Engaging the future of STEM

A study of international best practice for promoting the participation of young people, particularly girls, in science, technology, engineering and maths (STEM)

Authors: Ms Sarah Chapman & Dr Rebecca Vivian

This research was conducted as part of the 2016 Barbara Cail STEM Fellowship and funded by the Australian Government (Office for Women, Department of the Prime Minister and Cabinet), in partnership with the Chief Executive Women (CEW) Ltd.

FOREWORD

The next wave of industrial revolution is well underway. Australian businesses of the future will require people with STEM (science, technology engineering and mathematics) skills, and those without this knowledge will likely struggle.

Australian high school students are falling behind their global peers in their engagement with the STEM subjects, and the participation of girls in the STEM subjects is of particular concern. STEM literacy is weak compared to their OECD peers.

As leaders, we have a moral obligation to enable all our young people to participate to the fullest in the modern economy. Part of that is ensuring they have both the inspiration and the opportunity to engage with the STEM subjects.

In October 2015, the Minister for Women, Senator the Hon Michaelia Cash and Chief Executive Women announced joint funding for two Fellowships to examine ways to increase high school student participation in STEM, particularly among young girls.

Following a national application and assessment process, the Fellowships were awarded to Sarah Chapman, who is the Head of the Science Department at Townsville State High School in Queensland, and Dr Rebecca Vivian, Research Fellow at the Computer Science Education Research Group at the University of Adelaide.

Known as Barbara Cail STEM Fellows, Ms Chapman and Dr Vivian spent six weeks undertaking separate visits overseas, researching effective and innovative ways for promoting participation of young people, and particularly girls, in STEM fields during their education and subsequent careers.

Their research took them to schools, global businesses, universities, government departments and STEM advocacy communities all over the world. They spoke with leading thinkers and educators to find out what other OECD countries were doing that was having a positive impact on participation in STEM education.

This report outlines their findings and provides a framework for assessing the gaps in the Australian STEM ecosystem. It aims to add to the growing body of knowledge about what needs to be done to better inform young people about the importance of STEM literacy for setting them up for the jobs of the future.

CEW's mission is women leaders enabling women leaders. Our focus in this area is to ensure girls have the opportunities and support to acquire the skills and experience they need to succeed in their education and careers.

CEW hopes that the release of this report will generate discussion between the many interested stakeholders and generate a renewed commitment to address Australia's engagement in the future of STEM.

Belinda Gibson
Chair, Scholarships Committee
Chief Executive Women

About CEW, Barbara Cail and the Office for Women

Chief Executive Women (CEW) was established in 1985 by eighteen influential Australian women and now represents over 430 Australian women leaders from the corporate, public service, academic and not-for-profit sectors. Through its advocacy, targeted programs and scholarships CEW works to remove the barriers to women's progression and ensure equal opportunity for prosperity.

Barbara Cail AO was the Founding President of CEW in 1985 and has been a constant advocate for women and for STEM participation. Recipients of CEW's STEM Fellowships are known as 'Barbara Cail Fellows', in honour of CEW's Founding President.

The Office for Women is part of the Department of the Prime Minister and Cabinet, and is the central source of advice for Commonwealth agencies on the impact of Government policies and programs for Australian women. This includes policies and programs impacting women's economic empowerment and opportunity, safety and leadership. The Office for Women provides funding for STEM scholarships and fellowships through the Women's Leadership and Development Strategy (WLDS). Projects funded by WLDS aim to improve gender equality in Australia, including through promoting and supporting greater representation of Australian women in leadership and development roles.

CEW's partnership with the Office for Women will help to improve equal economic participation and secure opportunities for Australian women, to improve representation of Australian women in leadership and decision-making roles in key growth industries that will be important for Australia's future.

EXECUTIVE SUMMARY

Need for the research

STEM is more than just a collection of subjects; it's a critical part of the Australian economy. It has been estimated that advanced physics and mathematical sciences alone account for over 22% of Australian economic activity and more than a quarter of our exports. Already three-quarters of the fastest-growing occupations require STEM capabilities and the need for STEM-qualified workers is only expected to increase in the future (PwC, 2015).

The STEM-related opportunities in the future are endless. In Australia it is projected that a 1% increase in people choosing a STEM-related career would result in significant gains for our country's economy, exceeding over 50 billion dollars in revenue (PwC, 2015). The technological revolution will reshape our workforce, moving from traditional approaches to more innovative and effective ways of work. It will allow for more entrepreneurial approaches in the way we use, engage and apply STEM. These advances will have supreme benefits for Australian society, allowing us to be better connected with other countries, going beyond physical boundaries, enabling us to collaborate more effectively and efficiently (CEDA, 2015).

There are numerous prominent Australian STEM organisations and programs across the country, currently working to raise the profile of STEM. The organisations involved in Australia range from government, STEM industry (including organisations and businesses that rely on STEM skills and expertise to produce products or provide services), research organisations (that rely STEM expertise to innovate), learned academies, educators (from early years to tertiary education), and STEM professional organisations, groups and associations (for profit and not-for-profit that promote engagement and communicate the importance of STEM). As an example of the breadth of STEM activity, the Australian Chief Scientist's 2016 STEM Programme Index outlines over 250 active STEM programs across the country, provided by businesses, universities, science and education agencies, and government.

However, Australia is not producing enough people with STEM skills to meet the growing demand. Part of the problem lies with the STEM pipeline: the number of young Australians choosing STEM subjects in high school is in decline. Australia is also slipping down the international league tables when it comes to literacy in maths and science (OECD, 2016).

On top of this, there's a significant gender disparity in STEM in Australia, with females significantly underrepresented in STEM education and careers. Unless Australia can address both the mismatch between increasing demand and falling supply, and the gender imbalance, businesses and institutions will face a significant shortfall of appropriately skilled and diverse workers, which in turn will have consequences for our future prosperity and growth.

This research project was funded to investigate: what can we learn from international best-practices in engaging young people, particularly girls, in STEM education?

Key findings

The research investigated and observed activities in other countries being driven by particular stakeholder areas, which play a key role in the STEM ecosystem:

Government

All areas of government related to STEM and education, including policy makers, Chief Scientists, Ministers and Departments of Education are crucial enablers and communicators in STEM Education. Observed activities overseas identified that effective programs often receive funding support from government; receive acknowledgement from government to enable expansion; and involve close collaboration between government and other stakeholders, including teachers.

Peak organisations

In the STEM ecosystem, peak organisations can play an important role in bringing key stakeholders together and in administering strategic national action. They act as an umbrella for a national network and are dedicated to coordinating and connecting multiple organisations, groups and other stakeholders together to promote STEM engagement and support education through activities such as stakeholder mapping, conferences and events, knowledge sharing, developing communication materials, and conducting or funding research.

STEM industry

STEM organisations and businesses (industry) can support STEM engagement through a range of activities, such as providing expertise, funding, programs and experiences. Industry can play a key role in driving research, innovation and employment for STEM graduates. Their activities are diverse and include: programs to develop teacher capacity, mentoring programs, working with film and TV to challenge stereotypes, raising community awareness and providing unconscious bias training to their staff.

Tertiary education providers

Tertiary environments face the significant challenge of attracting students, particularly women and other underrepresented groups, to STEM programs. They play a key role in attracting and retaining engagement of young people in STEM careers. They are responsible for the development of young STEM professionals, and work closely with industry to meet industry demands for the professional STEM workforce. It was observed that many university STEM departments are involved in the professional development of pre-service and in-service teachers, harnessing their expertise to extend existing teacher training programs. While tertiary education providers were extensively involved in efforts to engage young people in their STEM disciplines, they often rely heavily on volunteer time of faculty and students, and a number of programs identified resourcing (financial and people) as a key challenge.

STEM outreach groups & organisations

STEM outreach groups and organisations (both for-profit and not-for-profit) provide outreach, engagement programs and advocacy. These groups and organisations can support STEM engagement by providing opportunities, expertise, programs and experiences. They can play a key role in promoting STEM engagement, connecting with key influencers, advocating for and informing STEM professionals and connecting young people to pathways for employment in STEM. These groups also identified funding as a challenge, and a number of organisations rely heavily on volunteer time.

Early childhood, primary and secondary education

Education plays a key role in STEM engagement and in many cases can be the first exposure to STEM for many young children. Early childhood, primary and secondary education provide many avenues to promote STEM engagement, such as providing learning experiences through curriculum-related activities, relevance by linking in real world experiences, expertise by linking in industry and research, and extension programs and experiences, such as mentorships.

Benchmarks for STEM programs for young people

Through observations of a diverse range of organisations undertaking STEM engagement programs, the following essential elements were repeatedly identified as key components in high performing programs aimed at young people:

- Tailored and accessible
- Open
- Evidence-based
- Evaluated
- Research-based
- Diverse
- Scalable
- Provides support
- Engages partners
- Relevant

Practical insights for implementing STEM programs: targeting girls

There are a diverse range of barriers and drivers that inhibit or enhance the engagement and retainment of girls on STEM-related pathways. The drivers often vary depending on the barriers that arise. This research uncovered a number of strategies for promoting the engagement of girls in STEM education and STEM pathways. Four key areas were identified:

Messaging:

Effective messaging can attract girls to consider STEM and help girls to envision themselves as STEM professionals, as well as help to support their key influencers. This includes the consideration of effective messaging strategies from marketing through to role model interactions.

Girls-only opportunities:

Offering girls-only experiences and learning spaces provides the opportunity for girls to be empowered and feel comfortable to question, experiment and lead in STEM. By structuring these safe environments, girls are more willing to try and experiment with STEM.

Family involvement:

The involvement of family, especially parents, in STEM learning experiences is invaluable in providing support for girls engaging in STEM experiences. Parents are role models and key influencers of a girl's career pathway considerations. Involving family in STEM not only enriches a girl's experiences, it also connects STEM into the home.

Authentic connections:

Connecting with real world experiences that make an impact and diverse female experts for support and inspiration, can provide girls with authentic STEM connections and opportunities that promote sustained engagement.

A vision for STEM education in Australia

From the observations of best practice in STEM internationally, a collection of perspectives for promoting engagement in STEM was derived. From this, a vision for a thriving STEM nation has been compiled, that includes the following key components.

The key components of a successful STEM strategy are:

- Coordinated collaboration between stakeholders across the STEM ecosystem. Stakeholders commit to actionable strategies that change the culture of STEM to be equitable for all, where there is a balanced representation of all groups of people within the STEM ecosystem.
- A shared vision, priorities and common language around STEM to develop a collaborative, positive and inclusive STEM culture within and outside of education and industry contexts.
- Sustainable inclusive education and engagement for all STEM fields, from early childhood through to professional leadership.
- Curriculum implementation (both in school classrooms and outreach) that empowers students through choice, skill development and allows students to realise real world applications of STEM.
- Sustained professional development, capacity and engagement of teachers.

KEY ACTION POINTS

Following this research project, the following key actions have been determined as pivotal points to drive positive change in the Australian national STEM ecosystem. The following action points have been developed, based on observed best practice from overseas models, to support the participation of young people, particularly girls, in STEM fields during their education and career.

1. **A coordinated national strategy for building teacher capacity in STEM Education and within specific STEM disciplines.**
2. **Develop an industry-funded national project to build capacity of practising STEM teacher professionals.**
3. **Map Australia's STEM ecosystem: identifying key stakeholders, programs and exemplars in best practice.**
4. **Develop a STEM framework, to provide guidance for STEM stakeholders, incorporating the benchmarks for quality STEM programs.**
5. **Maximise opportunities for engagement, inspiration and building aspirations of girls by establishing a Celebration of STEM Women.**
6. **Conduct industry-led research into targeted STEM Education topics in need of urgent attention.**
7. **Develop, in collaboration with industry, a national student STEM mentorship program.**
8. **Develop a suite of STEM engagement resources, drawing on existing resources available, tailored to the Australian STEM context and different STEM disciplines.**

To address our current and future global challenges we need young people who are adaptable, creative, able to think critically, that can use their initiative and collaborate with others to develop solutions and build a productive future for themselves and future generations. Through collective and sustained impact, within a STEM ecosystem, we can drive change and ensure a diverse and thriving STEM workforce of the future.

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WHY THIS RESEARCH IS IMPORTANT

Australia urgently needs more STEM professionals

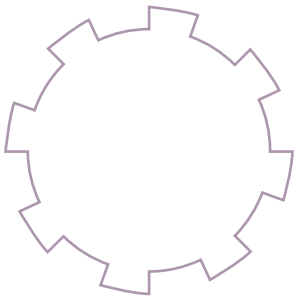
The global economy, tightly linked with technologies and innovation, is reliant on a workforce with expertise in science, technology, engineering and maths (STEM) for its continued growth. Australia is no different: it's been estimated that advanced physics and mathematical sciences alone account for over 22% of Australian economic activity and more than a quarter of our exports (AAS, 2015). And the demand for STEM is only growing. Over the next 10 to 20 years, it's expected that over 40% of the workforce will be replaced by technological advances and automation; already, three-quarters of the fastest-growing occupations require STEM capabilities (PwC, 2015).

There are numerous prominent Australian STEM organisations and programs across the country, currently working to raise the profile of STEM. Organisations in Australia range from governments, STEM industry (that relies on STEM skills and expertise to produce products or provide services), research organisations (that rely STEM expertise to innovate), learned academies, educators (schools and tertiary that engage with young people), and STEM professional organisations, groups & associations (for profit and not-for-profit that promote engagement and communicate the importance of STEM). These essential organisations are listed in the Australian Chief Scientist's STEM Programme Index.

Even with the action of these prominent STEM organisations, Australia needs to advance further to prepare our young people to meet this labour market demand for new skills. The number of young Australians engaging with the STEM disciplines in secondary school has been in decline, and compared to our global peers, the number of tertiary students graduating from STEM disciplines in Australia is low. For example, the Australian Computer Society (ACS, 2015) has estimated that an additional 100,000 more technology-related professionals will be required over the next five years, well over the number of domestic Information Communication Technology (ICT) professionals graduating from Australian universities.

In a recent survey of business and industry, more than half (53%) expected their needs for STEM professionals to increase over the next five to ten years; however, almost one-third (31%) reported difficulty recruiting STEM graduates (OCS, 2015).

Unless we can address this mismatch between increasing demand and falling supply, Australian businesses and institutions are facing a significant shortfall of appropriately skilled workers, which in turn will have consequences for our future prosperity and growth.



Opportunities in STEM

The opportunities for STEM in the future are endless. In Australia it is projected that a 1% increase in people choosing a STEM-related career, will have significant gains for our country's economy, exceeding over 50 billion dollars in revenue (PwC, 2015). The technological revolution will reshape our workforce, moving from traditional approaches to more innovative and effective ways of work. It will allow for more entrepreneurial approaches in the way we use, engage and apply STEM. These advances will have significant benefits for Australian society, allowing us to be better connected with other countries, going beyond physical boundaries, enabling us to collaborate more effectively and efficiently (CEDA, 2015).

