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Introduction:
How does an all-girls robotics class create safe conditions for rigorous learning? The case study was centered around TFEL domains 2.1, 2.2 and 2.4 which focus on democratic relationships, learning culture and challenging environment.

Background:
Females represent a minority of the STEM workforce. Participation and retention of females in STEM fields of learning and work is a longstanding national and international issue. The need to revisit female participation in STEM is being driven from a larger concern about Australia’s low productivity and key skill shortages that are putting the country’s innovation and economic competitiveness at risk.

Purpose:
This study explored psycho-social effects of subject areas to which females were under represented and the role of single-sex classes in coeducational school setting in addressing the ‘subject’ gender gap by creating safe and rigorous learning environment. To retain and increase the enrolment and engagement of girls in prime STEM subjects such as Computer Programming and Robotics. The case study specifically focuses on the effect the all-girls environment can have on student choices, learning and attitudes in STEM.

School context and student cohort:
The Australian Science and Mathematics School (ASMS) is a Science and Mathematics specialist co-educational public school for students in Years 10–12. Established on the Flinders University campus in 2002, the purpose-built facility and open learning environment is designed to promote and support highly collaborative, interactive, student-directed learning within an innovative curriculum. The ASMS has a focus on self-directed, student-centered learning and inquiry projects. In this way the school is ideally situated as a case study for improving the uptake of study in STEM, especially for girls. Students at ASMS are a self-selecting sample of students with a strong interest in and passion for STEM. Despite this, female enrolments in some related core STEM subjects are still low. This case study focuses on a cohort of year 10 and 11 female students in an all-girls robotics class. The class was team taught by two female teachers during the 100 minute ASMS Adventure Space program once a week. The learning environment itself had a number of group tables, 8 computers and was separated from the open learning commons by glass walls and doors. There is no assessment or grading; just plenty of encouragement.

Activity description:
Robogals introduced ‘engineering’ into the girls' vocabulary, and showed that it can be fun and exciting. Initially the girls participated in ‘hands on’ activities where they learnt to convert real-world activities into a set of coded instructions using symbols. For example the students work in groups of three to program one of their group members to stack cups in a particular pattern using a set of arrows symbols for the programming language. Another activity demonstrated how computers sort random numbers into order using a ‘sorting network’. This helped students gain an understanding of the need for precision in coding, practice debugging malfunctioning code and understand the usefulness of functions and parameters.

Second, students participated in an online program called ‘Hour of Code’. The hour was made up of a number of self-directed, drag and drop tutorials that were created in collaboration with engineers from Microsoft, Google, Twitter and Facebook. Designed in a game format, these tutorials taught the Robogal students basic coding principles, featuring videos with guest lectures Bill Gates, Black Eyed Peas founder will.i.am, Mark Zuckerberg and artwork from popular games such as Rovio's "Angry Birds" and PopCap Games’ "Plants vs. Zombies." Students were introduced to repeat loops, conditionals and basic algorithms.
Third, the students constructed and programmed LEGO NXT robots. These comprise a central CPU brick that is programmed using a simple, visual interface to use components such as light sensors, colour sensors, sound sensors, motors, sound outputs, and so forth. The lessons were designed to engage students in a range of computer engineering topics in a way that is fun and creative. Through problem and inquiry based learning, students were set a new challenge each week to help them master the skills involved in writing programs to get their robots to compete a challenge. For example students were set the challenge to program their robot to follow a line on a course that included obstacles. This forced students to use sensors in order to move to the goal area. The robot began at the starting area, touch the wall, follow a line, get to the calibration area using the sonar, touch, or light sensor, and finally reaching to the goal.

To aid the students in their building and programming of robots I made a link with a female STEM professional Dr Sherry Randhawa, Director of Studies for Biomedical Engineering at Flinders University.

Identified students learning outcome:

- Learn to convert real-world activities into instructions
- Gain practice coding instructions with symbols
- Develop an appreciation for the importance of precision in coding
- Practice debugging malfunctioning code
- Understand the role of functions and parameters
- Work with repeat loops, conditional and basic algorithms
- Achieve a number of Australian Curriculum ICT capabilities

What were the outcomes?

This study explored psycho-social effects of subject areas to which females were under-represented and looked at single sex classes in coeducational school setting as a way to close the ‘subject’ gender gap in a safe and rigorous learning environment. To retain and increase the enrolment and engagement of girls in prime STEM subjects such as Computer Programming and Robotics. After a term of offering Robogals as an elective at ASMS, female students were interviewed about their expectations, thoughts and attitudes to the all-girl environment. Students were interviewed in pairs or small groups and were asked passive and open questions rather than leading to ensure genuine responses.

