THE WINSTON CHURCHILL MEMORIAL TRUST OF AUSTRALIA

Report by Marita Cheng, 2011 Churchill Fellow

# THE NANCY FAIRFAX CHURCHILL FELLOWSHIP
To study strategies to get girls interested in science, engineering and technology

Churchill Fellowship undertaken January – March 2012

Germany, United Kingdom, United States of America, Jamaica



Marita Cheng 4 June 2012

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## Introduction

I have been involved with encouraging girls into science, engineering and technology (SET) careers since July 2008 through being the Founder & Executive Director of Robogals Global. I founded Robogals due to the low number of women in my engineering classes at university.

Currently, and consistently over the past 20 years, only 14% of engineering students in Australia have been female, funnelling to just 9.6% in the engineering workforce. In 2011, 6,000 engineering students graduated from universities across Australia, with 1,000 of them women. Engineering degrees overall have an attrition rate of 42%. These figures indicate that the women aren't dropping out of their engineering degrees; girls are just failing to enter in the first place. Australia needs to produce more engineers. We are already experiencing a shortage of engineers and the situation will only worsen over the next decades if nothing is done.

My organisation Robogals aims to get girls interested in engineering and technology tertiary studies and careers. Our primary activity is running robotics workshops for girls using LEGO MINDSTORMS NXT robots, while explaining what engineering is and how engineers make a difference to our lives. Most school students don't know what engineering is, so we introduce it into their vocabulary; engineering is the practical application of science to make things in the world better. From our first chapter in Melbourne, we have now taught robotics workshops to over 4,500 girls and grown to 20 chapters across Australia, UK, USA, Ireland, Netherlands and Japan.

Receiving the Nancy Fairfax Churchill Fellowship has given me the opportunity to accelerate my understanding in this area through meeting experts in the field and looking at techniques employed overseas. The Fellowship was a mind-blowing, inspiring, amazing and full-on experience and I am so thankful of the Winston Churchill Memorial Trust and the Vincent Fairfax Family Foundation for providing me with this opportunity.

I would like to acknowledge Mark Parncutt for accompanying me on most of my trip and "holding up half my sky", my two referees for the application and ongoing amazing mentors, Professor Jamie Evans and Dr Bronwyn Evans, and Glenda Graham. As well, so many people for their generosity during this trip, in particular Wendy Rannenburg from New Hampshire for lining up all the organisations I met there – you are one of those rare and special people in the world that I find so inspiring for your generosity, frankness, and eagerness; Ted Foster, Marvin Hall, Michu Benaim, Lope Gutiérrez-Ruiz, Philip Stehlik, Chimene Rosales, all the people I met with, the Sandboxers and the Robogals. Being surrounded by passionate, inspiring, and generous people every step of my trip is what made the whole Fellowship experience so amazing.

## Executive Summary

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### Highlights

- Meeting with not just the programme organisers, but also the students at the Academy of Science and Design in New Hampshire, and the Halls of Learning in Jamaica. Interviewing the students and doing some of the activities with them gave a more in-depth insight into the programmes.
- Being able to participate in some of the programmes' formal volunteer training, e.g. at STEMNET
- Outside my formal research, taking the opportunity to tour the MIT Media Labs, DEKA Research and Development, and the NASA Jet Propulsion Laboratory. They were amazing and emphasised the importance of site visits for programmes designed to inspire children about engineering!

### Major lessons

- Teach through projects that are based on a story that highlights the 'why' or the usefulness of the activity to the real world to which girls can relate.
- There needs to be a low entry level and then a quick rate of success.
- Self-confidence in a subject should be tackled before interest in a subject.
- Role models are important, as girls need to be able to visualise themselves as an engineer – include women in the marketing posters.
- Robots should be used to highlight other things like different disciplines of engineering, based on themes or to teach maths or science principles.
- Girls don't need competition to thrive. Girls can thrive on collaborative and mission-based tasks that have goals to accomplish and achieve.
- Volunteers should have experience doing the entire course so they are aware of all the challenges that the kids may experience.
- Girls should come out thinking, "It's not rocket-science, and even if it were, no big deal."

### Dissemination and Implementation

- I presented my findings at the Engineering Leadership Conference on 31 May 2012, and I've been invited to present for other organisations as well.
- The ideas I got as a result of my Churchill Fellowship are being used to create a new Robogals workshop curriculum and a robust volunteer training programme, a Robogals Club, and a Robogals Camp. Robogals will also work on creating a program to train teachers.
- As the new Robogals workshop curriculum will be created through collaboration between all Robogals chapters, my Churchill Fellowship will be disseminated to all Robogals members around the world.
- Other ideas I received as a result of my Churchill Fellowship will be introduced in Robogals over the coming years including family activities and awards programmes.