Young people are losing interest - and skills - in STEM

One of the main reasons for the diminishing pipeline of STEM-ready workers is the falling rate of participation in STEM subjects by school students. Between 1992 and 2012, the portion of year 12 students studying chemistry, biology, physics and advanced or intermediate maths subjects decreased dramatically (Kennedy, Lyons & Quinn, 2014). For example, the number of students undertaking advanced and intermediate mathematics in year 12 has fallen by 34% since 1996 (AMSI, 2014).

This declining engagement with STEM subjects is having an impact on the mathematical and scientific literacy of our school students. The recent Trends in International Mathematics and Science Study (TIMSS, 2015) report showed student performance in these areas in Australia has changed little over the past 20 years. At the same time, typically high-performing countries such as South Korea, Japan, Singapore and Hong Kong have continued to make steady improvement, while countries such as Canada, England, Ireland and the US have now overtaken us.

These trends are also reflected in the most recent Program for International Student Assessment (PISA) scores, which shows Australian 15-year-olds are getting worse at maths, science and reading (OECD, 2015). More than a dozen countries did better than us, including New Zealand, Finland, China, Japan and Canada. In other words, Australian school students are falling behind many of their international peers when it comes to STEM skills.

Diversity challenges in STEM

On top of declining interest and performance, Australia also suffers a significant gender divide in STEM. Despite the average female participation in tertiary education being more than half of all enrolments (57%), females are significantly underrepresented in science and engineering disciplines across all OECD countries (OECD, 2015a). In Australia, the OECD reports that there are 0.6 females to every male graduating with science degrees and less than half in engineering degrees. Further, the Australian Computing Society (ACS, 2015) reports that only 16.3% of young people choose computing and engineering pathways; more problematic, however, is that (less than 3%) 2.8% of females choose computing. And the problem is stubborn: women's participation in STEM in Australia has not altered substantially over two decades (ACOLA, 2013).

Various reasons for this disparity have been suggested. For example, research has found that the largest influence on female decisions to pursue computing, is due to controllable factors, such as encouragement and exposure, particularly within pre-college experiences, and that family influence and awareness of computing careers are critical in shaping decisions (Wang et al., 2015). Research has found that boys are more likely than girls to be encouraged into computing and engineering roles by key influencers such as teachers, parents and the media, and are more likely to be told by parents and teachers that they could be good at computer science (Google Inc. & Gallop Inc., 2016).

It is well known that perceptions about STEM professionals and career opportunities are an issue in Australia and globally, and these misconceptions start from an early age. PISA assessments of 15-year olds revealed that around 25% of boys and girls anticipate working in a science-related career; however, differences emerge in the type of science career (OECD, 2016). In almost all countries, boys see themselves as becoming technology professionals, scientists or engineers, whereas girls see themselves as being health professionals.

There are numerous programs and initiatives across the world targeted at increasing awareness, participation and diversity in STEM. One example is the success at Carnegie Mellon University (Freize & Quesenberry, 2015), which has seen a sustained increase in female computing enrolments by focusing on changing the culture (perceptions and environment) of computing and strategies focused on broadening participation for underrepresented groups (e.g. females). A great deal can be learned from cases such as this, and significant learning can be attained through curating and identifying common themes across multiple cases to identify key findings that can guide key stakeholders across countries.

Preparing the next generation of STEM professionals

To reshape and better upskill the future workforce, the focus must begin with education, as "STEM education underpins innovation and plays a critical role in economic and business growth" (PwC, 2015). Further, education in STEM is recommended as being the key to broadening community understandings of what STEM is saying and doing about the complex problems facing society, now and in the future (Office of the Chief Scientist, 2013).

Young people need to be digitally competent, adaptable and adopt core competencies that will enable them to respond to the ever-changing workforce (CEDA, 2015). STEM is a key driver of innovation and entrepreneurship that can significantly impact on the economy (PwC, 2015) and 21st century skills are recognised as a key component within a STEM skills set that enable young people to achieve success in our evolving workforce (World Economic Forum, 2016).

Increasing the engagement of young people in STEM will enable the building of aspirations for a lifelong journey in STEM. There are currently inequities that exist in STEM in Australia. Girls, students from low socio-economic status backgrounds, Aboriginal and Torres Strait Islander students and students from non-metropolitan areas are currently less likely to engage in STEM education

and are at higher risk of not developing high capabilities in STEM-related skills (Education Council, 2015). As a result, these groups are more likely to miss out on the opportunities STEM-related occupations can offer.

To increase our STEM workforce, a priority needs to be made to harness the STEM talents within these groups. Currently, only 16% of STEM qualified people in Australia are female (Office of the Chief Scientist, 2016). Besides there being the requirement for equity in the workforce in terms of pay and career progression for women (Prinsley, et.al., 2016), a significant priority needs to be made to promote the engagement and retention of underrepresented groups in STEM.

Defining STEM

There is no universal definition of STEM. The term commonly refers to the integration of four disciplines, namely science, technology engineering and mathematics. STEM is described as being "distinct and complementary approaches to knowledge and practice that have been proven to produce benefit to society" (Office of the Chief Scientist, 2013). However, there are also challenges within the use of terminology within STEM fields - with Science, Technology or Engineering often being used interchangeably and without clear definition.

For the purposes of this research report, we adopt the definition described by the Education Council of Australia (2015). STEM education is "a term used to refer collectively to the teaching of the disciplines within its umbrella – science, technology, engineering and mathematics – and also to a cross-disciplinary approach to teaching that increases student interest in STEM-related fields and improves students' problem solving and critical analysis skills"
(Education Council, 2015).

THE RESEARCH PROCESS

Aims

Barbara Cail STEM Fellows, Ms Sarah Chapman and Dr Rebecca Vivian, undertook individual research into international best practice for promoting the participation of young people, particularly girls, in STEM fields during their education and career. The research also looked at how STEM industries communicate their workforce needs for the future to young people, and to the key influencers of young people.

The scope of the research proposal was to investigate international best practices in STEM education, outside of Australia. OECD[1] countries were selected on the basis of consistently high Programme for International Student Assessment[2] (PISA) test scores and/or countries with cultural similarities. The countries visited included: Finland, Germany, Singapore, England, the United States of America (USA) and New Zealand.

STEM organisations were selected on the basis of extensive research, which included the criteria of proven and tested international programs and proven success in performance in particular STEM programs. Programs were selected that also had a focus on engagement with young people, in particular girls or underrepresented groups. Further, leading researchers in STEM education were interviewed to understand the latest in research and future directions.

Data collection and analysis

Research Fellows undertook participant-observer research. This involved visiting the sites of the organisations and institutions, immersing themselves into the context. Researchers undertook various forms of data collection, including:

- Program and classroom observations
- Informal and semi-formal interviews
- Collection of available STEM program metrics (reach and impact)
- Conference and workshop attendance and resulting publications
- Collaborative discussions
- Artefact collection

Upon conclusion of the research travel, the Fellows curated research findings to compare and contrast case studies and to draw out key findings across the international case studies.

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1 *The OECD provides independent and evidence-based analysis to help improve the economic and social well-being of citizens in its member countries and globally.* www.oecd.org

2 *www.oecd.org/pisa PISA is designed to assist governments to monitor the outcomes of education systems in terms of student achievement on a regular basis and within an internationally accepted common framework.*

Overarching framework: the STEM ecosystem

To contribute in a positive direction in STEM engagement, knowing the benchmarks for a high performing STEM engagement program is not enough: an understanding of the broader STEM landscape is essential. Understanding the STEM landscape, including knowledge of its components and complexities, allows for more productive partnerships and thus programs to arise.

To best describe the STEM landscape, would be to liken it to an ecosystem, with interconnected webs of interactions, inputs and outputs, all of which together foster innovation and the progression of STEM within the nation and within specific STEM disciplines. Partnerships should be authentic, meaningful, vision aligned and focused on solving challenging STEM education problems.

A conceptual diagram of a STEM ecosystem is shown and described in Figure 1. It is within this overarching framework that the research was conducted. To outline the roles of each stakeholder within the STEM ecosystem, the research findings include examples of each stakeholder and a range of corresponding international STEM initiatives undertaken by these stakeholders that promote STEM engagement.

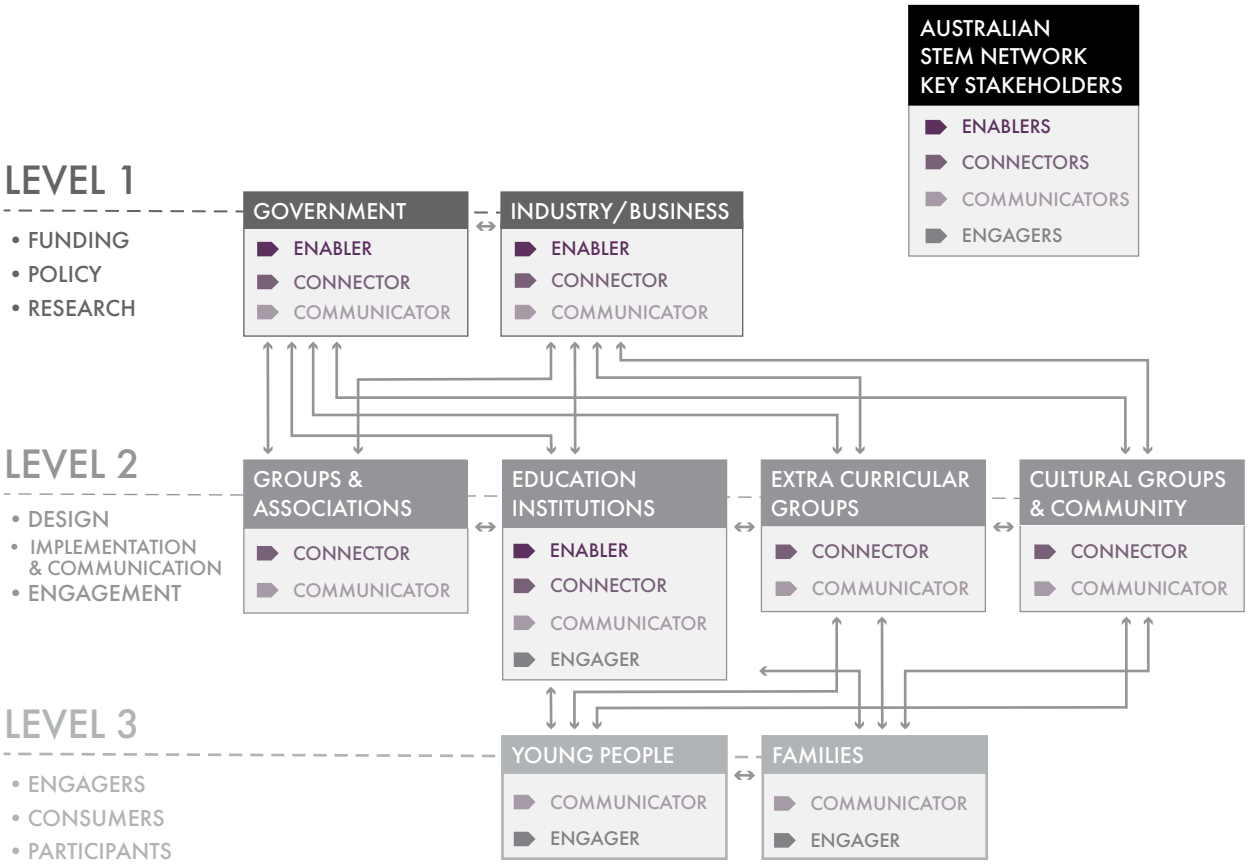


Figure 1.

A STEM ecosystem is one that has many components or key stakeholder groups:

- **Government**
- **Peak Organisations** (advocacy organisations that coordinate a broad range of industries/associations/groups under a common vision; they can be for profit and not-for-profit)
- **STEM Industry** (that relies on STEM skills and expertise to produce products or provide services)
- **Research Organisations** (that rely on STEM expertise to innovate new products and processes)
- **Educators** (from early childhood, to tertiary contexts)
- **STEM Groups & Associations** (for profit and not-for-profit)
- **Cultural Groups & Community**
- **Young People**
- **Families**

Within the STEM ecosystem lies the current STEM workforce, driving innovation, research and change which are all influencers of the economy. The future of the STEM ecosystem lies with its young people, so engaging, connecting and communicating effectively with our future STEM ecosystem builders is vitally important.

It is acknowledged that there are numerous efforts across our Australian STEM ecosystem, to raise the profile of STEM and specific STEM disciplines, and to provide STEM engagement programs, and this is evident in the Chief Scientist's 2016 STEM Programme Index. This study draws on key findings that were observed in ecosystems overseas with the aim to provide insights to key stakeholders in Australia.

Limitations

There were a number of limitations on the research conducted during this Fellowship:

- The duration of the Fellowship was limited to four to six weeks of continuous travel.
- The Fellowship travel was to be conducted between September 2016 and November 30, 2016.
- Fellows were required to contact potential participants, and/or with support through CEW's network.
- Availability of interviewees.
- Scope of the Fellowship travel, i.e. the number of places/ visits possible within the timeframes and budget; programs outside of Australia were the focus of the study, with programs inside of Australia excluded from the scope.

WHAT WE FOUND

STEM initiatives

This research investigated and observed activities in other countries being driven by particular key stakeholder areas, as identified in the STEM ecosystem. The key findings are discussed within the following stakeholder groupings. Selected examples of some of the initiatives observed within each of the stakeholder components are outlined in the following sections, with supporting case studies. These initiatives were identified to be key actions within each core grouping that enabled success in STEM engagement.

Government

All areas of government related to STEM and education, including policy makers, Chief Scientists, Ministers and Departments of Education are crucial enablers and communicators in STEM Education. Observed activities overseas identified that effective programs receive support from government, whether it be the administration of a STEM strategy or initiatives, financial Federal support for programs, or the allocation of financial assitance toward funding agencies that then invest in STEM programs and research.

Effective government engagement involved acknowledging existing quality STEM engagement programs or initiatives and played the part of enabling expansion through the provision of resources or networks. A particularly critical role that government can play is to initiate funding investment in long-term discipline-specific initiatives that bring together and expand existing efforts already being led by key stakeholders across the country for collective and sustained impact. Examples of such initiatives observed included Obama's CS For All initiative that established a clear national agenda and coordinating body for providing all children across America with access to Computer Science Education. Another key example is the 2015 United States Every Student Succeeds Act (ESSA), which provides a policy framework for quality K-12 learning and teaching.