Findings included:

- The all-girl environment:
  - Increased female enrolments in robotics from 2 to 14 students
  - Students chose robotics because of the teacher and the all-girls environment
  - Felt more comfortable
  - Easier to communicate
  - Could actively participate in the lesson and access resources
  - Could focus on task
  - Fostered positive self-concept, attitudes and increased confidence
- Girls and boys do not learn differently
- Robogals can lead to other programming courses
- Teachers at ASMS do not treat students differently based on gender
- The course did not appear to affect career or subject choices
- Students enjoyed rigorous inquiry and problem based learning
- The program was recognised as best practice by organisations and media

All-girl environment

Opening up the opportunity for girls to learn robotics in an all-girls robotics class immediately increased female enrolments in robotics from 2 in mix gender classes to 14 students in a single-sex class. Many of the students chose Robogals as an elective because of the teachers, humorous introduction of the course at the assembly and the all-girls environment. Students participating in Robogals said they picked
it as an elective because it was an all-girls class. When female students were asked why they chose an all-girls class, majority said it was because they felt more comfortable. In this environment, the students said they felt like they could ask questions, actively participate, access resources, felt free of judgment and that they would not be the only girl in the class.

Students felt like they could actively participate in the class by asking questions and participating in class discussion. Students commented, “I chose Robogals because I thought I would be more comfortable sharing ideas ... I felt quite comfortable asking a lot of questions not just to ASMS teachers but also people from outside the school”. Many of the students established that they could communicate easier with peers, teachers and adults in the all-girl environment.

The Robogals believed in an all-girls environment they were not judged on their actions and decisions in class. They could freely play with the equipment, make mistakes and learn from them. One students said if they were in a mixed gender robotics class “I don’t really know much about coding and I was worried I was going to be judged not having the experience ... I just imagined these really smart guys that would know what was going on”. Students felt they didn’t have to worry about what other people thought in this all-girl environment. They felt comfortable and safe to take risks. Some researchers argued that the lack of harassment by boys when making mistakes in single-sex classes is beneficial for girls’ academic self-concept (Lee & Bryk 1986; Lee & Lockheed 1990).

A number of Robogals did not previously undertake mixed gender robotics classes because it was seen as a ‘boy thing’ and they did not want to be the only girl in the class. By conducting these activities in a girls-only environment, the classroom dynamic is such that the girls are able to fully participate in the robot building and programming. Students felt could actively participate in the lesson and access resources that would be otherwise been ‘hogged’ by boys. Year 11 student Brianna Smith said she felt more comfortable learning about engineering among a class of girls and hoped to get into electronics or astrophysics at university. “I've always been interested in engineering and robots and I considered doing it last year, but the class was comprised mainly of boys ... It’s kind of cool being in a class where we can learn together at the same pace ... the boys kind of take over a bit.” Other students corroborated these experiences in class where they haven’t been able to participate because of male influence in the class; “[In] Metal Work they take over and you can’t do anything. I couldn’t get to the materials.” Brutsaert and Van Houtte (2002) established that single-sex classes my offer girls’ foundation of social commonality on the grounds of share gender identity. Moreover in coeducational classes the presence of boys enlarges the competitive atmosphere in the class. In single-sex classes on the other hand, the rivalry between genders is avoided, which enables the girls to feel much more comfortable and able to access resources.

Students felt they could focus on task and in teams in the all-girls’ environment. They found it more relaxing and laid back environment with girls and not as ‘crazy’. One student commented; “boys talk and argue more. I have been able to focus more in an all-girls class.” In mix-sex classes boys are said to distract girls from their work and attract most of the teacher’s attention. Girls will tell you a teacher spends all their time on boys, and they are, often due to behavioural issues (Maguire 2007). Similarly it is said boys and girls are distracted by the opposite genders sexuality in a coeducation classes and single-sex-class can allow girls to concentrate. Van de Gaer et al. (2004) suggests in a coeducation setting boys feel the need to perform in front of girls and indulge in ‘peacock behaviour’.