## Programme

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| January 12 – 14 | Sankt Augustin, Germany<br>- Roberta Initiative from the IAIS Fraunhofer, Thorsten Leimbach |
| January 15 – 20 | London, United Kingdom<br>- UKRC, Rukhsana Din<br>- STEMNET, London STEM Ambassadors Manager, Vickie Bazalgette<br>- The Royal Academy of Engineering, National HE STEM, (including the LEP, the London Engineering Project), Head of Diversity, Bola Fatimilehin |
| January 30 – February 1 | Boston, Massachusetts, USA<br>- MIT Media Labs, Lifelong Kindergarten, Ricarose Roque |
| February 1 – 4 | Manchester, New Hampshire, USA<br>- SEE Science Center, Director, Douglas Heuser<br>- International Coordinator, FIRST Robotics Competition, Carla Proulx<br>- Girls Scouts, New Hampshire and Vermont, CEO, Patricia K. Mellor<br>- Girls Inc., Greater Manchester Region Director, Kelly Hurtado<br>- Academy of Science and Design, various students and teachers |
| February 4 – 8 | New York, New York, USA<br>- RoboFun, Bonnie Bromberg<br>- Rochester Institute of Technology, Stephanie Ludi and Emma Nelson |
| February 16 – 21 | Kingston, Jamaica<br>- Halls of Learning, Founder and CEO, Marvin Hall |
| February 21 – 23 | Austin, Texas, USA<br>- Girlstart, Executive Director, Tamara Hudgins |
| February 23 – 28 | Pasadena, California, USA<br>- Pasadena Robotics of the Pasadena Educational Foundation, Director, Erik Dreyer |
| February 28 – March 5 | San Francisco, California, USA<br>- Robotica, Stanford, President, Michelle Grau |

This section describes each place and organisation I visited.

**Sankt Augustin, Germany**

My first stop was Sankt Augustin, Germany where I spent the day at the Roberta Initiative, one of the focus projects at Fraunhofer, one of the largest research societies in Europe. Roberta aims to get more girls interested in engineering or related jobs, and to raise their self-esteem in MINT (maths, informatics, natural sciences and technology) areas and self-belief. They do this by training teachers. The programme was founded entirely on research and fulfils a market-need, as all the projects within their Institute have to find a market need or change their research focus.

Given the similarities between Robogals and Roberta, and their focus on research-based approaches, I got tremendous value from visiting the Initiative. I also got to see commercial robotics projects by teams of researchers, browse through introduction to robotics books produced by Roberta and play with some robots made during the prototyping stage of the Roberta programme.

**London, United Kingdom**

Next up, I went to London where I was fortunate to meet with three of the top organisations that promote engineering to kids. I was particularly inspired by the Women of Outstanding Achievement Awards and the WISE Awards by UKRC, the animated discussion with HE STEM about the negative connotations around the word "engineer" and the need for more positive reinforcement of the engineering image in the media (for example, a TV show that shows engineering to be a fun and exciting career, with female role models), and the impact that STEMNET has throughout the country by providing a platform where people at all different levels of their STEM (science, technology, engineering and mathematics) careers can get involved with promoting STEM to young children in their community throughout the year. I went to an introductory session for STEMNET Ambassadors with other STEMNET inductees from around London. Many of the Robogals chapters in the UK are involved with their local STEMNET chapters.

**Boston, Massachusetts, USA**

Next up, I got a tour of the MIT Media Labs by a female engineer I had met the year before at the Grace Hopper Celebration for Women in Computing. I got to meet all the robots in the Personal Robots Group, including Kismet and Leonardo, see robotic flowers, witness a playground that integrated the digital with real-world physical objects, and a robot whose personality was stored on an Android phone!

I also met up with Ricarose Roque, another female engineer I had also met at the Grace Hopper, from the Lifelong Kindergarten, where the basis for LEGO MINDSTORMS was developed, as well as other engaging and creative learning

platforms. LEGO MINDSTORMS is the platform Robogals currently uses to facilitate our workshops. Ricarose proposed that reaching kids through stories was powerful, as was teaching families, so that not only were the kids affected, but their environment around them.

**Manchester, New Hampshire, USA**

In New Hampshire, someone else who I met at the Grace Hopper Celebration, Wendy Rannenburg, organised for me to meet with five organisations while I was in Manchester. She's a superstar! I first went to the SEE Science Center, an interactive learning centre established to promote the understanding, enjoyment and achievements of science, mathematics and technology. As well as speaking to the Director and key staff about engaging kids in science, I got to see the exhibits, which are interactive, colourful and informative. They also have a giant LEGO sculpture of the city of Manchester!