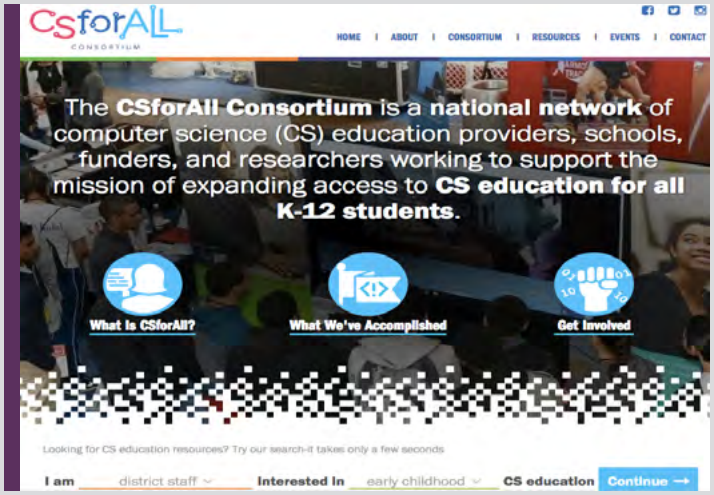
Government can also guide coordinated and national efforts through the provision of a research infrastructure for evidence-based practice and resources for STEM subjects. For example, the CS For All Consortium includes government funding toward research that underpins and guides the initiative. Government can also play a critical role in building community awareness of STEM, through policy, media engagement, and by making STEM a priority.

Departments of Education were also observed to be working effectively with key stakeholders and teachers in some contexts to develop curriculum materials and research projects. For example, in New York a "CS Education Visions" Meetup was organised, which involved a partnership between the Department of Education, the Hive Research Group (including researchers across universities in New York), and CSNYC to bring together key stakeholders in workshops to develop a blueprint for CS education curriculum and learning and teaching materials. In Singapore, the Singapore Science Centre works with the Ministry of Education to inform their programs.

CS For ALL Consortium, US

CS For All is an initiative launched by President Obama specifically, targeted at engaging young people in Computer Science (CS) from K-12 through sustained learning opportunities. A steering committee was established to lead the initiative and to coordinate the partnerships and allocation of funding. The Consortium Committee is chaired by CSNYC, as well as key stakeholders in USA Computing Education, including the Association for Computing Machinery (ACM), Code.org, The College Board, Computer Science Teachers Association (CSTA), and the National Center for Women & Information Technology (NCWIT).

A goal of the consortium is to build a shared vision and to bring all partnerships working in CS education together for collective and sustained impact. The Chair, CSNYC, see a key role of theirs as linking partnerships together and facilitating a long-term research and implementation strategy, and assessments. Funding has been proposed for teacher training and the development of classroom instructional materials, as well the establishment of regional and national partnerships and a call to action from government representatives, creative media, technology professionals, CEOs and philanthropists to pledge a commitment to get involved. As of December 2016, 30 states are represented, including 320 member organisations.



Screen capture of the CS For All Consortium website

Key lessons

- Strategy builds on existing quality programs for long-term, collective impact.
- A steering committee of key stakeholders, from existing organisations, are established to co-create a shared vision, goals, shared language and strategy.
- Initiatives have an allocation of funding toward longitudinal research to inform best practice and future directions.
- The program invites schools and partners to publicly pledge their commitment.
- STEM industry, organisations and philanthropists can pledge funding to contribute toward sustaining the program.

Peak organisations

Peak organisations (or bodies) are not-for-profit or for-profit organisations (including institutes and leading associations) that have a governing body and oversee multiple state-based or nation-wide organisations, associations or groups. In the STEM ecosystem, peak organisations can play an important role in bringing key stakeholders together and in administering strategic national action. They act as an umbrella for a national network and are dedicated to connecting organisations, groups and key stakeholders together to promote STEM engagement and support education. Such activities were observed in the National Girls Collaborative Project/Connectory, WISE Campaign, New York Academy of Sciences, and National Center for Women & Information Technology (NCWIT).

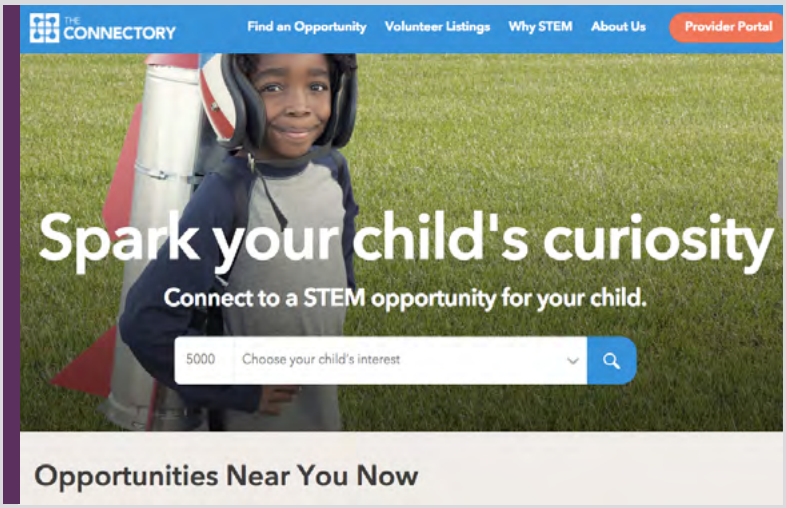
Peak organisations were observed to undertake mapping exercises to identify all groups and organisations supporting or working within STEM education disciplines in an effort to identify key stakeholders and potential partnerships across their nation. Peak organisations can play a role in working with schools, groups and organisations to inform and enhance the development of a suite of community-relevant STEM projects (for example, as observed with the National Girls Collaborative Project, Singapore Science Centre, Techbridge Girls).

With their position as an overarching organisation, they are also able to bring key stakeholders together, including industry, education institutions, outreach and STEM engagement programs to host large national STEM events. An example of this in action is the Grace Hopper Celebration, run by the Anita Borg Institute and the UK's WISE Campaign annual Conference and Awards event to celebrate women in STEM. Peak organisations work with industry to showcase diverse STEM stories and professions; for example, the American Association of University Women has developed a suite of videos and web-content resources that showcase diverse STEM professional stories.

Peak organisations were observed to also conduct or fund research into their STEM education landscape and strategies for engaging students and families, particularly minority groups (e.g. WISE Campaign, American Association of University Women). Through their research and by drawing on expertise from multiple industry partnerships, peak organisations are able to inform STEM education and outreach organisations of STEM innovation progression and need, to influence and enhance engagement and outreach (e.g. Singapore Science Centre, WISE Campaign, Anita Borg Institute).

National Girls Collaborative Project, Seattle, US

The National Girls Collaborative Project is a not-for-profit organisation that provides opportunities for girls and minority groups in STEM. It connects young people, educators, business and industry in a strong network that ensures strong relationships are built and the girls who engage with them, make long-term connections with STEM. The National Girls Collaborative Project takes an equity view on all processes, brings together organisations and quality resources, and provides a method of dissemination. A component of the National Girls Collaborative Project is the Connectory, which links into 5,000 programs with a STEM focus. It provides a program portal for collaboration between young people, families, industry, extra curricular programs and mentors. It also provides role model training, to prepare mentors with the right mindset and forms of communication that are effective for engaging young people.



Screen capture of The Connectory website

Key lessons

- Having an overarching body to connect programs, mentors, industry, educators and young people is an effective way of promoting STEM engagement through a range of sectors.
- Having quality, equitable programs and resources and a successful dissemination model ensures for the greatest reach to raising the profile of STEM.
- Having an extensive network of STEM professionals and invested partners enables targeted STEM engagement and advocacy to reach the right audience.

WISE Campaign, UK

A not-for-profit organisation that aims to inspire girls and women to study and build careers using science, technology, engineering and maths (STEM), WISE focuses on the "Push" (encouraging and inspiring young females to STEM) and the "Pull" (bringing young women into STEM and supporting them to rise to leadership positions) through various strategies. WISE works with partners across the UK to inspire, engage and develop positive STEM environments where women can thrive, through training, consultancy, events, and resource support. WISE performs mapping exercises to monitor the STEM landscape and key stakeholders within. They also monitor national STEM education and workforce statistics and use these metrics to develop targeted strategies that raise the profile of specific STEM fields.

The group generates revenue through members, and they use this funding to fund their people and activities. Their memberships include various categories, including industry and groups. These groups invest because they have an interest in engaging and promoting women in STEM fields. They have developed a series of evidence-based resources, and have undertaken scoping projects to develop informed, evidence-based strategies for creating a positive STEM culture and environments. An example of their evidence-based resource work was a sponsorship by the Network Rail to investigate what the research says about engaging girls in STEM. This resulted in the development of the "People Like Me" resource package (aligned with an App) and tailored to different STEM fields, that advises how to articulate STEM careers to girls. The organisation hosts an annual Conference and Awards event to celebrate women in STEM (including a male champion), as well as top companies who are changing culture to develop more inclusive environments where women can thrive. WISE are is also responsible for coordinating networking events and training showcasing corporate members, such as careers workshops and unconscious bias training and providing specialist consultancy to companies.

WISE Campaign "People Like Me" Resource Pack

Key lessons

- Develop evidence-based materials for key influencers (parents, volunteers, educators) to guide them in STEM education and messaging.
- Resources should be tailored to specific STEM disciplines.
- Peak organisations can map programs and key stakeholders within their STEM discipline to provide a landscape for developing partnerships and identifying pathways through programs.
- Use metrics on STEM education and workforce to inform and develop targeted strategies for specific STEM fields.
- Celebrate the achievements of women in STEM through award ceremonies, but also those of industry organisations and businesses who are making strides to make STEM environments a better place for women.

Anita Borg Institute (ABI), Grace Hopper Celebration, US

The ABI focuses on supporting women in Technology, through fostering a culture that supports women at all study and career stages to thrive. ABI partners with over 50 industry leaders worldwide and have created a Partner Council, with representatives from each industry partner.

One key initiative is ABI's annual conference: the "Grace Hopper Celebration of Women in Computing" (GHC), hosted in partnership with the ACM. This conference brings together industry, STEM organisations and outreach groups, researchers, academics and education institutions to celebrate women in computing and to raise the profile of computing (and engineering). It features leading STEM role models as keynote speakers and various presentations, workshops and panels for students and professionals throughout the day, and a party on the final night.

The conference also features an exhibition hall - the "Expo" - with over 200 booths comprised of education institutions, industry/organisations and networking groups. What is unique is the variety of industry and organisations that are present and are able to speak about possible careers in technology. The ABI have scholarships available for young female students, particularly those who are underrepresented, to attend the GHC.

The GHC makes an effort to celebrate diversity, through the representation of speakers, outreach programs and organisations involved, as well as badge-ribbons and niche networking events for people to connect. The event has grown drastically since its foundation in 1994 with around 400 technical women to 15,000 participants (including 1,000 men), over 1300 organisations, and over 400 academic institutions in 2016. ABI monitors and reports on GHC participation, including diversity metrics, each year. These findings are published as "impact reports" on their website.

2016 Grace Hopper Celebration Exhibition Hall

Key lessons

- Develop advisory board with key representatives.
- Operate as a connector for large-scale conferences, in which a range of industries, education institutions, and outreach groups are present and offer national awards for companies and STEM role models.
- Create events that celebrate STEM role models and for young students and professionals to connect with likeminded peers.
- Celebrate and make diversity visible at events.
- Collect data and publish impact reports on diversity and participation metrics.

STEM industry

STEM organisations and businesses (industry) can support STEM engagement through a range of activities, such as providing expertise, funding, programs and experiences. Industry can play a key role in driving research, innovation and employment for STEM graduates. STEM industry has a number of initiatives in development to change the culture of STEM, community perceptions, research into STEM education and participation, and raising the profile of STEM.

An example of an action to cultivate environments where diverse STEM professionals can thrive is the provision of unconscious bias training to staff; for example, Google's "ReWork: Unconscious Bias @ Work training". Such initiatives are driven by a recognition that supporting diversity in organisations by creating a culture where diverse professionals can thrive, can result in economic benefits and more diverse role models to inspire and engage future generations.

Industry recognise that teachers are key to driving change in young people's lives and a number of initiatives by industry are focused on developing teacher capacity through teacher-training programs or the development of resources. Industry was observed to invest in seed funding initiatives for STEM education and professional development programs; some examples include Google's CS4HS grant program and Project Lead the Way, supported by Lockheed Martin.

Raising the profile of STEM industries and being able to raise community awareness of opportunities in STEM were also regarded as important activities. Some companies were observed to work with the community television and film industry to challenge stereotypes around the portrayal of STEM professionals. For example, Google has been working with filmmakers in Hollywood to share their expertise and help filmmakers to depict diverse and accurate STEM professionals in movie roles.

STEM industry was observed to conduct or fund industry-led research into topics that inform STEM education, including on topics that guide evidence-based strategies for engaging students and families, particularly minority groups. Examples of such activities included Google's research in the CS education space, particularly in relation to engaging and retaining females, Hispanic and Black students and their key influencers.

Google Computer Science Education, US

Google focus on determining how best they can support and scale computer science efforts across the US, and globally. They have a diverse portfolio of programs and initiatives that support computer science education across K-12, college, industry, and teacher-training, as well as efforts intended to raise the profile and improve the culture of computing. Google's efforts are often focused toward finding ways to operate as a good partner, leveraging partnerships, investing in and conducting research, and advocating computer science, innovation and industry needs to key stakeholders, such as policymakers and media. They work to support new initiatives through seed funding, or to expand and scale quality existing programs.

Examples of Google's K-12 initiatives include the development of learning and teaching materials, such as within their CS First program and teacher-training support, through the CS4HS grant program. Google (US) also fund and/or conduct published research that seeks to understand the climate of computer science education and diversity and engagement challenges, particularly for underrepresented groups, such as females, Black and Hispanic students. Two examples of Google's efforts to raise the profile of computing and visibility of diverse professionals, has been their work with creative industries in their representation of technology professionals within film, and an initiative with Refraction Media to expand their Google Australia Careers with Code partnership to the US. Further, Google have developed freely available unconscious bias materials - ReWork: Unconscious Bias @ Work, that can be used by industry and organisations to increase awareness and action around unconscious bias in the workplace. Carnegie Mellon University's SCS4ALL Group have also partnered with Google to expand the resources as a Bias Busters program for use within their university context and have scaled the program to include a train-the-trainer model.

Key lessons

- Industry to act as a partner, and develop a strategy on how they can operate best as a partner with multiple organisations.
- Work to change the culture and perception of STEM disciplines – through training, messaging campaigns and resource development.
- Offer seed funding initiatives for STEM programs and teacher training.
- Conduct or fund research into STEM diversity and engagement in Australia, particularly within underrepresented STEM disciplines and for underrepresented groups.

Lockheed Martin, Washington DC, US

Lockheed Martin is a global company in STEM innovations in defence, flight, space and renewable energies. This global company works with and invests in supporting a range of organisations that provide STEM expertise in education, outreach and engagement, such as Project Lead the Way, which has enabled schools across the United States to access a range of excellent STEM programs in engineering, computer science and biomedical science.

