studies likely contributes to self-efficacy and perceived prospects for success and confirms social norms about the best fit of student profile to chosen discipline of study.

The pilot project that is the subject of this paper attracted support to research influencers on subject selection by Year 8 and 9 girls from a number of schools serving low socio-economic status communities in metropolitan and rural New South Wales.

The *Collabor8* project was designed and delivered by the UTS Women in Engineering and IT program, an initiative that has been supporting women in STEM for 35 years. The *Collabor8* program was able to therefore leverage the host WIEIT's experience with sustained evidence-based STEM outreach and engagement with girls and young women, and a record of implementing and reporting on small-scale widening participation funding for equity outreach and industry mentoring.

The overarching aim of the *Collabor8* project was to inquire into and address the issue of progressive decline in female enrolment in STEM and STEM enabling subjects as young women move from junior to senior high school and on to tertiary studies.

Evidence-based experience 1981-2015

The original *Collabor8* program drew on extensive experience and evidence of what works to engage girls and young women in STEM, such as practical and applied problem-solving, and demonstrable social benefit. In a sample of 3,500 undergraduate STEM students, girls, significantly more than boys, reported the importance of the influence of their teachers and mothers, and of their experience of targeted STEM outreach/programs (Lyons et al 2012).

The theory of change, intended outcomes and evaluation framework of the *Collabor8* project were influenced by Zecharia et al 2014. This team conducted an extensive stakeholder consultation to review efforts to increase interest of high school girls in STEM and found a lack of evidence-based approaches, much of which are 'gender-blind' They call for a 'gender lens' to be used to comprehend and respond effectively to the challenge of female participation in STEM. Key influences at play for a young person to choose STEM they found to be: relevance of STEM; perceived ability and 'science capital', which prompt three questions: *Is it relevant to me?, Do I feel confident?* and *Can I see the possibilities and pathways?* (Zecharia et al 2014 p.10).

Schools and teachers were recruited to *Collabor8*, with the engagement and support of STEM, gender and equity practitioners in the university and the state education department. There was regular communication throughout between the host team and each school.

The design and content of *Collabor8* was created in consultation with stakeholders, including STEM activity facilitators, trained undergraduate student volunteers, and industry partners. It incorporated teacher and student evaluative feedback from proven outreach programs. The content was designed to uncover and link the potential relevance of STEM studies to the age cohort's concerns; to build confidence through problem-solving team-based activities, and to inform and represent the diversity of possible pathways of study, recruitment and employment in STEM fields through personal biographies of junior, mid-career and senior professionals.

A two stage ethics approval had to be secured at both the university and state education department. Parental approval was necessary for students to be able to attend the university (Touchpoint 2) and industry hosted meetings (Touchpoint 4).Selection of 405 participants from Years 8 and 9 was by teacher nomination, and it was not possible in this pilot to ensure the inclusion of students who were not identified with STEM studies by this stage of their school education. This expansion of the cohort would be an opportunity for investigation in a second iteration of the program. The students were from diverse ethnic backgrounds, with 46% having both parents overseas born; 16% one parent overseas born; 11% were indigenous and 31% would be first in family if they were to attend university. In this investigation there was a pre- and post- *Collabor8* program survey conducted of all 405 participants, and an event survey evaluation at each of the four touch points. Teachers were also involved in the process through the coordination of two teachmeets that facilitated discussion and presentations about engaging young women in STEM and through phone interviews with teachers from participating schools.

Significant impacts

Across a number of indicators the *Collabor8* program was found to significantly improve girls' perceptions of the relevance of STEM study, confidence in their abilities, and their awareness of pathways and possibilities. Notably, 77% students who came to all touch points in *Collabor8* report they were interested or very interested in study of engineering/IT at university in the future at the end of the program, compared with only 25.8% who reported they were interested or very interested before participating in the program.

Further, the following outcomes were also found to be statistically significant:

- Over 90% agreed or strongly agreed that women make good IT and engineering professionals by the end of the program.
- 47.6% in the post-program survey agreed or strongly agreed with the statement "I have what it takes to become an engineer" whereas only 28.1% agreed or strongly agreed with this statement in the pre-program survey.
- 35.3% in the post-program survey agreed or strongly agreed with the statement, "I have what it takes to become an IT professional", compared with 25% agreeing or strongly agreeing in the pre-program survey.
- 89.2% of participants reported that their understanding of what engineers do as good or very good increased from 61%.
- 83.3% of participants reported that their understanding of what IT professionals do as good or very good increased from 55.5%.