Following that, we walked across the hallway in the same building to the International Headquarters of FIRST (For Inspiration and Recognition of Science and Technology). Founded by the inventor Dean Kamen, it aims to inspire students in engineering and technology fields. It was founded in 1989 and has an enormous reach, both depth and huge breadth for its beneficiaries. FIRST run a series of international robotics competitions catering for all age groups. Various Robogals chapters around the world have mentored teams and volunteered for FIRST LEGO League, one of the competitions FIRST runs. As well as speaking to FIRST staff, we were given a tour of FIRST Place, on their ground floor, where they hold educational programs and day camps for students and teachers. Upon them hearing that I was a big fan of Dean Kamen, we walked across the road to his office to see if he was at work that day. He wasn't there, but we got a tour of DEKA Research and Development, which was very inspiring!

Then I visited Girls Scouts, Girls Inc. and the Academy of Science and Design. Girls Scouts shared their experiences with robotics and engaging girls with me, Girls Inc. shared their experiences of having teams enter FIRST LEGO League, and I met with a class, eight female students from different year levels and a couple of teachers from a selective charter school, the Academy of Science and Design, that focuses on maths and the sciences and shared with them my Robogals story, asked them about their expected career projections and heard their thoughts about girls in engineering and science.

Manchester, New Hampshire, is a small city, but I think it’s inspiring and impressive that it is the home to “one of the world's most prominent and prolific inventors". Just goes to show that innovation and invention can happen anywhere!

**New York, New York, USA**

I visited RoboFun in New York City to see the fun, hands-on and creative exercises they run to engage kids in robotics. Like all the other United States organisations I've met, they do most of their activities during Summer through

their Summer school. They use different-themed scenarios like basketball, Star Wars and Harry Potter to engage the kids.

Another person I met at the Grace Hopper was Emma Nelson. She also does work in this area and was very excited about the work that Robogals does and wanted to share notes, so I spoke to her and her supervisor about a robotics project at the Rochester Institute of Technology. They design and run robotics workshops for the blind and visually impaired.

**Kingston, Jamaica**

Formerly a middle-school maths teacher, I first met Marvin Hall at TEDGlobal 2009 in Oxford, where he was TEDGlobal Fellow 2009, and was impressed by his passion and dedication to providing educational experiences equal to or exceeding international standards, regardless of background. So Halls of Learning was on the top of my list to visit when I first applied for the Churchill Fellowship. Marvin offered valuable insight into the building skills of young children and what engages and captures their imaginations. I also got to join Marvin for two afternoons of classes he ran and spoke to some of the kids he taught to get their insights.

Jamaica is a very chilled out and relaxing place, but there are still many opportunities for young people there. In particular, the brightest go on to study at the American Ivy leagues given Jamaica's close proximity to the United States of America. Marvin also takes a group of students to America with him every year to participate in FIRST LEGO League.

**Austin, Texas, USA**

Girlstart is very similar to Robogals in that it aims to empower girls in math, science and technology. However, staffed by permanent staff and with its own physical venue, I visited the offices of Girlstart and was blown away by the depth and thoroughness of work they do. Girlstart's Project IT Girl program had 87% of the program participants enter a 4-year university, with 80% of them pursuing STEM majors and careers! As well as advice about making STEM fun and interesting, I was given a lot of organisational and operational advice. I think it is Girlstart's laser-point focus on their goals and aim that enables them to do such an amazing job – the results speak for themselves!

I was also surprised and impressed by the creative and entrepreneurship culture I found in Austin, with the "trailer park" food, "Keep Austin Weird" slogan, the vibrant arts scene and all the landmarks that make up South by Southwest (SXSW) every spring.

**Pasadena, California, USA**

I was first introduced to Erik Dreyer through a student I'd met through starting up Robogals in the UK from the University of Edinburgh, who went to the California Institute of Technology on exchange. So I've already been using Erik

Dreyer's words of wisdom and insights in shaping Robogals' programmes. It was fantastic to finally meet him though and hear even more about his daily engagement work. I also invited Erik to run a robotics session for Robogals committee members in Pasadena, California, and it was great to see him and his workshop in action.

I also took the time out while in Pasadena to visit NASA's Jet Propulsion Laboratory for a tour and a talk about ATHLETE, one of the robot prototypes for transporting loads on Mars!

**San Francisco, California, USA**

I was introduced to Michelle Grau through another student I met at the Grace Hopper. Michelle is a Stanford University student, who runs "Robotica" robotics classes for underprivileged kids in the local area. Michelle showed me around Stanford and we compared notes about teaching kids robotics. I also took time out to visit the Apple headquarters and to take a photo outside Steve Jobs' childhood home.

**Notes**

The people who I mention as having met at the Grace Hopper conference refers to the Grace Hopper Celebration of Women in Computing, which is presented by the Anita Borg Institute for Women and Technology and the Association for Computing Machinery. It is the world's largest gathering of women in computing. There were over 3000 women at the Celebration in November 2011 in Portland, Oregon, which I attended.

## Lessons Learned

This section summarises what I learned from all the organisations I visited, grouped by topic.