The company also supports Discovery Education, which provides supplementary curriculum for students to engage with STEM jobs of the future.

Along with these programs, Lockheed Martin encourages the engagement of girls in STEM through their support of excellent girls-only initiatives including Girls Inc. and Girls Who Code. Girls who Code incorporates industry, field trips and involves the classroom teacher, and has been highly successful in engaging girls in a computer science future.

Key lessons

- Industry can develop supplementary materials about STEM careers.
- Can develop/partner for a program to support developing teacher capacity in STEM
- Can focus on supporting the expansion of existing quality programs that align with a particular goal, e.g. girls in STEM.

Tertiary education providers

Tertiary education providers include universities as well as vocational education and training. Education departments are responsible for attracting and training educators from early childhood through to tertiary contexts to teach STEM subjects. STEM departments in tertiary education environments (e.g. the disciplines) play a key role in attracting and retaining engagement of young people in STEM pathways, and face the significant challenge of attracting students, particularly women and other underrepresented groups, to STEM programs. They are responsible for the development of young STEM professionals, and work closely with industry to meet demands for the professional STEM workforce.
It was observed that many university STEM departments are involved in the professional development of pre-service and in-service teachers, harnessing their expertise to expand and supplement teacher training programs.

STEM disciplines were working to build teacher capacity through formal and non-formal professional learning opportunities, as well as through the development of resources that support learning and teaching of STEM subjects (e.g. Mind Labs, Exploratorium, Computing At School, LUMA Centre, Aalto University, Google CS4HS and CSFirst, University of Canterbury CS Education Group, Stanford Office of Science Outreach).

Tertiary institutions were often involved in existing STEM Group/ Organisation programs - whether it be through supporting STEM teacher professional development in other programs or connecting pre-service teacher programs with external learning opportunities. For example, the LUMA Centre Finland allows for pre-service teachers opportunities to practice teaching in their STEM programs, with real students in a classroom setting. Computing At School partners school teachers with STEM and Education faculty, as well as industry, to develop local professional learning programs.

However, STEM faculty were observed to rely heavily on volunteer time of faculty and students, and a number of programs identified resourcing (financial and people) as a key challenge. Funding to support the minimum costs of running programs included: grants schemes, such as Google's CS4HS program and the Project Lead the Way; charging participants fees to cover minimum costs; and funding received from government, industry or peak organisations. While the funding often covered minimum costs (such as food and beverages, teacher travel, materials or relief teacher replacements), there was still the challenge of faculty and student volunteer time. To overcome such challenges, faculty were experimenting with online modes of delivery, as well as providing credit toward student programs for participation.

Tertiary education providers *...continued*

Tertiary education providers were also extensively involved in efforts to engage young people in their STEM disciplines. Some key activities observed included:

- Hosting regular STEM networking events and workshops; bringing in industry professionals and mentors from small and large diverse industry (SheSharp, New Zealand).
- Running national competitions for students (SheSharp App Competition, LUMA Centre Finland StarT Challenge).
- Providing learning opportunities in schools and public spaces (e.g. SheSharp roadshow visits, The University of Canterbury's CS Education Group's events in public libraries, The University of Sheffield Engineering Faculty).
- Providing opportunities for high school students and high school teachers to undertake STEM research internships with research labs (e.g. the programs offered at the Stanford Office of Science Outreach).

Some STEM faculty developed their own professional development or student STEM learning opportunities on their own. However, other programs had established partnerships with key stakeholders or had developed a national program as an umbrella to coordinate efforts. Some notable programs that highlight collective effort in this regard included:

- The LUMA Centre Finland, which provides a national tertiary STEM framework for tertiary departments to engage in outreach and teacher professional learning through a coordinated and consistent approach.
- Strategic collaborations across the university between STEM departments, student representatives and university communications teams to develop programs that strategically market STEM to young people and families (for example, the University of Sheffield, Faculty of Engineering "Engineering Is" Campaign).
- Working with children's popular media to develop STEM education programs and national challenges, harnessing online environments. An example being the University of Helsinki's LUMA Computer Science Centre's Coding Challenge with a popular Finnish television program for children.

LUMA Centre Finland of the University of Helsinki, Finland

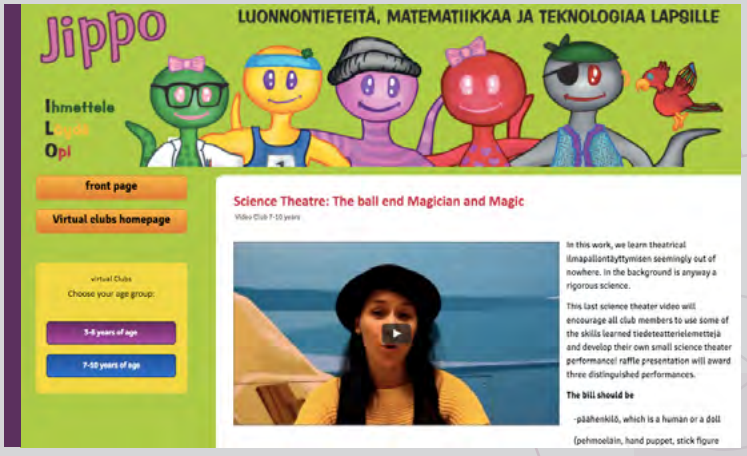
LUMA Centre Finland is the umbrella organisation that brings together Finnish university science, mathematics and technology faculties to implement STEM education and outreach across Finland for children ages 3-19. There are 13 Luma Centres across Finland. They have a common national strategy, budget and action plan for every year, and a national annual report is published. International collaboration is also informed by a collaborative strategy. Research of all participating faculties is recognised and acknowledged in LUMA.

Their mission is to: inspire and encourage boys and girls in STEM; promote awareness among parents; support educational research and lifelong learning of STEM teachers; increase visibility of STEM; and support pedagogy of STEM through research. Each faculty has ownership over their own STEM groups and programs, however, the LUMA Centre Finland provides a framework and central website for coordinated efforts and evidence-based practice. This includes international programs such as Lumat 2017 days for teachers around the world, their annual "StarT" STEM project-based learning challenge for kindergartens and schools, international LUMA camps for both young students and teachers, and their LUMAT publication - a Journal for Researchers and Teachers. All LUMA Centre Finland programs are evaluated by researchers, to inform new programs and improve practice.

Every LUMA Finland Centre has its own profile, for example, the oldest and biggest Luma Centre at the University of Helsinki reflects the strategy of University of Helsinki. There are four faculties collaborating: science, biosciences, education and humanities, and teacher education (informal and formal education) is very well integrated within the program. Teacher development and pre-service teacher training are linked strongly with the research community. This reflects the LUMA Founder's motto "Together we are more!". In the Chemistry Lab Gadolin pre-service teachers have extensive opportunities to learn formally and informally to develop their teaching competency. They have opportunities to run science clubs in the community, deliver student visitor sessions in the research laboratories, entertain children at science birthday parties and run teacher professional development. The trainee teachers become well skilled and equipped in their mastery of teaching through these informal opportunities. The LUMA Finland Centre learning community also engages young people inside school, where team teaching acts to learn/design/teach together. Teachers lifelong learning is big part of the Luma program, providing a strong inservice training program. Currently, Luma Suomi program has 35 novel pedagogical innovations within its research program.

LUMA Centre Finland of the University of Helsinki, Finland *... continued*

The **Mathematics Teaching Centre** "Summamutikka" is part of the University of Helsinki LUMA Science Education Centre (and has a new name, used since 2017). The Centre hosts Math Clubs and Math Days at schools or after school. Math Days involve working with the teacher to develop a program that includes a workshop and follow-up visits, whereas the Math Club is usually hosted after-school for all student year levels. They have also established the Math Classroom Origo on-campus in 2011, which is a modern and inspiring learning environment and a place where school mathematics and university meet. Additionally, with other LUMA centres in the university, they collaborate to host a summer STEM camp over 5 days at the University. To meet the high demand of requests and to scale their programs, the group have launched "Jippo", a virtual Science Club. This Club combines mathematics, science and technology and features engaging video lessons for children from 3 to 10 years old to watch, that include activity descriptions and STEM explanations. The other virtual club, called "Mathversum", is for youth and it combines mathematics with other subject areas, e.g. math and arts. Additionally, the Centre has been working with libraries to establish community Math Clubs, loaning teachers free mathematics teaching kits and making learning and teaching materials available freely online.



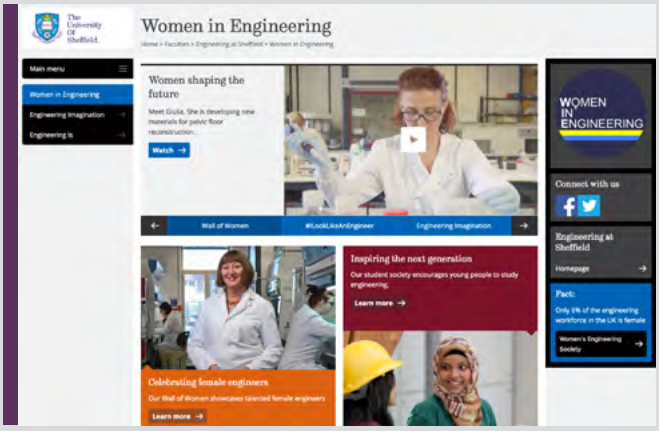
Screen capture of the "Jippo" - LUMA Clubs website *(translated from Finnish)*

Key lessons

- Establish a national tertiary STEM education outreach framework and program for tertiary departments.
- Involve pre-service teacher students in STEM tertiary programs.
- Informal learning experiences develop pre-service teacher confidence and skills.
- Support teachers to integrate STEM challenges and competitions into their classroom curricula.
- Explore models for taking face-to-face programs online to scale and relieve resource challenges.

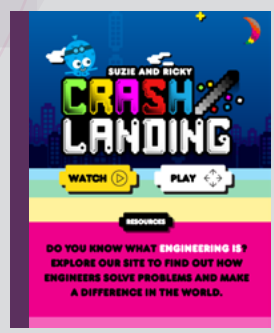
The University of Sheffield, Faculty of Engineering, Sheffield, UK

Individuals across the university work together, with a shared vision and goal, to increase female participation and leadership in engineering, and to raise the profile of engineering among the community. This includes initiatives to engage and draw young girls and women into engineering, but also efforts to create a culture that supports diverse students and academic staff to succeed. The Women in Engineering Group was established for this purpose, and is comprised of academics and students. Their website celebrates women in engineering and the diversity of engineering careers and highlights the various engineering engagement activities available.



Screen capture of the University of Sheffield Women in Engineering Homepage

The Women in Engineering Students Society at the University, is involves both male and female students. This group has a great deal of autonomy, where students lead engagement and outreach efforts, with support from academics. One example initiative includes the development of a children's book for young children and their families called "Suzy and Ricky"; which aims to inspire and highlight the various areas of engineering. Expanding this initiative, the students worked with academics from engineering and a communications expert at the university to launch the "Engineering Is" campaign, which features a micro-website with an animation and engineering puzzles to engage early years children and their families, and their original storybook as available as a digital download. The group launched a social media campaign to build awareness around the launch.



Additionally, the students work with academics to reach out to local schools and to run outreach events both on and off campus. Their key focus has been on student-led initiatives, promoting and retaining female role models, engaging young people and their families, and working together across the university by drawing on expertise to achieve a shared goal.

Engineering Is Campaign by the University of Sheffield Women in Engineering Student Society and Engineering at Sheffield.

Key lessons

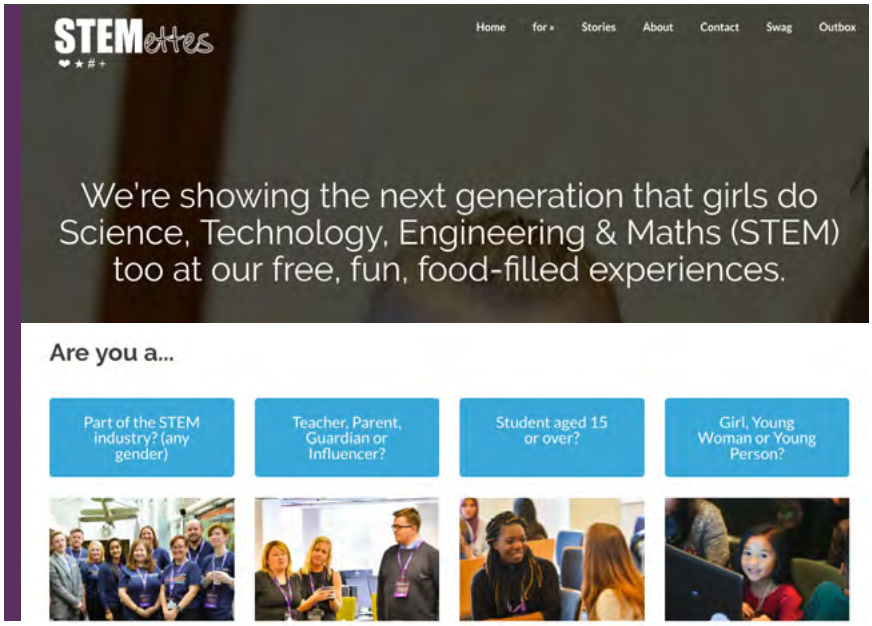
- Harness expertise across professional and academic departments.
- Allow students to develop and drive engagement initiatives.
- Develop programs specifically aimed at engaging families and challenging perceptions.
- Develop campaigns that can build public awareness with key stakeholders.

STEM outreach groups & organisations

STEM outreach groups and organisations (both for-profit and not-for-profit), provide STEM outreach, engagement programs and advocacy. This stakeholder category also includes industry groups, teacher associations (including across STEM subjects), principals groups, groups representing communities underrepresented in STEM (e.g. women, indigenous, disability), state/territory and national STEM groups, and education groups. All these groups and organisations can support STEM engagement through a range of activities, such as through providing opportunity, expertise, programs and experiences. They can play a key role in promoting STEM engagement, connecting with key influencers, advocating for and informing STEM professionals and connecting young people to pathways for employment in STEM.

STEM outreach groups and organisations have a number of initiatives in place or in development to change the culture of STEM, community perceptions, support STEM education, promote STEM engagement and participation and raise the profile of STEM. They were observed to develop specific and targeted programs to engage and build aspirations for young people in STEM that include mentoring, inquiry-based programs, camps and networking (Stemettes, Techbridge Girls, National Girls Collaborative Project, Girl Scouts STEM, SheSharp and Rails Girls), as well as the establishment of STEM networking events and groups for underrepresented minorities (e.g. Indigenous, females).

A number of initiatives were identified as having incremental STEM programs based on real-world contexts that enable young people to genuinely make a difference. These programs involve inquiry-rich tasks and resources for sustained engagement and contribution (e.g. Techbridge Girls, Museum of Flight, Girl Scouts STEM, Stemettes, SheSharp App development challenge).



