STEAMpunk Girls Co-Design: Exploring a more Integrated Approach to STEM Engagement for Young Women

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SESSION S1: Is Integrated Engineering Education Necessary?

CONTEXT

The call to increase the capacity of Australia’s STEM workforce has resulted in a spotlight on the comparably fewer number of women working in STEM. One strategy to address this lack of representation is an integrated, ‘STEAM’ approach to teaching and learning STEM. STEAM education recognises the role of arts/humanities and the potential utility of a more creative mindset, applied to learning and teaching STEM. Whilst STEAM is still a relatively new pedagogical approach, research suggests positive outcomes whereby young people can develop innovative and transdisciplinary skillsets that can enhance their employment prospects in disciplines such as engineering.

PURPOSE

The STEAMpunk Girls Co-Design program aims to determine if an integrated approach to education across the science, technology, engineering, arts and maths (STEAM) fields, can promote stronger engagement and a sense of empowerment, confidence and agency among young women in terms of their willingness to pursue STEM study and careers.

APPROACH

A 10-day program was conducted in November 2016, involved 26 girls (aged 15–16 years) from three Sydney high schools. Students were enlisted to design a STEAM-based educational pilot for their peers. Longitudinal data was collected from online pre- and post-program surveys.

RESULTS

Findings reveal a unique, female perspective that can utilised to improve STEM engagement programs for their peers (particularly if such programs seek to integrate the arts, humanities and social sciences as a means of increasing interest, engagement and retention in STEM). Students reported improvements in their understanding of the types of work people undertake in science, technology, engineering, and arts industries, as well as the variety of cross-disciplinary skills needed to work in STEM industries. Co-design proved to be a fitting methodological framework for the participants to experience a safe and supportive environment to experiment and trial their ideas. Program feedback was predominantly positive, with an average satisfaction agreement rating of 92% across all feedback categories.

CONCLUSIONS

The STEAMpunk Girls co-design program identified benefits STEM-Arts integration, as well as issues and obstacles that adversely affect young women’s engagement in STEM fields such as engineering.

KEYWORDS

STEM, STEAM, gender, co-design

Introduction

In Australia, STEM (Science, Technology, Engineering and Maths) knowledge is recognised as an important aspect of the fastest growing occupations and innovations. Despite this, interest and enrolment in STEM subjects appears to be on the decline among Australian students (Kennedy, Lyons & Quinn, 2014; Pricewaterhousecoopers, 2015). The call to increase the capacity of Australian students' STEM engagement has resulted in a spotlight on the comparably fewer number of women, in particular, enrolling in STEM programs, and working in STEM industries (Blickenstaff, 2005; Broadley, 2015; Greenfield et al., 2002). Early research suggests that academic attainment presents obstacles for women to enter STEM programs (e.g., Raffe et al., 2006). Other research suggests it is women's differing interest and motivations (Smith 2011), and their perceptions of self-efficacy in STEM fields (Falk et al., 2016; Nye et al., 2012; Valla & Cecil, 2014) that influences the numbers of women in STEM. Arising from and contributing to these factors are environmental, social, cultural, political and institutional factors (Ceci et al., 2009; Phipps, 2002; Smith 2011; Terzian, 2006) with the finding that certain STEM fields are perceived by women as being less welcoming or even hostile environments (MIT, 1999; Sonnert et al., 2007).

Harkening back to earlier studies examining attainment, Wang, Eccles and Kenny (2013) found that aptitude in maths and corresponding lesser aptitude in verbal/communicative fields was an influencing factor in students' decision to pursue a STEM career. Among students with strong quantitative aptitudes, the authors reported that women were more likely than men to possess symmetrical aptitude tendencies, i.e., women had a strong aptitude in both quantitative areas *and* verbal/communicative areas. Thus arises the contention that an additional explanation for women's underrepresentation in STEM is because women with high STEM aptitudes may be presented with more choice regarding their prospective careers. Whereas for men with strong academic aptitudes in quantitative areas, the options are narrower and/or clearer due to their more asymmetrical aptitude profile. Valla and Cecil (2014) refer to this as the 'breadth based' model of female underrepresentation in STEM. When considering this complex ecology of factors, there is not likely to be a single 'silver bullet' intervention. A common approach at the K-12 level has typically been to address girls' and women's' attainment gaps, and to increase confidence and exposure to STEM. Building on this approach, STEAM education is a relatively new intervention that has shown promise in its capacity to address a wider array of influencing factors. This paper presents findings from the STEAMpunk Girls Co-Design program that has utilised STEAM education to engage young women in STEM.