### "Why?"

If you introduce a pump to a physics class, most of the boys will listen and most of the girls won't listen. If you introduce it as an oil pump, most the boys will listen and some of the girls will listen. If you introduce it as a heart, most of the boys and girls will listen. Activities that are put into a societal, environmental or ethical context will instantly engage girls more than ones that are not, without disengaging the boys. Most girls ask, "Why? Why do I need technical skills? Why do we need these technologies?" Project need to have a why and be useful to the world.

Engage girls in projects that have a concrete link to real-world topics, biology, medicine, society and the environment – connect them to solving worldwide problems. Female students are more likely to say that they chose STEM (science, technology, engineering, maths) to make a difference. Using links to biology, society and medicine keeps it interesting for the girls and boys whereas war robots and war machines interest the boys and nearly no girls. (Roberta)

If you ask boys and girls what a robot should do, they say that the robot should "clean my room", "do my homework", or "make my bed". Kids say, "If I could program a robot, then I'd have more time to do stuff like homework". (Academy of Science and Design) You need to relate the concepts and scenarios back to things the girls can relate to. So to explain what sensors are, you need to relate it back to them. "Sensors sense stuff, like our own senses – they see, look, and hear." (Roberta)

Girls like to create things that are useful. After 20, 1-hour lessons, girls can create something useful from the lessons, like a conveyor belt to transport medicine across a hospital or library books back to their shelves. Through doing something useful, students get to see maths and science come alive as creative disciplines, and get to see maths and science principles as being able to lead to something more.

We want girls to go home to their mums and say, "Mum, I built a ____ for ____ today." So linking it to something useful, something that helps people can make them see that building with robots makes a difference to people's lives. (Halls of Learning) The philosophy is that people learn best or are really motivated when they're working on something they care about.

So there needs to be an answer to the question why and girls need to be picked them up at their level, so they form an emotional connection with science and engineering, and not just a practical connection.

## Self esteem

Self-confidence is of central importance. From educational research we know that confidence in a subject contributes more to success than interest in it. Girls, however, tend to have less confidence in their technical abilities than boys. This lack of confidence must be the focus of the teaching, because we need to get girls' self-esteem up. Girls should be able to participate if boys throw technical words around – we want to get girls talking about these things. (Roberta)

It's important to have low barriers to entry. And then milestones that are easy and quick to attain so that girls feel like they're making progress and quickly gain confidence.

Girls need to be confident in their building skills, then confident in their maths and their programming… They need to be confident to be able to make mistakes. Generally girls are more playful and creative, so it's not a lack of creativity or imagination, it's a lack of confidence, especially if they're in a minority. Not being intimidated by being the only girl is really important. Girls who come in and do well aren't intimidated by partnering with a boy.

Girls should come out thinking, "It's not rocket-science, and even if it were, no big deal." (Girlstart)

## Role models

Role models are so essential and incredibly important. Being exposed to role models makes girls decide to take up engineering, because it makes them realise it's something they can do and that engineering is friendly to women.

The students need role models – experts to the classroom. Bringing women engineers to the classroom is especially good, and female engineering students are also okay. In order to introduce the girls to engineering, Roberta introduces schools to companies in their regions and the teacher then gets the expert engineer from the company to speak to the class.

There are different role models that are good for every age group, as it's better to make sure role model isn't too far away in away from the girls. For example, the Chancellor of Germany, Angela Merkel, (who is a woman) studied physics, but that's not interesting to kids. It's proven people like role models closer to their age. The primary school kids need high school kids, and the high school kids need university students. Role models need to be young, credible and enthusiastic. Parents are also good role models.

When the Roberta teams in Berlin RoboCup do very well and girls see that team, they want to be part of the Roberta robot team, too. Telling stories about robotics competitions in Istanbul and Shanghai is also great, because it makes it exotic for the kids.

The UKRC's Women of Outstanding Achievement (WoOA) and WISE (Women In Science and Engineering) Awards take the classroom to boardroom approach in acknowledging women to provide inspiration. The WoOA is for very

distinguished women who have had remarkable careers, and the WISE Awards are for individuals and organisations that have done work in promoting diversity at different levels. The WoOA recipients have 3 foot tall by 1.5 – 2 feet wide photographs created of them that get toured around the nation during the year they win. The photographs travel to science museums, universities, offices and the Royal Engineering building. The photos are only housed for a couple of weeks at a time and changed regularly so that people notice them, before being displayed permanently in a location at the end of the year. The WoOA recipients serve as role models to other women and girls.

The girls from the Academy of Science and Design said that to encourage even more girls to get interested in science and maths, we "need to show them that it's not just a boy thing. They don't have the self-confidence to stand up for themselves. We need girls to realise they can be smart and strong."

Many school-aged students lack an understanding of what an engineer actually does, and any idea they do have is very limited and stereotypical. Therefore, if asked whether they could see themselves as an engineer, they could perceive the question as whether they could see themselves as a large, white man covered in oil; with the response being an emphatic 'no'.