Screen capture of Stemettes website

Screen capture of Museum of Flight website: Educator Resources

Notable programs also included the development of evidence-based STEM outreach training and materials for their programs, including unconscious bias training, effective role model training, effective communications and messaging to females, and accessibility in STEM (e.g. Google, Techbridge, United Kingdom WISE Campaign, Carnegie Mellon University).

Some programs also offer material support to key influencers of young people, educators and families, to engage with the program or STEM learning with children. Notable actions in this regard were the development of resources to support teachers to integrate STEM competitions and challenges with their classroom curriculum learning areas (e.g. LUMA Centre Finland STEM Challenge - StarT, Project Lead the Way/Lockheed Martin, Innokas), as well as resources that support families to engage in STEM learning activities at-home and to hold informed conversations (e.g. Techbridge Girls).

Screen capture of Techbridge Girls website: Family Resources

Some challenges identified by program leaders were: the ability to sustain smaller programs where resourcing was limited or relied on volunteer support; concerns about losing young people if programs are not available when they undertake a life transition (e.g. high school to university); concerns for reaching schools or communities in rural or regional areas with time and resource constraints; ability to scale programs efficiently and effectively; and genuinely reaching and bringing in underrepresented students who may not have someone to encourage them into the STEM program.

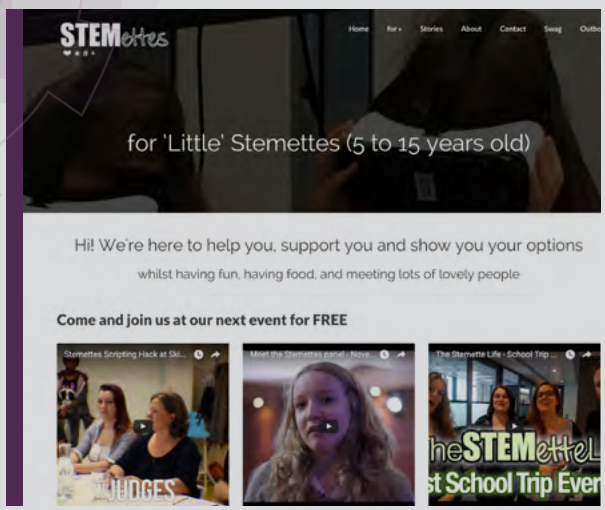
Stemettes, London, UK

Stemettes work to inspire girls from age five to twenty-two in IT. It provides avenues for girls to network with experts from a range of industries, builds aspirational pathways as well as networking with other like-minded girls, with these connections being sustained over time and distance. Along with building connections, girls also build confidence in themselves and their future direction, through fun activities that allow girls to meet others, try new things and see the possibilities for their future. Stemettes also aims to build knowledge about the skills needed in STEM, in particular in IT.

All programs are free and engage girls from all walks of life to be a part of this network. Some of the activities girls have the chance to participate in are hack-a-thons, summer camps, conferences, mentoring and school visits. The activities are linked to real world scenarios and involve industry expertise for authenticity. Stemettes also has Outbox, which is designed for young women to build their capacity in STEM.

The female focussed events provide a safe and supportive environment to engage and try new things. All of the mentors are also female to provide a positive and enriching experience for each girl involved. Stemettes also aim to connect girls and young women with experiences they would otherwise not get. One opportunity is to attend Grace Hopper Celebration of Women in Computing, the world's largest gathering of women technologists, that connects and inspires these young girls towards STEM pathways. This experience builds a girls confidence in themselves and connections with the STEM world.

This organisation has a high level of industry investment. Industry sponsor events, resourcing and components of the program which all contribute to the success of the Stemettes program.



Screen capture Stemettes: 'Little Stemettes' Support

Key lessons

- STEM engagement activities for 'girls only' promote a supported environment to engage with STEM.
- Providing free STEM opportunities allows for girls from all backgrounds to attend inspirational events that promote inspiration, engagement and connection.
- Industry investment provides STEM engagement opportunities.
- Providing free opportunities to connect likeminded girls enables them to sustain connections and engagement in STEM.

Techbridge Girls, Oakland, US

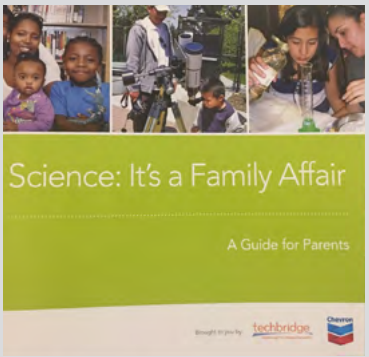
This organisation is invested in engaging girls from under-resourced communities and minority groups in STEM, in particular girls of color from low-income families. The organisation found that having incremental learning experiences across the spectrum of a young person's life is more likely to lead to sustained engagement. It caters for this by having afterschool programs that encourage incremental progress from play-based STEM learning in the early years to a self-driven maker project at the end of High School.

The programs run by Techbridge are free and based in the girls' schools, overcoming transportation issues, and provide familiarity and connection with STEM pathways. The programs are all linked to STEM careers, as students can experience a range of skills and how they translate to a career. The organisation has been successful by involving a diverse range of companies and industries in their programs. It has also succeeded by engaging the families of the girls in the programs. This has ensured a better understanding of the program by the family and encourages family support for the girls through their progression through the program.

Techbridge have developed resources for families, including the science guide and suggestions for helping families support girls in their interest in STEM through family activities and information about STEM and careers. Techbridge collects both short and longitudinal data about the impact of their program and publishes results on its website. Techbridge invites girls, parents, and teachers to participate in surveys, focus groups, and interviews as part of its evaluation process, and uses external evaluators to assess their impact.

Techbridge Girls identified that some role models do not bring the right message or cannot communicate effectively, so it developed a program Role Models Matter, which provides training to mentors to ensure quality interactions with impact. This is also provided to other organisations to ensure effective role model practice.

Screen capture of Techbridge Girls Role Models Matter Training Resources



Techbridge Girls "Science: It's a Family Affair: A Guide for Parents" Booklet

Key lessons

- STEM engagement activities for 'girls only' promote a supported environment to engage with STEM.
- Incremental STEM learning experiences ensure sustained and long-term engagement.
- Engaging families in STEM engagement programs promotes sustained engagement of young people.

Stanford Office of Science Outreach, Stanford University, US

In addition to numerous on and off-campus outreach activities, Stanford's Office of Science Outreach provide opportunities for both teachers and students from middle and high school to participate in research on-campus. The Office sponsors and organises the RISE (Raising Interest in Science and Engineering) Summer Internship Program. This is a 7-week program for local Bay Area high school students interested in science, engineering, math, computer science, or psychology, with the aim of engaging students, particularly those from underrepresented groups and low-socio economic backgrounds. The program aims to inspire students and provide an opportunity for students to see themselves studying or working in STEM. Selected students are partnered with a research lab at Stanford and spend 30 hours a week on-campus, working with the research lab on a project(s) under the guidance of a mentor (usually a graduate student) and attending weekly sessions offering STEM enrichment (field trips, faculty talks, information sessions about college application, etc.). Stipends support students who would otherwise be working summer jobs. To increase low-SES participation in the program, the Office connects with teachers in the Bay Area, inviting them to nominate students. This requires significant resources (time and people), however, the program's annual alumni surveys demonstrate that about 95% of alumni receive a Bachelor's degree and about 80% major in a STEM subject.

The Office also offer a Summer Research Program for Teachers (SRPT) in the San Francisco Bay Area, with the aim of providing middle and high school teachers with authentic research experiences and exposure to the latest STEM techniques and innovation. This is an 8-week paid research fellowship, in which teachers work in a research lab for four days a week on a research project(s), and meet once a week as a group for lectures, lab tours, and teaching seminars. The program provides an opportunity for STEM teachers - many of whom have never had any research experience - to gain experience and confidence working in a laboratory environment.

Key lessons

- Provide a stipend for low-SES students to participate in internship programs.
- Provide teachers with industry experience through university lab placements.
- Inspire and prepare high school students from underrepresented groups with STEM internships in research labs.
- Connect with teachers for targeted recruitment of underrepresented students.

Project Lead the Way, US

Although Project Lead the Way was not visited as a part of the Fellowship, this program was prominent in each school visited in the US and referenced by industry and several STEM outreach organisations as being an outstanding, diversely and equitably used, and highly regarded program. It is run by a not-for-profit organisation that has a large number of significant industry partners that fund the program. It aims to empower students to develop and apply in-demand, transportable skills by exploring real-world challenges.

Project Lead the Way has focused programs around computer science, engineering, and biomedical science, where students learn technical skills around solving real-world problems. The content is relevant and authentic and develops in-demand skills required for the STEM workforce. Teachers are provided with in-depth training, on-going resources, and support they need to engage students in real-world learning. Project Lead the Way has engaged over 9,000 schools, over 2.4 million students and 35,000 teachers across the 50 states of America. It has both career and college based programs, by linking in industry and research partners.

This program also provides grants for districts to develop local STEM student and teacher programs. Students also have access to an online social platform to connect and network with other likeminded young people in STEM. There are opportunities for students in Project Lead the Way to engage in internships to gain more in-depth experiences in STEM industries. There are also scholarships to support students' postsecondary studies. This program was embedded in schools with students from both high and low socio economic and diverse backgrounds.

Key lessons

- An organisation that is heavily industry-funded and provides quality hands-on programs that are current and develop in-demand STEM skills for students, combined with teacher professional development, can have extensive national reach and impact.
- In-depth teacher professional development, linked to resources that are relevant and authentic can build teacher capacity and confidence.
- Providing seed funding for schools, universities and other organisations to develop STEM teacher capacity and promote student engagement in STEM can contribute to broad national reach.

Computing At School (CAS) - UK

Computing At School is a large volunteer organisation, dedicated to promoting excellence in the teaching of computing as a school subject. CAS is part of BCS, The Chartered Institute for IT, and is supported by Microsoft, Google, and other partners. CAS was developed as a grassroots initiative and has involved teachers from day one to build a community of practice in which teachers are valued colleagues. CAS have a motto: "There is no "them", there is only us", which emphasises the sense of collaboration and community partnerships that underpin this model for building teacher capacity and quality teaching of computing. Since the announcement of England's new K-12 Computing curriculum, CAS receives some government funding to support the implementation of teacher training across the UK.

CAS see face-to-face professional learning support as a critical component of supporting teachers to implement quality computing education. In this effect, CAS has established the CAS Network of Teaching Excellence in Computer Science, which provides an umbrella name for all of the professional development and networking events they coordinate. This network consists of regional centres based in ten leading universities in England, Master Teachers, local hubs and lead schools all committed to developing and delivering local face to face support to teachers in their communities.

CAS has established an open, online community, for people to network and share practice and resources. In February 2017, the organisation has over 25,442 registered users (globally) and 3,817 online teaching resources. CAS host an annual national conference, bringing together teachers, researchers and academics to share best practice. The organisation is also responsible for the development of a more formal professional development option: the BCS Certificate in Computer Science Teaching. CAS have published extensive Computing education resources for teachers, such as the Quick Start Computing Guide, Tenderfoot resources, Barefoot Computing and regular "Switched On" newsletters, which are supported by funding from partners. More recently, CAS, in partnership with Raspberry Pi, launched a new magazine for educators called "Hello World" , which is to replace the 'Switched On' series.

Key lessons

- Build a community of practice that involves teachers from the very start as empowered, valued colleagues.
- To scale efforts, adopt scalable face-to-face models, such as "hubs" for regional coordination, master teachers and train-the-trainer approaches.
- Strong collaborative partnerships between industry, tertiary and schools can provide rich professional learning opportunities for teachers.
- Involve teachers in research through a national teacher conference.

STEM outreach groups & organisations *...continued*

Community organisations, such as science centres, museums and public libraries, are open to the general public and provide a range of services relating to that locality, including cultural perspectives and relevance. Community organisations can support STEM engagement through a range of activities, such as providing relevance, expertise, resources, programs, experiences and research input. These organisations can play a key role in communicating and promoting STEM. Community organisations have a number of initiatives in place or in development to change the culture of STEM, community perceptions, STEM engagement and raising the profile of STEM within communities.

Community organisation initiatives that were observed included:

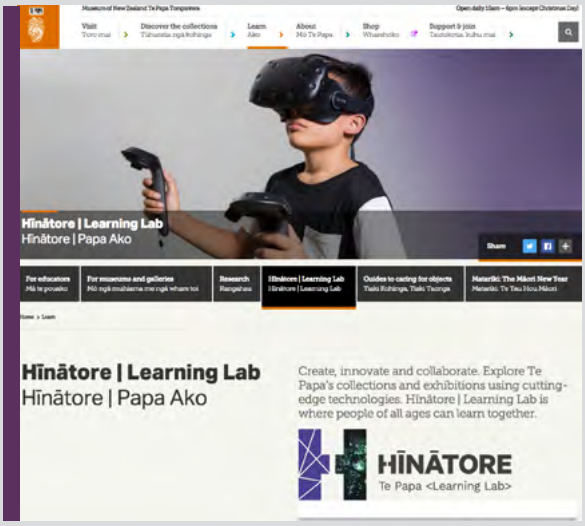
- State-based STEM centres for the public, particularly families and young people (e.g. Washington STEM).
- Local STEM hubs for student learning, teacher professional development and the public; coordinating groups (e.g. New Zealand MindLab, Washington STEM, National Girls Collaborative Project, Girl Scouts STEM, Stemettes).
- STEM public spaces work with industry and tertiary to host public events about STEM topics (e.g. Exploratorium, Te Papa).

Te Papa, Wellington, New Zealand

Te Papa is a national museum that provides engagement and information about STEM from bicultural perspectives, enabling influencers from different cultural backgrounds in New Zealand to have access to key information. Te Papa's role is to be a forum for the nation to present, explore, and preserve the heritage of its cultures and knowledge of the natural environment. It includes multiple perspectives and representations to inform and improve practice.

The museum has a transformative, 'connectivism' approach, where people experience hands-on learner-centric experiences, enhanced with digital technologies that build connections, empowering visitors and bettering their lives and thus the community. To ensure inclusion in each museum visit, the experiences reflect the Maori word 'ako', meaning non-hierarchical learning, and that anyone can learn from anyone. This draws the value of each individual and perspective, allowing collaboration and connection with a broader audience.

Te Papa has a Hīnātore Learning Lab that provide school programs and STEM engagement activities for young people aged three to thirteen. It brings together digital technologies, cultural aspects and current world problems, to challenge young people about their future and encourage innovation. It provides virtual excursions for young people to access, regardless of location. The aim is to build awareness around digital identity, link young people to the culture of their country and engage them as lifelong learners in STEM.