Such findings that female perceptions of STEM subjects and of their prospects in related careers can be significantly shifted by an intensive gendered program of experience, interaction and 'science capital', align with those of a major study of STEM subject choices for 58,000 high school students 2008-13. Finding that STEM subject choices correlated significantly with success in standardised literacy and numeracy tests and not with any absolute or comparative advantage of males in mathematics, Justman and Mendez concluded that gendered patterns of specialisation in STEM subjects are likely therefore to be shaped by 'social norms and perceived economic incentives' (2016 p. 23).

Conclusion and Recommendations

An original pilot of a purpose designed program inquiring into influencers on subject choices for Year 8 and 9 girls in low SES schools has been able to significantly shift their perceptions about relevance, self-confidence and pathways and possibilities arising from choosing further studies in STEM subjects.

These results confirm recent conclusions - firstly by the profession (EA Policy Note 2015 pp. 9-10) that while low numbers of girls in STEM subjects are a problem (for female enrolment rates into engineering), of likely more importance is that engineering is not seen as an attractive career option by girls. Secondly, from their recent investigation of choices of a very large sample of junior secondary students, Justman and Mendez find the influence of 'social norms and perceived economic benefits' outweighs any possibility of an absolute or comparative advantage in mathematics by males, which they find is not supported, in accounting for gendered patterns of subject choice (2016 p. 23).

A gender lens

The findings from *Collabor8* project seen together with the above, confirm the case for a 'gender lens' as proposed by Zachariah et al (2014) to be applied to the persistently low rate of female engagement and enrolment in STEM fields and particularly engineering, and the persistently low rates of retention in engineering and IT by successful female graduates.

Such a perspective requires that any intervention addresses the deterrents and barriers to entry *and* the reasons for exit of many women who have made a significant investment in their STEM qualifications and career. Each element of the 3 step model of Zachariah et al used in this pilot, of perceived relevance of STEM, confidence to achieve and awareness of the pathways and possibilities of STEM study and career or 'science capital', can be seen to be subject to the influence of social norms about the gendering of subjects and consequent courses of study and professional practice, as more 'naturally' suited to males. Such norms continue to have wide currency as illustrated by the social media campaign #Ilooklikeanengineer and the backlash to a technology recruitment advertisement that prompted it and to be enduring in the workplace (Faulkener 2009a, 2009b, Mills et al 2013, Male in Bilimoria & Lord 2014). There are new findings that employment outcomes on graduation are poorer for women studying in non-traditional fields of engineering and IT who are from a low socioeconomic status, than for low SES males in the same and other fields (Richardson et al 2016). These are red flags that the hazards and barriers for many women navigating careers in STEM need also to be confronted together with the more popular - and proliferating efforts to attract girls and young women to these fields.

Follow-up on *Collabor8* and disruption of gender stereotyping

With these findings, there is a strong case for follow-up iteration and development of the *Collabor8* program and research to measure any longitudinal effects of participation in the program. There is also a need for significant resourcing of evidence-based strategies to disrupt gendered representation of courses and careers in school education, VET colleges and universities, and in mainstream media and popular culture. One of these is the gendered bundling of courses in secondary education (Joensen and Nielsen 2015 cited in Justin and Mendez 2016) including through timetabling. New offerings in university transdisciplinary courses are being developed in a bid to attract women and a diversity of students to STEM studies and entrepreneurship in accelerating economic transition and uncertainty. It is recommended that the touch points and content developed from the *Collabor8* program in 2015-16 be used as a benchmark for best practice for female STEM outreach.

Workplace gender equality

For the credibility of the 'science capital' accrued by many, although not enough, young people about pathways and possibilities in STEM - institutions, the professions and employers for their part, need to acknowledge and dismantle, or transform - those workplace features, conditions and cultures that deter women's retention and prospects for continuing attachment and success in the STEM workforce and its many and emergent enterprises. This would expand opportunity and accelerate innovation by both attracting a greater diversity of talented people in STEM and disrupting stereotypes about working in these fields.

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