The general population doesn't understand what engineering is, so it's hard to encourage young people (both genders) to do engineering. Young kids like engineering activities and programmes but kids don't want to be engineers. Engineering has a public image problem. There needs to be radio and television programs about engineering targeting kids and parents. The engineering industry could fund it and work together with two or three production companies – put together people doing really interesting projects and talk about some of their projects, how much they earn, etc. With the right production, of choosing women engineers and ethnic minority engineers, and highlighting an engineer's position to change the world, the image can be changed. The image needs to be very energised and it shouldn't be too worthy or too smart or it will turn people off. The media leaves a very lasting impression. Women engineers and scientists should be groomed in media training, should be groomed to write blogs and should be put in front of media.

One-way to attract kids into engineering is to tell them about an amazing course at university where you do heaps of experiments when you get in, and you have a great job waiting at the end… and it's called "Pomegranate". The problem is, as soon as you hear the work engineering, it's a big turn-off. The problem is that the word "engineer" is a verb, not a noun. You don't "medicine" or "law" something. Alternative is to protect the name "engineer". For example, you can only be called an "engineer" if you graduate from a 4-year degree; otherwise, you're called a technician. Having letters after the name is very prestigious because you can't fake it. (Royal Academy of Engineering)

Historically, law and medicine have been a gentleman's profession, while engineering has been for the proletariat. There's a perception that engineering is dirty and no one's telling them anything different. The perception of wages is also very different to the reality of wages, such that engineering is not even on

the table for a lot of students. There's so much potential to retell the story in a good way.

**Activities**

There needs to be a low entry level and then a quick rate of success. Lessons need to be delivered based on ability, not age. And there needs to be varying degrees of difficulty in the lessons.

Engineering is promoted through problem solving. For example, give them the story of bees and tell them how bees communicate with each other – bees tell the other bees if they're far away or nearby. The teachers tell them how it could work then leave them alone with their own ideas to work out on their own. After half an hour, the students have to show off their robots. The students are told to Do → Program → Test. And if the robot doesn't achieve the task, to loop through Program → Test until it does work.

There needs to be a strong link between the robot and the subject. Robots shouldn't be used just because they're cool. They should be used because they're useful. For example, SEGWAY robots can be used for teaching integration and differentiation, because integration and differentiation is needed to keep a robot standing. Aeroplanes can also be used to explain those concepts.

Do robotics based on themes, and not for the sake of doing robotics. Robotics can be done without MINDSTORMS kits using a wide range of products like household items or waffle balls. Everything can be used as STEM supply materials. MINDSTORMS Kit doesn't stretch the mindset or learning process, like girls extending learning when they go open-source, scrappy and free, so that girls can go home and continue learning.

Bring along weird science things and ask, "does anyone know what this it?" Challenge the ones who are really keen and encourage the ones who aren't as keen. Keep things informal, fun and accessible.

Show photos of bad engineering to engage kids and show why engineering is so important. Compare it to good engineering to highlight how good engineering makes our lives easier. Ask them "what would you change?" and "How would you make this better?" Show real headlines and show fake headlines and make kids guess which is which. This engages and excites them.

Tell girls that they *are* scientists or engineers after they have completed the activities, to let them know it's okay for them to be one. Makes them feel pride for the work they did that day.

To engage girls in engineering, need hands on stuff like robotics workshops where there is a bit of theory then application, which is related to the world of work. Tell them, "You need to know this because this is actually used in aircraft education, etc."

Get kids to take things apart and put them back together. For example, get kids to bring in old pieces of junk from home to pull apart and explore. Young girls 12

- 14 can take a computer apart, take out a motherboard, answer all your questions and put it all together again in about half an hour. Another activity is to get kids to pull something apart, and then give them 1 minute to put it all back together. It gives them a good skill set and has them competing against time rather than the person next to them.

Attractive across both genders is stories. Narrative can be a very motivating context, especially for young girls. Frame the class as "animation" or "storytelling on the computer" rather than game design (most of the girls will say they do not play games, even though they do play casual games). Telling them they will make a game or movie that will be posted on the Internet is highly motivating for girls.

Aesthetics are also very powerful. According to research by the MIT Media Labs, girls want to make pretty things, so cloak the engineering in something pretty and colourful, like a fashion show. They are less interested in the mechanical side of things - girls prefer to make something colourful rather than building something with as many wheels as possible. Girls are better at more creative things and have had more experience there, for example, making up stories and different scenarios for their soft toys. LEGO works though because it's so colourful.

At the Halls of Learning, for the first half of the first lesson, the students are sat down and have the different LEGO pieces explained to them, told how to find them, and told about the structure of their lessons. In the first lesson, everyone has to build his or her own motors. It all has to be done in a playful sense, with no immediate or pressing goal, and has to be colourful.