Screen capture of Te Papa website: Hīnātore Learning Lab

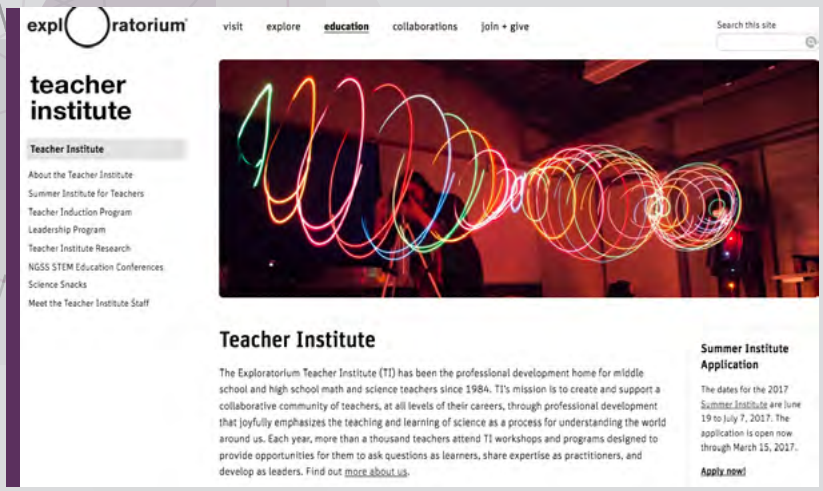
Key lessons

- Inclusion of cultural perspectives in STEM engagement programs, preserve the heritage of a culture while enabling the public to connect with it.
- Virtual excursions can provide access to STEM opportunities regardless of location.

Exploratorium, San Francisco, US

The Exploratorium links science and art to build public awareness. It involves a range of stakeholders that all have a common goal to support a culture of experimentation and collaboration, inspire curiosity and understanding, and stimulate fresh ideas and directions. It allows the public to engage with science and explore concepts, whilst making them fun and engaging. It also offers a range of public events held on nights and weekends to engage a broad audience. It also has a strong online presence, providing programs globally to people and engaging with organisations across the world.

The Exploratorium is on the cutting edge of science and public engagement, with all programs and displays being part of their research and development. The research informs continual improvement and best practice in inspiring curiosity and developing understanding throughout the museum's displays and activities. The Exploratorium also has the Teacher Institute - which provides a range of programs from three-week summer institute, Saturday workshops and two-year Leadership Program (coaching/mentoring) / Teacher Induction Program. The aim to increase teacher retention in education, by building teacher confidence and networks. It also links with universities to get credits for teachers, credits can be used to get rise up on the payscale . 4000 teachers have participated in the summer institute since 1984. he Teacher Institute also conducts research around the training they do with teachers, to better inform their practice.



Screen capture of Exploratorium website: Teacher Institute

Key lessons

- Cutting edge science engagement opportunities, informed by research, that allow people to explore STEM concepts provide high STEM engagement to the general public.
- Having a range of activities at different times enables engagement of a broad audience.
- Interactive exploration of STEM concepts allows the public to engage and build public awareness.
- Supporting teacher development throughout the teacher's lifespan will ensure greater teacher retention.

Early childhood, primary and secondary education

Early childhood, primary and secondary education includes any institution involved in the delivery of formal STEM learning and teaching of young people. Education plays a key role in STEM engagement and in many cases can be the first exposure to STEM for many young children. Early childhood, primary and secondary education provide many avenues to promote STEM engagement, such as providing learning experiences through curriculum-related activities, relevance by linking in real world experiences, expertise by linking in industry and research, and extension programs and experiences such as mentorships.

Education can play a key role in connecting young people with future pathways, including employment in STEM. It also plays a crucial role in connecting and communicating with key influencers of young people, including their families, which can play a pivotal role in changing perceptions about STEM on a broader scale. It was identified through the Fellowship research that primary and secondary education (no early childhood facilities were visited) had a number of initiatives in place to change the culture of STEM, promote STEM engagement and participation and raise the profile of STEM.

Some key activities observed in the study included the creation of both extra-curricula and curricula experiences, as well as programs that support teachers in schools to deliver quality STEM learning and teaching. Extracurricular experiences observed included one-off and sustained opportunities that engage young people in learning outside of the classroom or connect parents/family to different STEM pathways. Examples include clubs for students in STEM subjects (e.g. those being run at High Technology High School, Thomas Jefferson High School, Raisbeck High School, Olari Lower and Upper Secondary School and the LUMA Centre Finland).

Additionally, students were provided with opportunities to work with STEM experts in industry, research, and STEM business to provide genuine opportunities for young people to make a difference and experience STEM-based pathways before they leave school (e.g. High Technology High School, Thomas Jefferson High School, Raisbeck High School).

Schools facilitated extended STEM learning through mentorship programs that formed a part of formal school learning. These mentorship programs enabled students to connect with industry and research, have real-world experiences of STEM and conduct research projects that contributed towards their level of achievement (e.g. High Technology High School, Thomas Jefferson High School).

Key activities also included the creation of meaningful STEM curriculum experiences. This was observed through programs that linked curriculum to real world concepts, context and opportunities that allowed students to make a real-world impact and explore their passions and interests (e.g. High Technology High School, Raisbeck High School, Olari Lower and Upper Secondary School).

Teachers were supported to deliver such curriculum through the development of embedded learning and teaching units that support students to undertake STEM learning through inquiry-based projects (e.g. High Technology High School, Thomas Jefferson High School). Teachers in schools were also supported through resources provided by STEM outreach groups and organisations to link classroom curriculum with competitions and programs (e.g. LUMA Centre Finland, High Technology High School and Innokas).

Schools were also found to support the development of teacher capacity to implement STEM learning through linking teachers with professional learning opportunities that are both non-formal and for accreditation, as well as resources that support learning and teaching of STEM subjects (e.g. Olari Lower and Upper Secondary School).

High Technology High School, New Jersey, US

High Technology High School is a special high school designed to develop student skills in pre-engineering. It was developed as a benchmark school for education excellence. The school aims to develop student skills for the broad range of careers that requires engineering technical skills. It creates opportunities for extra-curricula programs/clubs for students in STEM by providing a range of clubs and outreach. Some of the STEM Clubs are self-formed by the students (e.g. STEM*in*ists is a group of girls that run lunchtime experiments, do outreach to local primary schools and link with female mentors to discuss women's issues).

A range of their classroom curriculum is linked with competitions and programs developed by STEM outreach organisations, which provides incentives and relevance to student learning (e.g. VEX Robotic Competitions). High Technology High School's learning and teaching units support students to undertake STEM learning through inquiry-based research projects.

Research is a large component of student learning and contributes towards their overall grade. Student research projects link to real world concepts and opportunities that allow students to make an impact. Many students go on to share their developments, research and innovations through competitions or with local industries. High Technology High School provides students with mentorship programs within their senior curriculum, allowing students to be placed in industry or research for one day per week for a semester. Students found the mentoring program is a great way to determine their future pathways in STEM and to engage and work with STEM experts in industry, research or business.

Screen capture of High Technology High website overview

Key lessons

- Inquiry-based learning promotes high student engagement and achievement.
- Linking STEM learning to competitions promotes high engagement, skill development and relevance.
- Mentorships enable students to connect with STEM experts, supporting current learning and future pathways.

Thomas Jefferson High School for Science and Technology - Alexandria, US

Thomas Jefferson High School for Science and Technology is a public STEM high school that provides students with a challenging learning environment to develop their skills in STEM. The school has a core focus of developing students 21st Century Skills around critical thinking, creativity, communication and collaboration. It also aims to develop students that have advanced communication skills. Students develop their 21st Century Skills and undertake STEM learning in everything they do in the school. Every student is a school leader, taking visitor tours and advocating for the school, linking in with the STEM community and conducting and sharing their research-based projects.

In their research project students are able to explore their interests through the research they conduct, whether it be quantum physics or oceanography and this is a major component of their overall grade. Links to real world concepts, contexts and opportunities through the teaching and learning at Thomas Jefferson High School, allows students to make an impact in the world around them. One of the main avenues the school does this is to provide research projects as a part of the curriculum and mentorship programs. This allows students to engage with and work with STEM experts in industry or research.

The mentorship program in particular provides the opportunity for concentrated research or project development in a specialised field under the leadership and direction of experienced local scientists, engineers, and other professionals in scientific and technological industries or businesses. Students apply for the mentorship program, for successful students into the program it provides them with an avenue to explore their interests and apply themselves in a real-life setting. The projects students complete are presented at the conclusion of the program and contribute significantly towards their final grade. The mentorship program has proven to develop student confidence, resilience, creativity and critical thinking skills in solving relevant and stimulating problems.

Thomas Jefferson High School is an outstanding example of what a school can achieve with partnerships. It has a separate Partnership Fund that fundraises and establishes partnerships for the school. This Partnership Fund has supported the school to acquire new research equipment to account for any gaps in public education funding, enable internships for students in local STEM companies during the summer, promote and link the school with global partners and, support outreach programs so that more students can benefit from the Thomas Jefferson High School experiences. Parents, corporate leaders, and staff work collaboratively to drive the success of the Partnership Fund to raise the profile of STEM.

Key lessons

- Targeted development of 21st Century Skills builds capable, articulate and adaptable students.
- Mentorship programs provide real world STEM experiences for students to prepare them for their future pathways and promote high STEM engagement.
- Research projects (school-based or through mentorship programs) contribute towards a major component of a student's level of achievement being embedded as a part of learning, not an add-on.
- Partnerships with the community, alumni, industry, research and business can enable and extend school programs and student opportunities.
- Involving key influencers in school initiatives can raise the profile of STEM.
- Outreach opportunities for students to give back to the community in areas of STEM, and also providing special STEM programs during the weekend and in the summer for younger audiences, provides positive connections with the community.

Olari Lower and Upper Secondary School, Espoo, Finland

A public high school that provides extension in mathematics and science. This high school provides a range of extra-curricula programs and clubs for students to engage in including local science and mathematics competitions.

The learning and teaching supports students to link to real world concepts, contexts and opportunities. Students regularly go on excursions into the local environment and to industry to see the application of their learning in real life. Students get to engage with local STEM experts in industry, research and business to extend their knowledge and experiences beyond the classroom, an example of this was students working with Rovio the company that developed Angry Birds from Espoo around computer programming and other relevant concepts.

Olari Lower and Upper Secondary School provide their teachers with autonomy and the room to apply their professional skills as necessary to teach concepts in the classroom. Teachers are supported to build their capacity by the school linking teachers with professional learning opportunities both locally and nationally.

Key lessons

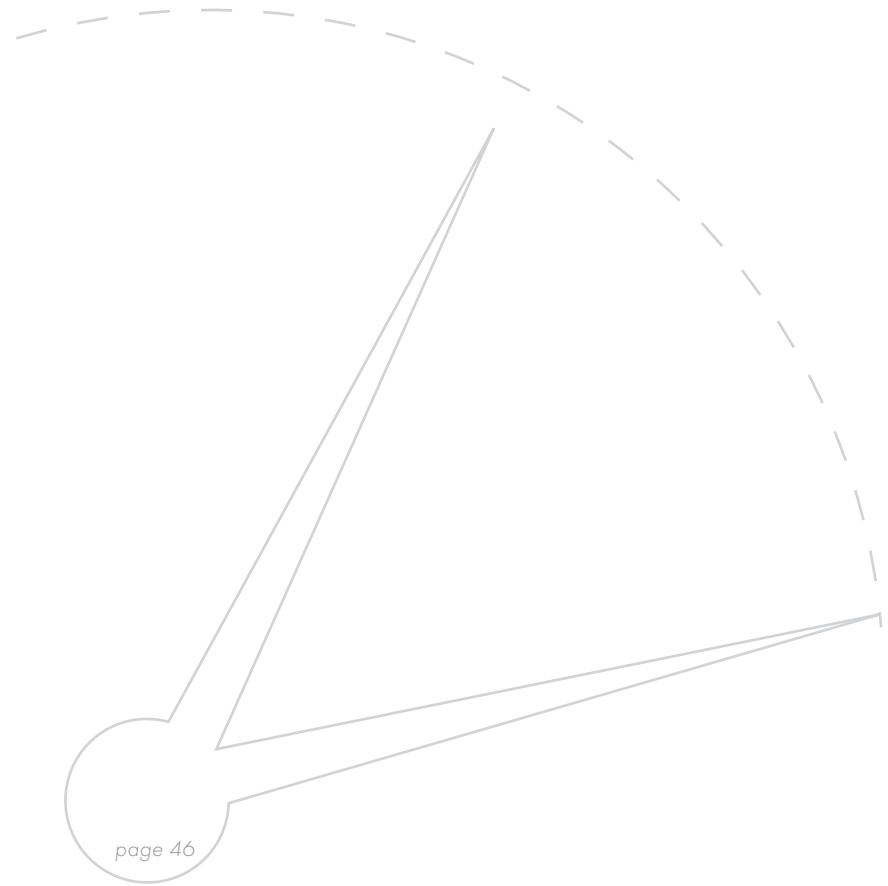
- Engaging students with STEM experiences in the local environment promotes student engagement and provides authentic learning applications.
- Supporting teachers to build their skills set in STEM teaching build professional capacity.

Benchmarks for STEM programs for young people

Through observations of a diverse range of organisations undertaking STEM engagement programs, essential elements were repeatedly identified as key components in high performing programs aimed at young people.

These elements contributed toward program success in engagement of young people, the number of young people engaged, the impact of the engagement activities, the diversity of programs, the ability to engage young people from underrepresented groups, the longevity of the program, the diversity of partnerships involved and the accessibility of programs for a broad range of young people in various locations.

Table 1 identifies these key elements as benchmarks, which can be used to inform new STEM engagement programs with the necessary key elements to successfully engage young people and sustain their programs. These benchmarks will also enable established programs to diversify, to evolve and be sustainable.