STEAM

STEAM stands for Science, Information Technology, Engineering, Arts (including creative arts, the social sciences and the humanities) and Maths (Miller & Knezek, 2013). It may be defined conceptually as the integration of its constituent disciplines within a broader philosophy or way of thinking and doing that also incorporates creativity and innovation. Originating in the US, STEAM is a movement that has gradually gained momentum since 2010 (Ellis, 2016). Though there is variation in STEAM approaches, at its heart is the understanding and application of social and human contexts related to issues. Operationally, STEAM can manifest in learning and teaching approaches, through educational institution policy and practice (e.g. curriculum and assessment design), and through organisational culture in workplaces (e.g., in recruitment, professional development, and human resources policies). The benefits of the STEAM philosophy have been espoused both internationally (Care & Luo, 2016), and locally (Barr et al., 2008), with many countries looking to integrate 'transversal' competencies into their education systems.

Though of potential benefit to all STEM fields, STEAM approaches may be of particular utility in engineering due to the field's susceptibility to changes in technology, the economy, the environment, and the attendant, evolving needs of clients and the community. Savage, Chen and Vanasupa (2007) recommend that educational institutions should enable students to become versatile “global engineers”. The attributes of a global engineer include versatility and multi-disciplinary thinking, the ability to adopt a more holistic approach to problem-solving, effective communication skills, the ability to work with different people in diverse setting, and to demonstrate social awareness and responsibility (Miller & Knezek, 2013). STEAM pedagogy can contribute to achieving these objectives through its emphasis on constructivist, student-centric, creative approaches that emphasise a social or human context inherent to many, if not most, problem issues. In terms of engineering pedagogy, Connor, Karmokar & Whittington (2015) refer to the dominant instruction method in engineering as being ‘chalk and talk’ and support a more inquiry based approach borrowed from arts-based pedagogies. When applied to STEM learning, STEAM education also has potential to appeal to a wider variety of learners beyond merely the STEM-inclined (Ahn & Kwon, 2013)

The STEAMpunk Girls Co-Design Program

The co-design program was conducted across eleven days in November 2016. The aim of the program was to empower young women by positioning them as experts on how they wanted to engage with STEM and STEAM, and to provide them with a platform to design a learning experience that the project team could subsequently pilot. Co-design was selected as a particularly suitable methodology. It enables an atmosphere of collective creativity by placing the design process in the hands of the people who gain value from the outcome (Sanders & Simons, 2009).

Twenty-six female students aged 15-16 years from three Sydney high schools attended a full day workshop at a Sydney university where they learned about STEAM (through case studies and meeting STEAM practitioners), design thinking, and empathy. They then spent the following nine days interviewing peers on the topic of engaging young women in STEM and STEAM, using questions of their own design. Each participant was provided with a diary to take notes and reflect on their gleanings. Participants returned to the University for a second workshop to engage in further design thinking through unpacking their interviews and identifying key insights. They worked in teams to apply their new knowledge to prototyping their vision of a STEAM school of the future. To assist this creative process, students were provided with craft materials to create their (‘low-fi’) prototypes.

Image 1: Students’ participating in the co-design phase of the program

Data was collected through pre- and post-program online student surveys. The aim of this was to assess changes in student perceptions of self-efficacy relating to the STEAM disciplines, and to ascertain learning preferences and attitudes regarding future study and work. Descriptive statistical analysis was undertaken using Microsoft Excel 2016. Correlational statistics was not undertaken due to the small sample sizes. The participating schools were selected based on existing relationships with UTS and the ability of teachers to devote adequate time to support and lead the program in their schools. A convenience sampling method was used to recruit participants with teachers asked to identify students at their schools who were likely to be interested in participating. All students had parent/ guardian consent to participate in the research and have their photographs used by UTS.