At Girlstart, the mission and goals are defined from the beginning so that projects are collaborative, mission-based and have goals to accomplish and achieve. If you get everyone involved in a common challenge, then team A encourages team B, and they both encourage team C. The teams solve it for themselves, and then help the next team. If you set targets, everyone walks away learning through fun and rigour, and there's no need for cutthroat competition.

For example, use the oil spill from the summer of 2010 as an example. The robot is the pelican, and the challenge is to return the pelican to its family of robots. The girls will name the pelican and come up with a story behind it. Because their interest was in saving the pelican and not in winning, once they've solved the challenge, they'll encourage the other teams. In competitions, you're either winning or you're not. This isn't like that. Different problems that require science to solve are set, and even though it's not the main draw point of the exercise, girls will walk away knowing how to program a robot, liking robotics and wanting to do more.

Teach kids to be multidisciplinary, through teaching them about the different kinds of engineering, while showing them the connection with the real world. For example, do an activity where a NXT needs to find a light source, just like a satellite, and then follow it with a field trip to a place such as the aerospace corporation where they build satellites. Tell kids they built their own satellites a

week ago and kids will be inspired. Other good field trips include lab tours, site visits and going to robotics competitions.

### Separating the genders & dealing with gender differences

Many of the organisations I visited recommended teaching girls and boys robotics separately, at least initially. When girls see that they are able to do it just as much as the boys, then you can teach them together. It's also the best solution for the boys, because then the boys feel less pressure to succeed.

Girls will generally take longer because they do things properly, whereas the boys think things are "good enough". If you told the students to get their robots to form a square, the boys would be happy to get the gist of the task and move on to the next activity even with an imperfect square. Girls on the other hand, are more likely to keep labouring on with the task until their robot draws a perfect square. So the boys race ahead in a class, and the girls think they're not as good as the boys and loose self-esteem in their technical abilities. Boys are less worried and self-conscious about getting stuff wrong.

Organisations that focus on getting girls interested in STEM, favour teaching girls alone. The Roberta Initiative focuses primarily on attracting girls to their lessons given the low participation rates of females in engineering. Girlstart only focuses on girls, because that's their area of focus and they just don't offer it to boys; and the Halls of Learning have girls-only classes, due to the low number of female participation rates in the co-ed classes. All three of these organisations think it's of high importance that girls and boys are separated for these activities to address their particular learning needs.

Organisations that do not differentiate between genders tend to have a huge skewing of male participation (> 80% boys). The Halls of Learning began their all-girls classes in response to this. RoboFun also began all-girls classes in response to this. FIRST has worked on a variety of initiatives to address this, and even the Academy of Science and Design is dominated by boys! So a concerted effort for encouraging girls in particular into STEM is vital.

Erik Dreyer from Pasadena Robotics said he was considering girls-only classes after observing the disenfranchisement of girls in his programme, but found he was able to conduct good co-ed classes by having the schoolteacher, who knows the kids well, to choose good pairings. In fact, Erik said sometimes you can have a strong alpha girl with a timid boy and you get the same problem in reverse. The teachers in this case didn't think all-girls classes were necessary, but that they just needed to get the pairings right.

The London Engineering Project noted that sometimes people raise concerns about focusing on girls, particularly as to whether this approach puts boys off. They found that in practice it does not – rather what has become apparent is that while good practice provides improvements for all students, poor practice disproportionately affects those students who are already the most disenfranchised (girls and ethnic minorities).

It is very important that the girls have the same learning environment, support and encouragement as the boys. To that end, it was always ensured at London Engineering Project events and activities that girls were not fewer in numbers. The most straightforward way to ensure this is to ask the teachers to send equal numbers of boys and girls.

In a co-ed environment, activities need to be appealing to both genders. If a chosen activity is more likely to be more attractive to the boys than the girls, it can be adapted. For example: a bridge building exercise may be more appealing to the boys than the girls; unless the bridge in question is Waterloo Bridge. The original Waterloo Bridge was demolished in the 1920s, and a new span, which was reportedly built largely by women, was built between 1942 and 1945.

Use the terms 'boys and girls' and 'girls and boys' with equal frequency in documents. When addressing a mixed group, avoid using the term 'guys'. Whenever possible, challenge the idea that engineers are male by referring to them as 'she'. Use of women volunteers is important, so they can keep saying "It's for you. I did it. You can too."

Sometimes girls feel like he can do it "because he's a boy", but feel discouraged because the boys have more experience. Fine motor skills in girls are often not as developed; guys do building from 4 or 5, girls from 7 or 8. Intro at different ages means boys are way better than girls, by age 6 or 7. Get girls early, but even more importantly, get them into gender-only environments, just like with ballet. (Halls of Learning)

Starting point better when they're on their own. When they're more experienced coming to NXT then they can do it with the boys. Boys have had more experience building LEGO, doing more and building more intricate things. Girls are better at more inventive things and have had more experience there. Need to get girls interested in fine-motor skills from a young age, so that they do FIRST LEGO League at 12 or 13. (Halls of Learning)

Make sure girls have time to go through curriculum. Girls need more time because they are more measured and more calculated, so they go through the curriculum slower. Ask girls what they think the answer is, so they have the chance to participate, as boys race ahead and play with the robots without doing the curriculum – they just dive in. Once girls feel comfortable, they feel like they can do it too. Girls can do quite well in the classes because they measure more and do more pre-planning.