* Fostered positive self-concept, attitudes and increased confidence (TfEL domain 2.2) *

The Robogals environment fostered positive attitudes in the students and redirected their thinking about their capabilities in STEM. Many of the students participating in the course had no previous experience writing code or working with robots. Initially many of the students seemed to have low expectations of their capabilities in robotics. Some thought that “it would take them longer to get the hang of than it would the boys” or “that is was going to be really hard working with code and numbers”. A vast amount of research has demonstrated that girls, on average, have a more negative academic self-concept concerning core STEM subjects than boys (Fredericks & Eccles 2002; Marsh & Yeung 1998; Sullivan 2009).
After the first term student confidence had demonstrably improved. Some said they “felt smarter”. Students commented at the start they did not think they were going to progress as far as they did by the end of the term. Students documented their learning journey in their very own ‘Robogals ebook’. Here they kept a log of what they were doing or learnt, pasted pictures of the different robots they build and took screenshots of programmes they wrote. This proved to be beneficial in tracking their progress and reflecting on how much they have learnt about robotics and programming. Research in single-sex education indicates positive development in girls’ self-concept, attitudes and behaviours. A single-sex environment is said to have a positive psychological influence on girls in terms of comfort, confidence, self-esteem and efficiency.

Over the last three decades, it has been repeatedly demonstrated that single-sex classes contribute to a more positive STEM academic self-concept among girls within coeducational schools (Kessels & Hannover 2008). Some researchers argued that the lack of harassment by boys when making mistakes in single-sex classes is beneficial for girls’ academic self-concept (Lee & Bryk 1986; Lee & Lockheed 1990). Younger & Warrington (2002) suggest single-sex classrooms were generally constructed, by both staff and girls, as pleasant and safe places for girls, offering opportunities for confidence-building, enabling girls to be themselves and to develop self-esteem. Belif et al (2011) examined non-academic outcomes of single-sex classes and their findings support the proposition that single-sex classes are advantageous for girls’ school wellbeing and self-concept.

Robogals lead to other programming courses

Robogals used hands-on LEGO techniques to build their robots and more intuitive Mindstorm program with visual symbols for building programs on the computer. Mindstorm is a graphical programming environment that uses pictorial building blocks and controls which students can adjust visually to control their robot. The visual programming language enables students to write simple programs and downloading them to the NXT Brick. This means that rather than requiring users write lines of code, they instead can use flowchart “blocks” to design their program.

Students learnt basic functions and parameters using visual building blocks. Some of this understanding can be transferred to writing lines of code for more sophisticated programming. One Robogal commented, “I know the basic ALFS and the functions and that, how to use them now, so I could use this to code with words … it’s kind of a beginner’s step to more advanced programming”. This student has gone on to learning more sophisticated programming languages such as Java and Python and is using these languages to write phone apps. The understandings of programming can be transferred. That is why Robogals is a suitable stepping stone for encouraging female participation and enthusiasm for programming.

Teachers do not treat students differently based on gender

When asked if female students felt like they were treated and or taught differently by teachers because of their gender, the students in Robogals quickly dismissed the idea; “it depends on the teacher, not the gender.”

Perceptions of learning differences between the genders are unsubstantiated

Whilst they were in an all-girls environment, all students from Robogals believed that boys and girls did not learn differently. One student commented that learning styles “had less to do with gender and more to do with individuals”. While some students identified that generally boys are thought to think more logically and girls communicated better, they still concluded that everyone worked differently.

A common message being sold to educators and parents these days is that brain-imaging research tells us that there are profound differences between male and female brains. Supposedly, these brain differences mean that boys and girls learn differently, and should therefore be taught in different ways or even in different classrooms and schools. But a look at the complete scientific evidence reveals that research has identified very few reliable differences between boys’ and girls’ brains, and
none that are relevant to learning or education (Fine 2010). Most gender differences are thought to arise within social, cultural and personal environments that influence what hormones we produce and how our genes work.

*The course did not affect career or subject choices*

Whilst some female students did express interest in STEM career pathways, many were still undecided and it was unclear from the interviews conducted if the Robogals course had any influence on career aspirations. By Year 10, many students have already formed an idea or identity around what their future career pathway will be. Sikora (2013) argues that girls in girls-only schools are more likely to take up physical science and STEM subjects than their female counterparts in coeducational schools, but single-sex schooling does not affect the likelihood of girls planning a physical science or STEM career.