Results

Demographic information

Twenty-five participants (from three schools) took part in the pre-program survey, while 21 students took part in the post-program survey. At the start of the program (n=25), there were 11 girls (44%) were aged 15 years, 13 girls (52%) were aged 16 years (50%), and 1 girl (4%) was aged 17 years. Half of the participants were born in Australia, while more than 73% of students had at least one parent who was born overseas in predominantly Asian countries. Nearly an equal number of students spoke mainly English at home, or another language. Most mothers (77%) and fathers (81%) had completed a university course.

Subject and learning preferences

The overwhelming majority of students agreed that it was important for them to study Maths (92%), Science (85%), and Technology (77%). Most students listed science, maths and IT as being their favourite subjects. Interestingly, there were two new subject areas/themes evident in the post-program survey responses. Engineering was a new subject area mentioned by one student in the post-program responses. Additionally, four students mentioned that they enjoyed a mix of subjects, with some explaining that it was the integration of certain subjects that they found appealing.

> *[I] like engineering because it has a lot of hands-on activities and not much homework – 15-year old, post-program survey participant*

In terms of learning preferences averaged across pre- and post-program survey responses, students reported a strong preference for (in order of preference): learning facts, learning by doing, solving problems, applying learning in the real-world, making models, experimentation, and teamwork. Students also ascribed greater importance in studying maths, science and technology, ahead of arts. Students' self-rated confidence levels (averaged across pre- and post-program surveys) showed higher levels of agreement in relation to confidence in Science (81%) and Arts (71%), and comparatively lower levels of agreement relating to confidence in Maths (69%) and IT (61%). Nevertheless, all the students agreed that they were confident they could do whatever they set their mind to.

Future study and career plans

All the students agreed that they would like to attend university, and the majority in the pre (88%) and post-program survey (90%) agreed that there was a link between STEM subjects and their future career plans. When asked about the types of jobs students preferred, their responses mostly fell within fell within the Sciences and Health Sciences fields (e.g. dentistry, medical research, medicine, optometry, nursing, pharmacist). Remaining responses were distributed (in order of preference) across IT, Creative Arts, Law, Arts/Humanities, Engineering, Media/Communications, Architecture and Building, and Music. The most common explanation was that students expressed a strong interest, aptitude or passion for the disciplines/topics. The students also expressed their desire to do something that could benefit the community.

> *I enjoy Medical sonography or radiography because I truly do love helping people. This job gives me satisfaction and life fulfilment because it makes me a part of something great, which is helping to save people's lives. In addition to other radiology modalities, the images taken help to diagnosis, treat, and cure many people with diseases or life threatening illnesses which I found very interesting – 16-year old post-program survey participant*

Sixty-two percent indicated that they were interested in studying maths at university in the pre-program survey, while 60% said they were interested in studying maths the post-program survey. Regarding students' interest in studying technology at university, the figures were also similar across both surveys, with 58% in the pre-program survey, and 55% in the post-program survey. The most notable differences in the responses was in engineering, where interest in studying engineering increased from 50% to 65%. The second most notable difference was in interest in studying arts, which rose from 58% in the pre-program survey, to 65% in the post-program survey. There was also a slight increase in interest in studying science at university, from 65% to 70%.

In terms of the students' perceptions regarding the link between STEM subjects and their future career, the percentages were very similar across the pre- and post-program surveys. Eighty-eight percent of students agreed that there were links in the pre-program survey, while this percentage increased to 90% in the post-program survey. Regarding students' perceptions on the link between arts and their future career, the percentages remained consistent at 60% across both pre- and post-program surveys.

Engineering as a profession

Students' perceived understanding of what engineers do in a professional context increased from 81% in the pre-program survey to 86% in the post-program survey. Though the students harboured some uncertainty about their aptitude for a career in engineering, over half of them (across both surveys, respectively) felt they had what it takes to become engineers. When asked about the skills or traits that engineers need to possess, three main themes emerged from the qualitative responses. The highest number of references (13 references) were made in relation to 'soft skills' and personal attributes associated with working in the field of engineering. These include the ability to problem solve, think creatively, work cooperatively, and being focused, motivated and dedicated.

