

Girls in STEM: Addressing SDG 4 in Context

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Abstract: Raising girls' aspirations for STEM careers is one way to address Sustainability Development Goal 4 (SDG4)—quality education—which seeks to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. Various strategies have been suggested in STEM education research literature to achieve this. One such initiative begins with exposing girls to STEM industries during their formative school years. While a range of industry-school partnerships exist, examples of successful models that might inform practice are scarce. This article describes an investigation into how industry professionals, university educators, teachers, and students successfully implemented a STEM education experience (Girls as Leaders in STEM (GALS)). Formative and summative evaluation processes were used to generate data through a co-design research approach to describe and measure changes in student practices, attitudes, and engagement in relation to STEM and leadership as a result of connecting to industry problems. This research focused on the analysis of teacher and student interview data generated upon the completion of the program, which provided feedback on the different aspects of the process and, in particular, the role of industry in relation to the girls' attitudes. This research highlights the benefits of industry involvement with girls in terms of their engagement with STEM, the authenticity of STEM learning, and the novelty of the learning experience. These benefits are discussed with respect to how they can raise girls' STEM aspirations and ensure equitable educational opportunities—aligning with SDG4.

Keywords: girls in STEM; industry partnerships; engagement; career aspirations



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1. Introduction

The United Nations 'Decade of Education for Sustainable Development' (ESD 2005–2014), built on previous understandings of sustainability, sought to influence the future through raising awareness, building capacity, and enabling experimentation and the implementation of good practice [1]. Seventeen worldwide Sustainability Development Goals (SDGs) were identified by the United Nations Development Program [2], with the aim that these goals would provide guidance for the future well-being of Earth and its inhabitants. Across the 17 goals, 169 targets and 232 indicators were developed to provide substance to the implementation of the goals, with an aspirational time interval of fifteen years (2015–2030). The SDGs consider the environmental aspects of a sustainable Earth, but with an awareness of the economic, social, and ethical impacts. There is a need for a broader, more sustainable approach across the planet, including a transformation within society and the sciences. Trying to service the needs of large national economies, political agendas, ecological needs, and social and cultural needs is a complex problem, and no one group or entity can solve it.

While sustainability issues can be found at specific locations around the world, the underlying causes of aspects such as poverty, epidemics, challenges to biodiversity, and conflicts (e.g., war) are linked to global societal patterns of living and behaviour. Van der Leeuw et al. [3] suggested that collaboration needs to occur at local, regional, national, and international levels if humans are to mitigate or solve these problems. Specific competences,

knowledge, skills, and attitudes are required to enable solutions to be found. This has major implications for teaching and education [4].

1.1. Links between Sustainability, Science, and Science Education

Over two decades ago, Kates et al. [5] proposed the idea of ‘sustainability science’, which they determined ‘seeks to understand the fundamental character of interactions between nature and society’ (p. 641). Recognizing the complexity of the problems set in both social and ecological/scientific fields, solutions can only be achieved through the collective action of multidisciplinary teams that adopt participatory approaches [6]. Spangenberg [7] suggests that what is needed is ‘traditional disciplinary-based science for sustainability and the transdisciplinary science of sustainability’ (p. 275). Sustainability science engages in broad transdisciplinary ways to focus on solving sustainability problems. Through education, we can involve young people by providing them with opportunities to engage in critical dialogue and practices [8]. In addition, science knowledge and practices, which provide insights into the way the world works, input into multiple industries, and social interconnections, are vital aspects that can help bring about change. Engaging young people in science provides opportunities for sustainability issues to be understood and advancements to be made.