### Teach in teams of 2 or 3

Initially you want the kids to work in pairs or groups of three. If there are three or four students in a team, the third and fourth members get bored. So the perfect size is two. If one student is in front of the computer and the other is sitting next to her and not doing anything, then the teacher should switch the students around so that the other one has to tell the student at the computer what to do. Having three in a team can work if they are each rotated through the

tasks. The kids need to be kept occupied because if they are bored by the lessons, they come out and say, “I’m not interested in technology”.

Students may join a class simply because their friend was doing it.

At the Halls of Learning, the students are told to choose their partners, and then told to do a partner’s creed and pledge to not harm their partners and to respect the LEGO. Halls of Learning used to give everyone their own robot. However, when it got to forming teams to compete in the FIRST LEGO League competition, the students couldn't compromise and decide on a way to go. So it’s important for students to share computers and robots initially, so that they can learn how to work with others and learn how to work at a group pace. Different team-role positions should be suggested to the girls so that each individual gets the chance to be active in different roles.

### Competitions and awards

“Competitions are really good because it makes you think of things outside of what you would normally think about. It also helps you gain skills like doing FPS or Future Problem Solving like collaborating on ideas. It let’s young people build on other people’s ideas. And it involves creative stuff like projects.” (Academy of Science and Design)

It’s a good experience for girls to get involved in competitions and to have teams in for example, the RoboCup Junior DanceBot competition. If they’re participating in such a competition, they learn all the soft skills they need to do well at a company. (Roberta)

On the contrary however, Girlstart is one of the few organisations who prefer not to use a competition model, because they want everyone to walk away feeling good, and thinking, "I'm good", and "I learnt something”; not about being one person that wins. They believe the competition model is not effective in reaching girls and sustaining interest in STEM, that competitions are not pedagogically rich and that there are other ways to engage girls; so they do their own programmes and don’t do FIRST. They believe the purpose is not to win or lose. The purpose is to go in, do it, and learn. It’s about the process, not the end-project. There are many, many ways to set up programs meaningful for girls, and they don't need to be competition based. Girlstart did comment though that girls’ teams in competitions do well because they stick together, work together and are collaborative.

The person I spoke to at Girl Scouts also felt that many robotics competitions were too competitive and this was off-putting to girls. The person I spoke to from Girls Inc. on the other hand, thought that putting girls into a competitive environment was good as it allowed them early exposure into the cutthroat real world.

Pasadena Robotics has its own competition for scheduling reasons and so that kids can achieve learning objectives (such as learning *variables*) through the competition, while being challenged at the right level year after year. In the

Pasadena Robotics challenge, boards are released on the day of the challenge. Kids arrive at 8am and have 3 hours to build and program the robot. The competition is navigation-based, just like what they learn in class.

The person I spoke to at FIRST believes awards are a good incentive, and that girls want to be recognised for her achievements on an equal footing with boys, not simply recognised because she's a girl. FIRST has a list longer than an arm worth of awards to get kids interested. All are very prestigious, with two or three being the cream of the crop, that are even looked at by colleges for scholarship opportunities!

Roberta doesn't have any competitions, but there are Roberta trophies in RoboCup Junior. The rules for it are that the team needs to have over 50% girls, and it needs to be supervised by a trained Roberta teacher.

Awards also raise the profile for females, getting them publicity and being very encouraging.

**Community influence**

Kids need a supportive peer group, parents and teachers.

Kids are inspired when someone in their own age group does something. A classmate of some girls I interviewed made a robot to put socks in the drawers. It gives them a different conversation about what's possible!

Teachers need to be confident too. Nowadays, students learn faster than teachers, so teachers have to be self-confident and okay with not knowing everything. Teachers should say, "let's find out", rather than, "no, we don't need to know that" because they don't know.

Counsellors and teachers should not prejudge what students are good at and tell them what to and what not to take.

The people I spoke to at MIT Media Labs was more interested in the family unit and family outreach and was conceptualizing family dinners, for example, once a week for two hours.

Roberta is also in the Science Museum – Deutsche Museum in Bonn with a kid-parent and kid-grandparent program. They build and program robots as a team in order to promote SET within the family unit.

**Ages to target**

All institutions agreed that the earlier the girls started, the better. For example, kids can even form their likes and dislikes at the 6 – 8 years old band, so it's important to not discard the younger age ranges.