*Students enjoyed rigorous problem and inquiry based learning*

Another outcome from the interview with students demonstrated that they enjoyed and benefited from the rigorous problem based and inquiry based learning style that Robogals was taught. A safe all-girls environment was created whilst maintaining a high challenge and rigorous learning environment (TfEL domain 2.4). Students were set a challenge each week and used inquiry based learning to master the building and programming involved in robotics. Students commented, “It is not like you (Robogals teachers) tell us what to do and we do it. We don’t write stuff down. It’s more interactive and I like that because I feel like I can really put myself out there... everything seemed like a fun activity instead of having to learn something.” Students concluded that the problem and inquiry based teaching and learning style and the subject had helped them develop their problem solving skills. One student said “Sometimes when I was building my robot I had to start over and it was just good learning ... The subject helped me develop my problem solving and other strategies I have used to get passed problems.”

*Recognised by a numbers of media and organisations as best practice*

The Robogals program at ASMS was recognised as best practice and received a lot of attention from the media. The Advertiser published two articles about the ASMS Robogals program. Also TV programs Behind the News and Totally Wild filmed and nationally aired a short segment about the girls and their successes. This recognition was really rewarding for the students.

Finally the ASMS Robogals program was recognized as a case study for best practice in economic Security 4 Women Career Exploration Project Report (Butler, Clarke & Simon 2014).

**Implications for education policy and practice?**

**Refinement or changes for the future:** Briefly record the schools review or planning for the next year etc. in response to your research.

**Recommendations**

- Use all-girls elective classes as a stepping stone for female participation in other programming, ICT, engineering or STEM courses.
- Problem and inquiry based learning should be used to teach programming and robotics.
- In order to positively influence female student career pathways towards particular STEM, earlier application of this type of elective may be more effective.

This study explored psycho-social effects of subject areas to which females were under-represented and looked at single sex classes in coeducational school setting as a way to close the ‘subject’ gender gap. To retain and increase the enrolment and engagement of girls in prime STEM subjects such as Computer Programming and Robotics we need to provide a safe and rigorous learning environment.
An all-girls robotics class is not necessarily the answer to permanently increasing the enrolment of girls in stereotypically ‘male’ subjects such as robotics. However it may act as a stepping stone to introduce girls to otherwise male-dominated STEM fields and demonstrate that they should not be viewed in gendered terms. Some students would benefit from being provided the choice of single-sex classes.

While the results from this case study demonstrate the benefits of single-sex classes in a limited single weekly class setting, there is no certainty that the results would be replicable at a larger scale. Further, a scaled program of single-sex classes the potential benefits could be outweighed by the opportunity costs associated with the displacement of other existing effective learning environments, retraining staff, and redirecting resources. This case study does not consider whether there are other pedagogical and climatic strategies within coeducation settings that may be more effective or more easily implemented, depending on the school environment.

Another outcome from the study demonstrated that students enjoyed and benefited from the rigorous problem based and inquiry based learning style that Robogals taught. The all-girls environment provided a social safety net, however a high level of challenge needs to be maintained to ensure it is a rigorous, challenging and engaging learning environment for the students.

As Robogals did not appear to have a tangible impact on subject or career pathway choices within the study sample, amendments may need to be considered. It may be suggested that educators should be focusing on earlier years to influence career choice. Many students have already made up their mind about the career or direction their career will go by Year 10. We may be able to have more impact on earlier years by exposing them to careers, professional STEM mentors and courses such as robotics.

As educators we should inspect the different ways in which education can be structured and delivered to best meet the needs of students. The challenge is to ensure that new policies and programs meet the needs of all students without privileging some and without reproducing gender stereotypes.

**Sample questions for Robogal interviews**

- Why you chose to do Robogals in Adventure Space?
- Have you ever done coding or robotics before?
- what made you think a girls only group would be for you
- Have you felt more or less comfortable to ask questions in this group? Why?
- A part from the fact there are no males in the group, is there anything different about this class rather than the other classes you’re in?
- Do you think girls learn differently to Boys?
- At this school you have classes where your teachers are both male and female, have you ever experienced any difference in how you have been taught by a male or female teacher?
- As far as you confidence in yourself and your ability to tackle challenges and learn new things, has this experience influenced that at all?
- You have made quite a lot of progress is a few shorts week, what has this done for you personally in terms of how you see yourself?
- Do you think this course has changed your ideas of which university courses you might choose in the future or careers that you might work in?
- Did you think at the beginning did you envisage that you would be this far along by this point?
- Would you recommend the course to other girls?
- Would you have chosen this group if it would have been a male and female group?
- Is there anything else you would like to add?
Reference List


Maguire, S., 2007, ‘The Good Life; It’s a boy/girl thing Parents and teachers have long agreed that boys and girls are simply different. Considerable research into the brain is showing us why, Townsville Bulletin, 5 July, pp. 1 – 28.


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