Element	Elaboration
Tailored and accessible	Program can be customised to suit the audience needs, or is developed with the community context and audience in mind. Can be delivered in a range of formats to enable broad accessibility, for all learners and contexts. *i.e., reducing limitations that come with physical location (rural/remote), resourcing (low cost, flexible resources available in a range of formats), special needs (learners with disabilities) and be translatable across different cultures.*
Open	Resources are free to use for education purposes or published under Creative Commons Share-Alike Attribution for remixing and re-sharing for non-commercial purposes. *Open-source resources allow for community customisation and re-sharing and enable communities to adapt resources for different contexts and needs; or to take resources and deliver them in their own contexts.*
Evidence-based	Programs are established on empirical evidence around the best practice for promoting and sustaining engagement in STEM.
Evaluated	Systematic evaluation of program effectiveness and impact is integrated into the program. Measurements focus on both reach (how many young people engage and the location that they engage) and impact (the extent the program supports or influences young people's decisions to choose STEM pathways). Program evaluations are published online.
Research-based	Either conducts research on STEM engagement topics (depending on the type of program), or supports others to engage in research that builds a shared understanding of STEM engagement and the STEM context. *i.e., partnering with research or STEM organisations/groups on research projects; providing access to participants or data for STEM research.*
Diverse	Specific and targeted STEM evidence-based strategies or training, integrated into the program or informing the design of materials, to effectively engage and build aspirations for girls and other underrepresented groups.
Retains and Extends	Programs are designed to sustain engagement and exceed "one-off" events or experiences. Identified pathways for the intended audience to stay engaged in STEM programs, learning and communities. *i.e., acknowledges where their program fits within the broader STEM education landscape, as well as other programs that provide extensions or further support. (e.g. could be point participant to an extension program or resources after reaching an age-limit or completing a training course).*
Scales	Considers strategic opportunities for scaling effective programs to have greater reach and sustained impact, with greater efficiency and use of resources. i.e., using peer-training models, harnessing online technologies, open-source resources.
Supports	Develops resources, or curates existing resources, that can inform and support key influencers about STEM and STEM engagement. *i.e., Resources that provide support for parents to engage in informed conversations with their children; resources for teachers to integrate or connect the program into their classroom learning.*
Partners	Has links to relevant industry, business, education, community organisations that can inform and enhance the program(s).
Relevant	Experiences are authentic, relevant and linked to the real world. *i.e., Programs provide opportunities to link with audience interests, make an impact to real world problems and/or link to STEM mentors.*

Table 1: Benchmark elements identified for high-performing STEM programs

Following the identification of the benchmarks of high-performing STEM programs, these factors were mapped against the Four Pillars (Education, Outreach, Innovation and Research) identified by the Australian Chief Scientist, as essential in the path to Australia's successful future in STEM. Figure 2 illustrates the how the benchmarks fit within the four pillar model, and shows the key partnerships and interconnections essential for STEM programs to succeed.

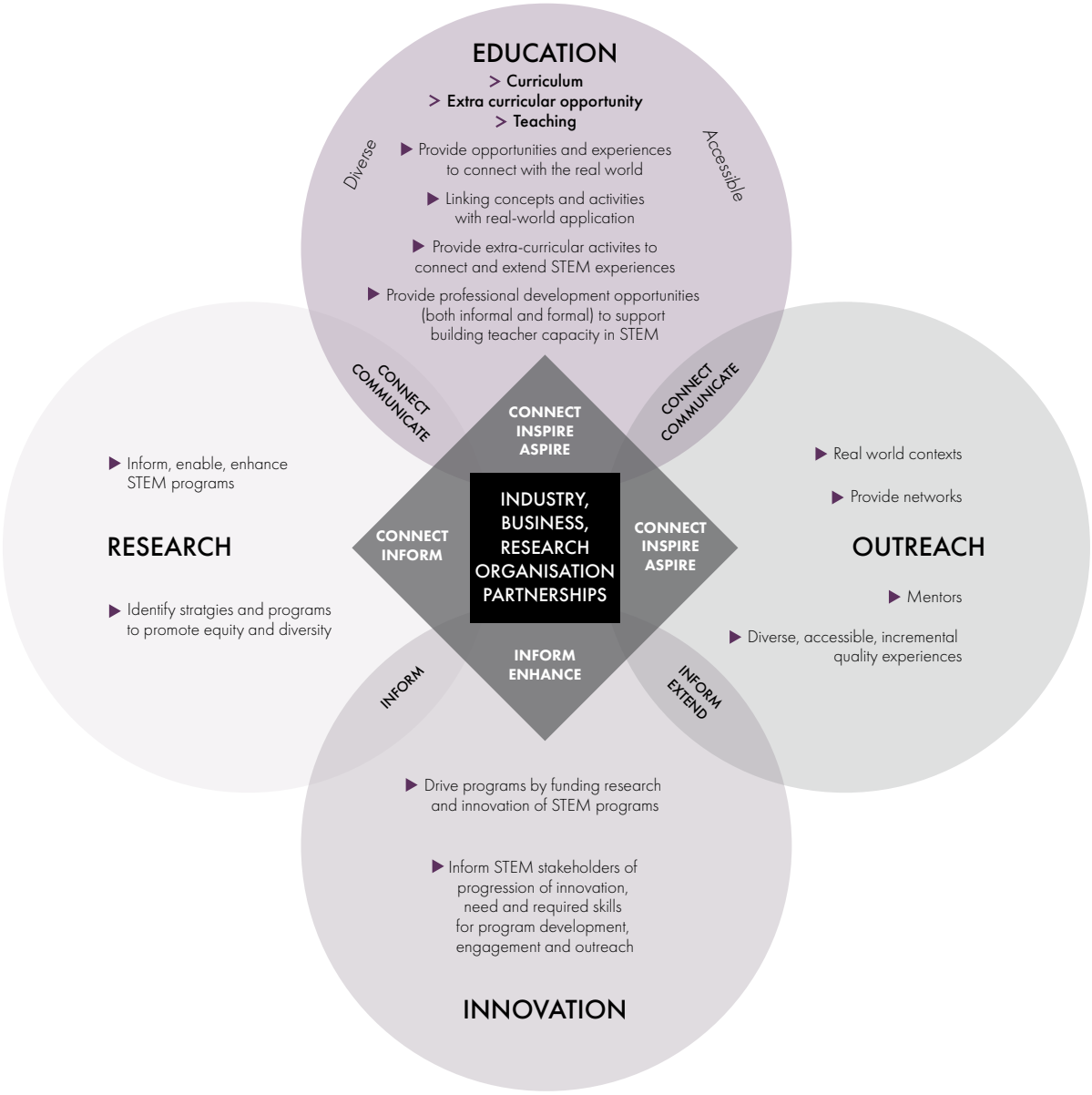


Figure 2: Benchmarks and key STEM initiatives linked with the Australian Chief Scientist's Four Pillars

Practical insights for implementing STEM programs: targeting girls

There is a diverse range of barriers and drivers that inhibit or enhance the engagement and retainment of girls in STEM-related pathways. The drivers often vary depending on the barriers that arise. The diversity of these barriers vary from country to country and for girls of different backgrounds. This issue deserves dedicated research to be completed within the Australian context to best identify the specific barriers that exist for girls in this country, and the key drivers for engaging Australian girls. Through the Fellowship research, observations were made around the key challenges and strategies required to engage girls from the perspective of the organisations visited in different countries.

Challenges/Barriers observed for girls engaging with STEM

- The fear of failure and lack of confidence of young girls in STEM
- The lack of relevance to everyday life, STEM being an abstract construct
- Lack of links to the 'humanness' around STEM
- Parents/Caregivers lack of understanding and therefore lack of support towards STEM pathways
- Misconceptions and stereotypes perceptions around STEM industries and professions
- Lack of funds to access opportunities for disadvantaged girls
- Lack of role models in STEM industries and post-secondary education, particularly in leadership positions
- Challenges around the culture of STEM industries and support for women to thrive
- Lack of clarity on STEM careers (including job titles) and professional activities.

Key strategies for engaging girls

This research uncovered a number of strategies for promoting the engagement of girls in STEM education and STEM pathways. Figure 3 below focuses on four key areas: messaging, girls-only opportunities, family involvement and authentic connections. This is not an exhaustive list, rather, it is intended to provide some insights into actionable strategies.

MESSAGING

Effective messaging can attract girls to consider STEM and help girls to envision themselves as STEM professionals, as well as help to support their key influencers. This includes the consideration of effective messaging strategies from marketing to role model communication.

Key tips for effective messaging:

- Use adjectives to describe and characterise STEM professional roles and activities.
- Have role models and volunteers share their interests and activities outside of their STEM-related activities.
- Develop resources for individual STEM fields for targeted messaging and information.
- Evaluate STEM program and organisation media for unconscious bias, and ensure diverse representation in media.

Example Resources:

- Techbridge Girls: Role Model Resources
- WISE Campaign: People Like Me Packs
- Hypatia: Good practices on gender inclusion in STEM communication
- National Alliance for Partnerships in Equity: STEM equity pipeline
- Bias Busters @ CMU

FAMILY INVOLVEMENT

The involvement of family, especially parents, in STEM learning experiences is invaluable in providing support for girls engaging in STEM experiences. Parents are role models and key influencers of a girl's career pathway considerations. Involving family in STEM, not only enriches a girls' experiences, it also connects STEM into the home.

Key tips to promote family involvement:

- Host orientation and family evenings that family members can be involved in.
- Provide updates for family members on achievements and opportunities and events to celebrate achievements.
- Provide resources for families to engage in STEM learning activities at home with their children.
- Provide information resources for parents that inform them on STEM career opportunities and pathways.

Example Resources:

- Girls Inc.: Tips for parents
- Techbridge Girls: Science: It's a Family Affair
- University of Sheffield Women In Engineering: "Suzy & Ricky Crash Landing"

GIRLS-ONLY OPPORTUNITIES

Providing girls-only opportunities and learning spaces provides the opportunity for girls to be empowered by opportunity and feel comfortable to question, try and lead in STEM. By structuring these safe environments girls are more willing to try and experiment with STEM.

Key tips to design positive girls-only opportunities and spaces:

- Provide a comfortable and safe learning environment.
- Create a gender-neutral environment, free of "STEM stereotypes".
- Provide opportunities for girls to connect with female mentors in STEM.
- Ensure the environment supports girls to try, play and fail without judgement.

Example Resources:

- FabFems
- Techbridge Girls Role Model Training: "Giving Girls Feedback"
- WISE Campaign: Girl Friendly Physics

AUTHENTIC CONNECTIONS

Connecting with real world experiences that make an impact, female experts for support and inspiration and STEM pathways provide authentic connections with STEM opportunities that promote sustained engagement of girls in STEM.

Key tips to enable girls to build authentic connections:

- Industry visits and experiences.
- STEM projects that solve compelling problems, with real life contexts for 'social good'.
- Mentorship programs where girls link with diverse female STEM experts.
- Supporting girls' attendance at special STEM events and celebrations.
- Emphasise the human element & opportunities of STEM professions, through awareness raising sessions.

Example Resources:

- Techbridge girls: Changing the Game for Girls in STEM
- National Girls Collaborative Project: Collaboration Guide
- Girl Scouts STEM Programs Benefit Girls
- WISE Campaign: Science: It's a People Thing

FIGURE 3: Top strategies and example resources for engaging girls in STEM programs

A VISION FOR STEM EDUCATION

From the observations of best practice in STEM internationally, a collection of perspectives for promoting engagement in STEM was derived. From this, a vision for a thriving STEM nation has been compiled, that includes the following key components, which have been collated from a combination of outstanding STEM organisations.

Many of these components are prominent in Australian STEM organisations and programs listed in the Australian Chief Scientists STEM Program index. This vision's purpose is to outline the key components as a whole, which may enable national gaps to be identified and programs to be enhanced and strengthened.

The key components of the successful STEM strategy are:

1.

Coordinated collaboration between stakeholders across the STEM ecosystem, adjudicated by prominent STEM bodies currently active within Australia. This includes:

a. A national vision for engagement, inclusion and strategic global collaboration.

b. Opportunities for Australian STEM stakeholders to intersect and cross-pollinate and contribute towards driving a national vision.

c. Guidelines for how stakeholders can engage and a process for establishing commitment to action.

d. Coordinated, co-created and strategic efforts for a national STEM agenda, but also targeted efforts for raising the profile and quality of specific STEM fields.

e. Strategy driven by relevant STEM statistics and mapping of the stakeholder landscape.

f. Infrastructure to connect stakeholders to build capacity within the STEM ecosystem.

2.

Stakeholders commit to actionable strategies that change the culture of STEM to be equitable for all and to ensure equality, where there is a balanced representation of all groups of people within the STEM ecosystem. Factors necessary to change the culture of STEM include:

a. A shared vision, priorities and common language around STEM to develop a collaborative, positive and inclusive STEM culture within and outside of education and industry contexts.

b. Inclusive communication with families and other enablers, particularly where enablers require support to communicate STEM to young people.

c. Increasing the opportunities to engage with STEM in everyday life through various forms to make the concept of STEM more accessible, including STEM stories, information, activities and videos via the media, social media and community events.

d. Celebrating STEM achievements within mainstream environments.

e. Inclusion and diversity in all components of the STEM ecosystem, including underrepresented groups.

f. Unconscious bias training to build awareness and inclusivity within industry, business, research and education.

3. Sustainable inclusive education and engagement for all STEM fields, from early childhood through to professional leadership. Factors to be considered for success include:

a. STEM stakeholder landscape mapping, with regards to STEM engagement, to identify best practice. These exemplars can be used to address gaps and streamline efforts to focus on coverage and needs, rather than duplication.

b. Training for deliverers and mentors, to ensure quality delivery and messaging.

c. Quality programs developed using evidence-based research.

d. Opportunities that allow engagement in playful and inquisitive STEM learning.

e. Development and expansion of programs with scalability and accessibility in mind.

f. Incremental opportunities for sustained engagement and contribution.

g. Iterative development, guided by data collection (short-term and long-term) and regular program evaluations.

h. Industry, business and research links.

i. Targeted opportunities that reach out and bring in underrepresented groups into STEM programs.

j. Networking/mentoring opportunities that lead to sustained STEM connections between like-minded individuals and diverse role models.

k. Diversity in programs, including online collaborative programs and face-to-face programs to ensure accessibility and broaden the scope of outreach.

l. Quality resource development that is inclusive, authentic, dynamic and responsive to current STEM trends.

4. Curriculum implementation (both in school classrooms and outreach) empowers students through choice, skill development and allows students to realise real world applications of STEM. For success this includes:

a. Linking concepts and activities with real-world application that show diversity of STEM and provide genuine opportunities to make a difference.

b. Skills/process focussed inquiry-rich activities that develop learners as innovators and problem solvers.

5. Develop and sustain professional capacity and engagement of teachers. Components to develop this include:

a. Mentoring for beginning teachers - to promote collaboration, networking and skills development (linked to experienced teacher/s in leadership roles).

b. Leadership training for established teachers - to build professional capacity, sustain engagement and promote retention (linked to mentoring program).

c. Building teacher capacity through professional learning opportunities that are both non-formal and for accreditation.

d. Contextualised STEM education professional development that allows teachers to develop depth of knowledge and skills within a particular STEM discipline.

e. Support for grassroots peer-to-peer professional learning and collaboration to allow for 'cross pollination' of ideas and local champions.

KEY ACTION POINTS

Following the STEM Fellowship research, the following key actions have been determined as pivotal points to drive positive change in the Australian national STEM ecosystem. The following action points have been developed, based on observed best practice from overseas models, to support the participation of young people, particularly girls, in STEM fields during their education and career.

1. A coordinated national strategy for building teacher capacity in STEM Education and within specific STEM disciplines. Best practice in teacher education is adopted uniformly across the nation, to ensure consistent and quality pre-service teacher professional competencies. This would be achieved through a national university STEM framework, similar to LUMA Centre Finland.