Women in STEM & STEAM

All the students across both surveys agreed that women would make good engineers, and that this was a good career choice for women. The vast majority of students felt there were no barriers to women working in arts (90%), followed by science (85%), maths (60%), and finally, engineering (45%), and IT (45%). The students who said there were barriers mainly felt that they were to do with gender – e.g. being female presented an obstacle to pursuing careers in engineering because of society's perception that STEM careers are not a 'typical' female occupation.

Perceptions of parental/guardian and teacher support of studying STEM and Arts

All the students felt that their parents/guardians thought studying STEM subjects was important. Nearly all the students felt that their teachers encouraged them to study STEM (96% pre-program, 90% post-program survey). Students' views regarding the importance of arts did not differ greatly between pre (68%) and post (65%) program surveys. Similar findings were reported regarding students' perception of their teachers support in studying arts (56% pre-program, 55% post-program). The greatest difference was in students' perceptions of their parents/guardians' support of studying arts, which increased from 40% to 55%. Students' own views about the importance of studying arts was nevertheless still higher than their perception of teacher encouragement, or their perception of parental/guardian support to study arts.

Program feedback

Program feedback was predominantly positive, with an average satisfaction rating of 92% across the 10 feedback categories, based on the 20 responses received to this question from the post-program survey (see Figure 1). Students indicated that the program helped to improve their understanding of all the STEAM disciplines (see Figure 2) – science (70%), arts (70%), engineering (60%), and IT (60%). Students were however less equivocal about the program assisting their understanding of maths, with half the students indicating 'yes' and the other half indicating ‘no’. Students mentioned that their general understanding and awareness of the individual STEAM disciplines as well as how the disciplines could be combined, had improved as a result of participation in the program.