The earlier the girls start, the shorter the time it takes for them to pick it up. If they start at 8, 9 or 10 years old, then across one week – one hour per day over 5

days, they can quickly pick up the basics. Sometimes one successful experience is all they need to get engaged.

In the "Girls Conquer Robots" programme initially, introducing Roberta to schools, teaching 10-year-old girls seemed early enough. The robots were such a new concept to them and a huge "wow" factor. Now however, most kids have already seen the robots and Roberta thinks they need to start earlier. Regardless, girls need to be targeted before they turn 15; otherwise it's too late, because they've already chosen their senior high school subjects. Ten to 14 is a good age, but the younger the better.

Pasadena Robotics thinks that middle school students (i.e., around the ages 10-14) is the best age to target as kids that age are young enough to have curiosity, but old enough to start understanding complex concepts. So the perfect time for them to get interested in engineering is the 6th grade. In the 6th grade, they have a flame, and teachers should do their best to grow the flame and passion inside of them.

### Volunteer (workshop demonstrator) training

Bring the volunteer through the entire experience – have them get their hands dirty by building the models and doing the programming. Send them through the entire course so they are aware of all the challenges that the kids may experience. Have volunteers who follow instructions.

Train volunteers to be good at recognising what's needed with each student. Tell volunteers to not give answers at all, but to guide the students in the right direction by getting them to try different things through trial and error. The students should be allowed to figure out their own ideas, with teachers being more like moderators - not giving them answers, but helping students discover answers.

It's ideal that the volunteers have some education background, or at least understand exploratory theory. At that young age, the most important thing is for the students to have fun. If the volunteers have fun, the students will have fun.

When you interview the volunteers, give them an unprepared challenge. Say, "Here are 3 blocks. Give me a story now." It shows freedom, spontaneity and creativity. If volunteers are spontaneous and creative, it frees up kids to be spontaneous and creative as well.

Volunteers need to show kids their competency – that they can do what the kids are doing. At the same time though, volunteers shouldn't be afraid about making a mistake at their level. Saying "I made a mistake too", lets students feel ok about making mistakes, and that they can compete with you.

### What you need to tell them

Posters for engineering outreach activities need to prominently feature women in the images.

As inspiration, talk about the career and how it relates to what they're currently studying. Another appeal is to tell girls that this is a “good, special thing to do”. Telling girls "studying science keeps their options open" is also attractive to kids more than other stuff.

When girls find a way to make meaning out of engineering, they will be interested in engineering. They need to imagine what the day-to-day of what being an engineer is like. Getting up, having breakfast, driving to work, what they’ll be doing in the office, etc.

Most school students don't know all the different engineering disciplines, and should be exposed to all the engineering jobs from a young age. They need to be given a clear understanding of what engineering is. Tell them it’s creative, logical and helps people, such as medical robots. Give them the right picture, by using real world examples. Also that you can work on interesting and world-changing projects, that there is so much flexibility with your career – there’s no set career path, that there are worldwide travel opportunities, and that it pays well. The thing that will excite them most is the interesting and world-changing projects.

## Conclusions and Recommendations

### Major conclusions

- Teach through projects that are based on a story that highlights the 'why' or the usefulness of the activity to the real world to which girls can relate.
- There needs to be a low entry level and then a quick rate of success.
- Self-confidence in a subject should be tackled before interest in a subject.
- Role models are important, as girls need to be able to visualise themselves as an engineer – include women in the marketing posters.
- Robots should be used to highlight other things like different disciplines of engineering, based on themes or to teach maths or science principles.
- Girls don't need competition to thrive. Girls can thrive on collaborative and mission-based tasks that have goals to accomplish and achieve.
- Volunteers should have experience doing the entire course so they are aware of all the challenges that the kids may experience.
- Girls should come out thinking, "It's not rocket-science, and even if it were, no big deal."

### Dissemination

- I presented my findings at the Engineering Leadership Conference in Adelaide on 31 May 2012.
- I've been invited to present my findings for other organisations as well.
- Robogals members around the world will receive a copy of my findings.

### Implementation

- The ideas I got as a result of my Churchill Fellowship are being used to create a new Robogals workshop curriculum and a robust volunteer training programme, a Robogals Club (for girls with the aptitude for SET to further their skills and pursue their interest), and a Robogals Camp.
- Robogals will also work on creating a program to train teachers.
- Relevant findings from my Churchill Fellowship will be integrated into the Robogals SINEs (Seminars Inducting New Executive committee members, the Robogals conference), held annually in each Robogals region, and Robogals' training manuals.
- Other ideas I received as a result of my Churchill Fellowship will be introduced in Robogals over the coming years including family activities and awards programmes.

### Other improvements

- More incentives are needed for students to study the harder maths and physics in senior high school.
- Effort should be made to get engineering into the media to raise its profile so that Australians recognise the importance of engineering and invest in it as a way of ensuring future economic success, as well as seeing it as an appealing career path.