2. Develop an industry-funded national project to build capacity of practising STEM teacher professionals, which would provide in-depth teacher professional development targeting the scientific and key processes of STEM education. This would be combined with continuous access to relevant and quality resources, based on real world problems that develop in-demand STEM skills aligned with the Australian Curriculum, similar to Project Lead the Way.

3. Map Australia's STEM ecosystem, identifying key stakeholders, programs and exemplars in best practice. The launch of a study, similar to this Fellowship to review best practices of existing STEM programs and initiatives in Australia, and those particularly targeting Australia's underrepresented groups (e.g. girls and women and Aboriginal and Torres Strait Islanders).

4. Develop a STEM framework, including the identified benchmarks in Table 1, to inform and validate the planning, implementation and evaluation of STEM engagement programs. This framework can be used to inform the continuation of mapping the capacity and needs of the Australian STEM ecosystem, and guidelines for how stakeholders can get involved.

5. Maximise opportunities for engagement, inspiration and building aspirations of girls by establishing a Celebration of STEM Women, modelled off the Grace Hopper Celebration and encompassing the STEM ecosystem, with the provision of major funding to promote participation of young women, in particular from underrepresented groups, and from regional and remote areas.

6. Conduct industry-led research (either conducted by STEM industry, funded or in partnership with a funding agency/organisation) into targeted STEM Education topics in need of urgent attention, including particular STEM disciplines with significantly poor participation and engagement of Australia's most underrepresented groups (e.g. girls, women and Aboriginal and Torres Strait Islanders).

7. Develop in collaboration with industry, a national student STEM mentorship program and provides extended, in-depth, immersive experiences for senior secondary students that connects and sustains student engagement in STEM. This program would allow students to conduct a research project, embedded into their industry/research placement, contributing towards their overall level of achievement. This program could be modelled on the successful mentorship programs established in High Technology High School and Thomas Jefferson High School.

8. Develop a suite of STEM engagement resources, drawing on existing resources available, tailored to the Australian STEM context and different STEM disciplines that can support key stakeholders in communicating STEM careers and opportunities effectively, and in particular supporting families. This includes resources for effective evidence-based messaging by key influencers, unconscious bias training (outside of industry and in relation to young people) and effective marketing of STEM fields to young people and their families.

CONCLUSIONS

STEM isn't simply a description for the combination of subjects; it is a much more complex idea and as such requires strategic and coordinated action. Engaging and sustaining young people in a lifelong journey in STEM requires a different type of approach. It requires students being active participants in learning.

Educators, industry, mentors and volunteers are the facilitators and enablers on this journey, and young people are the enactors, taking control and collaborating with others to solve real-life problems. This type of approach reflects the way STEM industry works, develops key 21st century skills in young people and connects them with relevant experiences to enable them to be well prepared to embrace a future in STEM.

A limitation of this research is that the scope focused on international best practices of STEM programs outside of Australia. Many quality STEM programs exist in Australia, as outlined in the Australian Chief Scientist Index of STEM programs, however, key lessons identified from this research can guide the development, adaptation or expansion of STEM programs here. While we can learn from STEM programs overseas, it is also important to determine key strategies and programs that support our unique Australian context and broaden the participation of Australian students in STEM to meet the needs of our Australian STEM industry.

The Key Action Points of this report have been identified as the practical next steps to promoting engagement of young people, in particular girls, in STEM. Collaboration, funding, research, resourcing, quality experiences and a STEM framework, are key to progressing Australia's STEM ecosystem.

Global action, connection, collaboration and communication will ensure our STEM ecosystem thrives, that our young people are global citizens and that they evolve with the ever-changing world we live in. To address our global problems we need young people who are adaptable, creative, able to think critically, and can use their initiative and collaborate with others to develop solutions and build a productive future for themselves and future generations. Through collective and sustained impact, within a STEM ecosystem, we can drive change and ensure a diverse and thriving STEM workforce of the future.

ACKNOWLEDGEMENTS

This research is funded by the Australian Government (Office for Women, Department of the Prime Minister and Cabinet), in partnership with Chief Executive Women Ltd (CEW). Thank you to the following individuals and organisations for their support and guidance: Fellowship interview panellists, Fellowship mentors (Belinda Gibson, Lyn Beazley & Sally-Ann Williams, Professor Katrina Falkner), endorsers and supporters of Fellows (QLD Chief Scientist's Office, Women in STEMM Australia, Google, The University of Adelaide, The Queensland Department of Education and Training, The Global Tropics Future Project and James Cook University).

Thank you sincerely to the individuals and organisations who participated in this research project. While not all programs and people visited are mentioned explicitly in the report, their expertise and advice have greatly informed the key findings of this report and their time and willingness is greatly valued.

Acknowledgment of the key people and STEM programs that contributed towards the Barbara Cail STEM Fellowships

(also outlines the itinerary by country)

New Zealand

- Dr Andrew Luxton-Reilly and Nazish Khan
  University of Auckland, Computer Science Education Research
- Dr Mahsa Mohaghegh
  UniTech, SheSharp
- Prof. Tim Bell
  Computer Science Education Group, University of Canterbury
- Richard Rowley
  The Mind Lab, Auckland
- Matthew Richards
  Te Papa Museum, Wellington

UK

- The University of Sheffield,
  Engineering Education and Outreach,
  host Prof Elena Rodriguez-Falcon
  https://www.shef.ac.uk/mecheng/staff/rodriguez-falcon2
- Keith Purves
  Women in Science and Engineering (WISE) Campaign
  https://www.wisecampaign.org.uk/
- Dr Sue Sentance
  King's College
- Prof Simon Peyton-Jones
  Computing At School Director
  and Researcher at Microsoft Research Lab
- Anne-Marie Imafidon
  Founder, Stemettes - London
  http://stemettes.org
- Karen Davies, Manager Learning research projects and
  Beth Hawkins, Enterprising Science, Science Museum London
  http://www.sciencemuseum.org.uk
- 2016 ASDC conference
  (Association for Science and Discovery Centres in the UK)

Finland

- Prof Lauri Malmi,
  Director of LeTech Group, Aalto University
- Linda Luikas,
  Hello Ruby and Rails Girls http://railsgirls.com/
- Kati Sormunen, Coordinator,
  Innokas Program - University of Helsinki
  http://www.innokas.fi/en/events/digitalfabrication
- Rita Järvinen, Mathematics teacher, consultant teacher and Kaisa Tikka, Headmistress
  Olari lower and upper secondary school
  http://olari.fi
- University of Helsinki
  - LUMA Centre Finland
    (Computer Science- Linkki Centre, Dr Lea Kutvonen)
    (Mathematics - Summamutikka Centre, Professor Juha Oikkonen, Jenni Räsänen & Emma Haakana)
    (Chemistry - Gadolin Centre)
  - Teacher Training, University of Helsinki (Tiina Korhonen)
  - Dr Maija Aksela, Director of the Luma Centre Finland

Germany

- 2016 Workshop in Primary and Secondary Computing Education (WiPCSE) and
  International Conference on Informatics in Schools (ISSEP) joint Conference
  - Various speakers, educators and researchers present at the two conferences.

Singapore

- A/Prof Lim Tit Meng, Chief Executive, Chew Ling Ling, Saminathan Gopal and Anne Dhanaraj,
  Science Centre Singapore
  http://www.science.edu.sg/Pages/SCBNewHome.aspx
- Brendan Burke, STEM Coordinator,
  GEMS World Academy
  http://www.gwa.edu.sg

US

Alexandria

- Dr Evan Glazer, Principal and Pam Gravitte, Assistant Principal
  Thomas Jefferson High School
  https://www.tjhsst.edu/

Houston

- 2016 Grace Hopper Celebration for Women in Computing
  Various programs, speakers, attendees and initiatives present at the Celebration.

New Jersey

- Kevin D. Bals, Principal,
  High Tech High - New Jersey

New York

- Google K-12 CS Education (Dr Chris Stephenson)
- CSed Visions/CS4All Roundtable
- Dr Leigh-Ann DeLysser,
  CSNYC Team, Co-Chair CSforAll Consortium http://www.csforall.org/
- Suzanne Harper, Chief Girl Experience Innovator,
  Girls Scouts STEM http://www.girlscouts.org/en/about-girl-scouts/girl-scouts-and-stem.html
- Stephanie Wortel-London, Director of the Global STEM Alliance,
  New York Academy of Science
  http://www.nyas.org/WhatWeDo/ScienceEd/NeXXtScholars.aspx
- 2016 World Maker Faire

US *continued*

Los Angeles

- Dr Colleen Lewis and Professor Zach Dodds,
  Computer Science Education, Harvey Mudd College

San Francisco

- Linda Kekelis, Martha Pena, Techbridge Senior Program Manager,
  and Renny Talianchich,
  TechBridge Girls
  http://www.techbridgegirls.org
- Kaye Storm,
  Stanford University Office of Science Outreach
  https://oso.stanford.edu/
- Dr Shuchi Grover, SRI International
- Mo Fong, Director, K-12 (Pre-University) Education Outreach and
  Maggie Johnson - Director of Education and University Relations, Google
  https://www.google.com/intl/en/about/
- 2016 FabLearn Conference, Stanford University
- Lexie Carlson, Program Manager, Teacher Institute, Exploratorium

Seattle

- Emily Thatcher Project Manager and Therese Tipton, Principal,
  Boeing Academy for STEM Learning / Raisbeck High School
  http://www.highlineschools.org/raisbeckaviation
- Reba Gilman, VP of Education, Seth Margolis, Director of the William A Helsell
  Education Department, and Melissa Edwards, Director of Digital Learning,
  Museum of Flight
- Gilda Wheeler, Washington STEM Program Coordinator, Washington STEM http://
  www.washingtonstem.org
- Casi Herrera (and Karen Petersen), Program Manager,
  National Girls Collaborative Project
  https://ngcproject.org/about-ngcp

Pittsburgh

- Dr Carol Freize and Dr Jeria Quesenberry,
  Carnegie Mellon University,
  SCS4ALL Group
- BiasBusters@CMU Workshop
- Capacity Building for Accessibility in Computing Workshop
  https://www.scs4all.cs.cmu.edu/news/new-workshop-capacity-building-for-accessibility-at-cmu/

Washington DC

- Jennifer Mandel, Head of STEM initiatives,
  Lockheed Martin
  http://www.lockheedmartin.com/us.html
- Ana Kay Yaghoubian, STEM Senior Manager, Shana Sabbath and Claudia Richards
  American Association of University Women
  http://www.aauw.org

ABOUT THE AUTHORS

Sarah Chapman

Sarah Chapman is the Head of Department of Science at Townsville State High School, North Queensland, and is in her fourteenth year of teaching. Sarah is passionate about inspiring, engaging and empowering people through STEM, fuelling sparks of curiosity in the classroom that build strong lifelong connections with the wonder, ingenuity and dynamic possibilities of STEM. Sarah commits extensive portions of her own time lifting the profile of science education, by working with students, teachers and the broader community. In 2016 Sarah was instrumental in establishing a Virtual STEM Hub for North Queensland. In this role Sarah developed authentic STEM enhancement opportunities, with industry, research and education, for students (gifted, Indigenous and socio economic disadvantaged) from regional, rural and remote areas of North Queensland. In 2014 Sarah, with support from Inspiring Australia, established the Townsville STEM Hub to bring together STEM organisations in the region. Sarah is an Executive Committee member of Women in STEMM Australia, promoting the priorities of STEM education for girls and assisting in the coordination of STEM engagement events. She became a Science Teachers Association (STAQ) member in 2008 and the STAQ Vice President in 2016. Sarah has travelled to Japan in 2014, the United States in 2015 and Singapore, Finland, England, the United States and New Zealand in 2016 to expand her knowledge, skills and networks in STEM education, contributing towards building the capacity of STEM education nationally.

Sarah Chapman was selected for one of the inaugural Barbara Cail STEM Fellowships in 2016, to research best practice in engaging young people into STEM. Sarah was awarded the prestigious Prime Minister's Secondary Science Teaching Prize for Excellence in Science Teaching in 2013. In 2014 she was selected as a Queensland Government Science Champion. Sarah's work has also been recognised with a prestigious Peter Doherty, Outstanding Teacher of Science Award in 2008 (Queensland Government) and an Australian Award for Teaching Excellence in 2009 (Teaching Australia). She also led a cluster of schools to be awarded the Commonwealth Bank of Australia Showcase Award for Excellence in the Middle Phase of Learning in 2009 (Education Queensland). In 2010 Sarah was awarded the James Cook University Alumni – Outstanding Early Career Award. Sarah graduated from James Cook University with a Bachelor of Science with Honours Class 1 in 1998, where she was awarded the Quantum Scientific Prize for best overall performance in the Physiology & Pharmacology Honours Program. She completed her Graduate Bachelor of Education in 2003.

Dr Rebecca Vivian

Dr Rebecca Vivian is a Research Fellow in the Computer Science Education Research (CSER) Group, at The University of Adelaide. Dr Vivian holds a Bachelor of Education (With Honours) and PhD in Education and holds expertise in K-12 computing education, STEM education and technology-enhanced learning. Dr Vivian is passionate about raising the profile of STEM fields in Australia and inspiring the next generation of STEM professionals. Her efforts focus on increasing awareness among the broader Australian community about the opportunities and diversity of STEM careers and building teacher capacity in STEM. In her role, Dr Vivian has developed innovative models for professional learning, including CSER's world-leading community-centric Digital Technologies MOOCs for teachers, with over 7,500 enrolments and over 6,000 community resources generated. Additionally, she co-developed PL-in-a-Box, with Google Australia, to empower teachers to facilitate professional learning at scale. She is a course designer for the AdelaideX edX MOOC, 'Think. Create. Code', that demonstrated innovative use of pedagogy and received high female participation and an excess of 20,000 enrolments in its first release.

Dr Vivian has collaborated with various stakeholders across industry, education, and government to deliver STEM education and research initiatives. She has acquired over $7.4 million in research funding, including $6.9 million from the Australian Federal Department of Education to expand the highly successful CSER Digital Technologies teacher-training program. Demonstrating her passion, Dr Vivian commits a great deal of her own time toward various STEM outreach endeavours including advocacy, events for Science Week and the Hour of Code, and presentations at teacher events. Her achievements as a young researcher and education leader have been acknowledged through awards such as the 2015 Australian Council for Educational Leaders (ACEL) "New Voice" in Education Leadership Research, 2016 University of Adelaide's Women's Research Excellence Award, the 2016 Barbara Cail STEM Fellowship Award, and in being selected to represent Computing Associations for Science Meets Parliament in 2016 and 2017. Dr Vivian was one of 50 Educators selected for Google's 2014 Certified Innovative Educator Program in Sydney, Australia. Further, Dr Vivian receives frequent invitations to contribute her expertise from a broad range of communities, including Computing, Higher Education, Teacher Education, government, industry and community associations. Dr Vivian has travelled widely across Australia and internationally, to present her research work and to learn about best practices in STEM Education, and has published her work in a number of high-quality journal and conference venues.

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