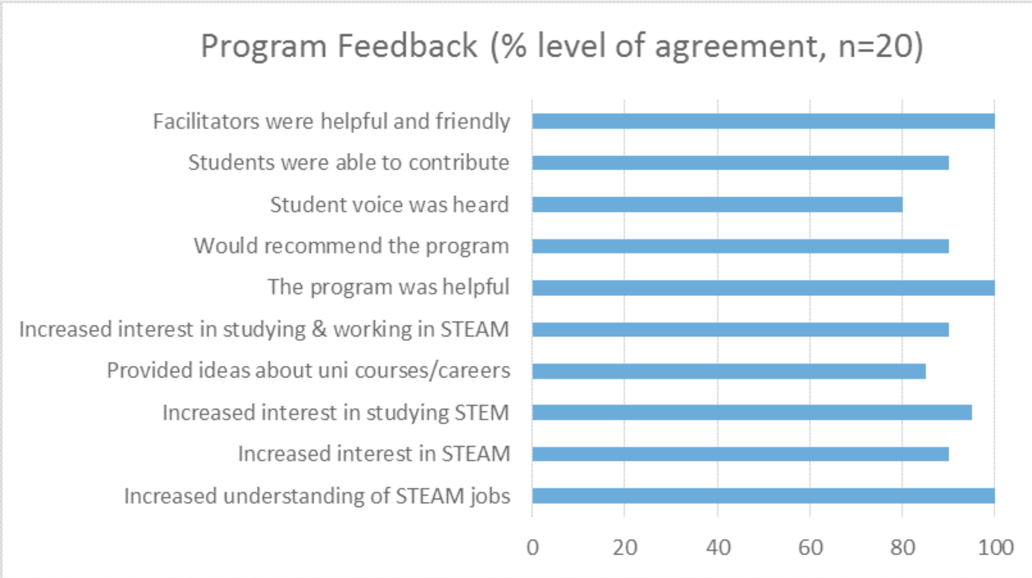

Figure 1: Program Feedback

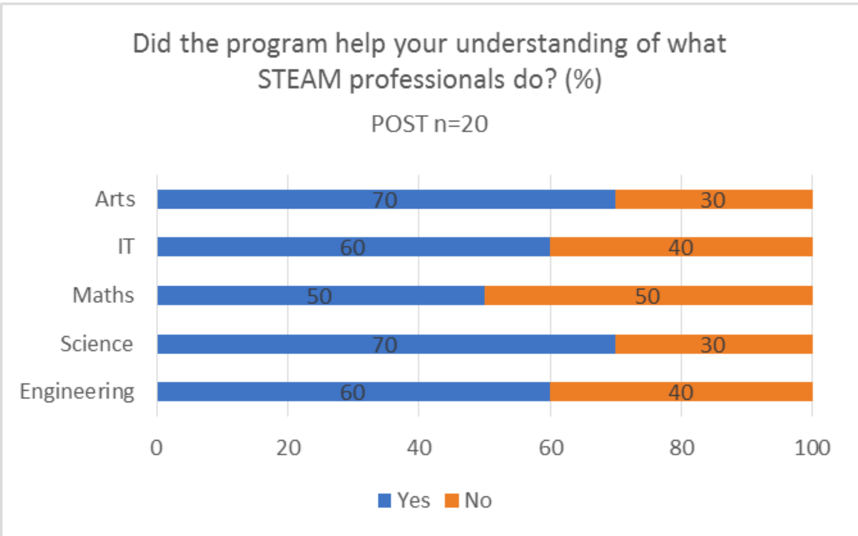

Figure 2: Students’ perception of whether their understanding of STEAM professional roles had increased as a result of the program

Discussion

The aim of the co-design program was to provide young women aged 15-16 years with an opportunity to learn more about STEAM thinking, to provide their thoughts and ideas about engagement with STEM and the arts, to meet STEAM role models, and to co-design a STEAM program for their peers. Findings from the present study revealed improvements in participants’ understanding of the all the component STEAM disciplines (except Maths), of the type of work people undertake in STEAM, and about the variety of cross-disciplinary skills and traits one needs to work in STEM industries. Related to this, participants also reported greater understanding and appreciation of how different types of knowledge can be integrated and used to address problems.

The inconclusive findings related to perceived improved understanding of maths (see Figure 2) signalled to the project team that more should be done to demonstrate the integration of quantitative-based skills and techniques (and their practitioners) into the pilot program, in a way that will be engaging and meaningful in an interdisciplinary context.

Students indicated that interest, passion and social impact were significant factors they considered in contemplating future careers. This sentiment aligns with the oft-discussed attributes of Generation Z (i.e., digitally connected, pragmatic, collaborative, entrepreneurially-minded and aspire to have their work impact on society (Hajkowicz et al., 2016)). This finding reflects past research that reports on women's inclination to work in jobs where they feel able to be of help to others (Corbett & Hill, 2015).

Overall, the findings point to a strong preference among participants for awareness and exposure to the practical value of their learning, preferring a hands-on approach. The students wanted to see how the information and knowledge they acquire at school could be used in the community and/or in a professional context. They enjoyed learning facts, but at the same time also learning by doing. These preferences have subsequently informed the project-based learning approach utilised in the pilot program in 2017.

A more personalised, constructivist approach to learning about and applying STEAM thinking will allow students to bridge the gap between theory and practice, demonstrating utility of abstract ideas and promote engagement in STEM through exposure, practice and exemplification. Such student-centric modes of learning have been associated with increases in student self-efficacy (VanMeter-Adams et al., 2014). Integrating a social/human context to STEM may work to address issues of women's reportedly lower perception of self-efficacy in STEM (Falk et al., 2016), even when their interest levels may already be high. In instances where women possess strong aptitudes in STEM as well as in verbal areas, the integrative and interdisciplinary nature of STEAM may appeal because it moves beyond disciplinary 'silos' and enables women to utilise a wider variety of aptitudes (Wang, Eccles & Kenny, 2013). It is noteworthy that the students in this study were more likely to cite soft skills ahead of (and in addition to) disciplinary or academic expertise and training required to work in engineering. This may be indicative of a higher level of awareness demonstrated by these students in relation to the array of personal and professional attributes that STEM-related professions require to operate in the modern workforce. These are the very skills which are sought after by employers and often lamented to be lacking in graduates (Sander, 2017).

All the participants perceived strong links between STEM and the kinds of jobs they might like to have in the future. They recognised the importance of studying STEM subjects, expressed high levels of confidence in STEM, and in Arts, and were confident that they could do whatever they put their mind to. They felt that women would make good engineers, but at the same time felt that there were significant barriers to women working in certain STEM roles such as engineering. This may imply that although the students may possess interest and academic aptitude, they nevertheless felt less confident about their potential professional self-efficacy in STEM fields. Aligned with this finding, Corbett and Hill (2015) refer to the unconscious gender bias (even demonstrated by women) concerning women in STEM fields. The authors found that a significant percentage of young women were pessimistic about overcoming the barriers to pursuing engineering and IT careers. The present study also found that young women were aware of societal perceptions that females possess lesser acumen or lesser aptitude for STEM fields, or have skills that are less suited to STEM. Findings regarding student, parental/guardian and teacher perceptions of the importance of studying STEM and arts subjects revealed similar opinions from these different stakeholders regarding the importance of studying STEM (i.e. near unanimous agreement that it was important), but far less congruence regarding the importance of arts. Students' own views about the importance of studying arts was higher than their perception of their teachers' encouragement, and their parents'/guardians' support. This may indicate that more could be done to raise awareness among parents/guardians about the benefits and utility of integrating the arts into STEM learning. Furthermore, despite being a more STEM-inclined cohort (as indicted by their professed favourite subjects) more students expressed an interest in studying arts subjects at university *after* participating in the program. Reflecting the breadth-based model of female aptitude (Valla & Cecil, 2014), this outcome could be due to the students being more open to integrating non-STEM elements into their university programs because of a newly validated or reinforced interest and aptitude in arts. Interestingly, fewer students indicated that they wished to work in engineering or IT, despite more students indicating they wanted to study engineering at university after the program. It appeared that interest in studying engineering did not automatically translate into willingness to work in engineering. Again, the explanation could be a lack of perceived potential professional self-efficacy when it comes to engineering as a career. Further research could be undertaken in this area, to obtain more nuanced findings to elucidate this discrepancy.

Overall, the findings contribute to extant explanations of women's underrepresentation in fields such as engineering as being more than just about academic attainment and aptitude, but also about awareness, access to opportunities, perceptions of self-efficacy, and societal norms. Giving young women a safe space to experiment and fail, and to work on projects and problems that are meaningful to them, could work to mitigate the decline in women's STEM engagement. As a learning and teaching methodology, STEAM education provides a promising operational framework to achieve this.

External factors are also at play, particularly students' sources of support and influence such as parents/guardians, schools, teachers, peers, role models, and the organisations and employers they may eventually work for. Greater awareness regarding the value of interdisciplinarity and diversity in STEM among these other stakeholders would contribute enormously to creating STEM classrooms and workplaces that are more welcoming for all students (including women). STEAM can be utilised as a valuable approach and in 're-branding' contemporary STEM education and workplace cultures.

Conclusion

The co-design of the STEAMpunk Girls program has been invaluable in enabling evidence-based design of the subsequent pilot program in 2017, and in adding to a growing body of knowledge about STEAM program design and outcomes. These findings may also have wider implications for STEM and STEAM education and STEAM program and resource design. For example, education developers and instructors designing programs and resources in engineering may wish to adopt a more interdisciplinary approach, emphasising the social and human contexts as they relate to the topics at hand. Though the comparison of longitudinal student survey data is useful in identifying program outcomes, the findings reported in this study are of limited generalisability due to the use of the convenience sampling method. Further, correlational analysis was not undertaken due to the small sample size. What this permitted, however, was consideration of the breadth-based model of female underrepresentation in STEM. If young girls perceive themselves as having high interest and aptitude in both STEM-based subjects and arts subjects, educators should capitalise on this symmetry with curriculum design that can harness this inclination. This is the aim of the pilot phase of the project. The pilot phase will additionally explore the intrinsic and external factors that contribute to girls' interest and engagement in both STEM study and career, and if a STEAM approach is likely to have an impact on this interest. Findings from the pilot phase are currently being analysed and will be reported in future publications.

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