1.2. Inequities in STEM and Science Opportunities

The national and international focus on STEM has increased significantly in recent years [9], particularly in light of STEM’s potential to impact global sustainability. Despite the international need and focus, many western countries, including Australia, have witnessed a significant decline in STEM participation in schools and higher education pathway choices and in STEM careers over the last 20 years. There is an ongoing international trend where science and STEM are impoverished by a lack of contributions from women and other diverse cultural groups [10,11]. The under-representation of women and cultural minorities in STEM disciplines is a concern. In particular, women are conspicuously absent from STEM fields, and research evidence suggests that girls’ self-selection away from STEM fields starts at an early age [9–12]. Falco and Summers [10] suggest that even with a degree in science or engineering, women are less likely than men to be employed in their STEM field, highlighting the under-representation of women in mathematics, physical science, and engineering fields. The pursuit of STEM careers, starting in secondary schooling, is also low [9]; this has been attributed a number of factors, including a lack of self-confidence in STEM subjects, low STEM identity [13], low STEM career aspirations, and a lack of support and/or encouragement to pursue STEM-related career goals [14,15].

The lack of inclusion of females in STEM careers is an equity issue and relates to the provision of quality, inclusive, and equitable education opportunities. This, in turn, aligns with Sustainability Development Goal 4, which calls for ‘Quality Education, ensuring Inclusive and Equitable Quality Education and promote lifelong learning opportunities for all.’ Ensuring quality science and STEM education for all young people, particularly girls, is indicative of the very real need to ensure that all people across all societies have equitable access.

Pahnke et al. [8] suggested that STEM education for sustainable development (STEM4SD) offerings consider a number of guiding principles. These principles suggest that STEM education in schools should:

1. Promote inquiry-based learning and scientific thinking and practice.
2. Encourage interactive, learner-centred teaching that enables exploratory, action-oriented, reflective, and transformative learning.
3. Reinforce a whole institution approach that focuses on the systemic development of the educational facility towards quality education and sustainability and considers the role of management at the school, state, or government level.
4. Foster independent thinking and responsible action that takes place in the learner’s context and involves the institution’s social and natural environment, providing

the opportunity to implement and experience real changes in the learners' own community, which then strengthens their capacity for agency.

5. Be compatible with the goals of sustainable development.
6. Strengthen evidence-based and reasoned argumentation, recognize complexity, promote diversity of opinion and change in perspectives, and encourage the critical reflection of values.
7. Empower present and future generations to use science, technology, engineering, and mathematics (STEM) skills and reflective reasoning to solve complex sustainability problems.

In this paper, we report on a project (Girls as Leaders in STEM (GALS)) funded by a philanthropic organisation (The Invergowrie Foundation) where the relationships between university educators, teachers, students, and industry professionals work together to provide girls with an experience of 'STEM as a way of thinking and acting' and the 'human nature of the STEM enterprise' [16] (p. 180). This unique partnership between different stakeholders, combined with the use of recognised teaching and learning methods, offers a useful model for leveraging industry partnerships to motivate girls in STEM. We argue that engaging girls in STEM offers the potential to respond to SDG4 in an authentic way. Our research questions are:

1. What is the impact of an industry-sourced problem solving and university-based mentoring program on girls' motivation in STEM?
2. How does the GALS program of collaboration between industry, universities, and schools facilitate ESD and SDG4?

2. Theoretical Perspectives

2.1. Girls and STEM Learning

A recent systematic review [13] of research that focused on the experiences of female students (aged 15–18) in STEM and employed social identity theory found that the social environment affected girls' STEM identity development and that 'ensuring STEM contexts are welcoming would encourage more women to pursue STEM degrees'. In addition to this, research has long advocated that social issues or elements draw girls' attention more than a clinical science experimental approach to STEM. For example, a recent study by So et al. [17] found that girls became more interested in STEM careers when they believed that STEM professionals built social relationships with others. This understanding of the social nature of girls' learning needs resonates with further work by Ortiz-Revilla et al. [18]. Ortiz-Revilla et al. [18] proposed a theoretical framework for integrated STEM education, which is applicable in this research. In considering the development of a framework for STEM education, the authors brought together Lauden's [19] ideas of the triadic network (commitment with theories, with methods, and with the aims of scientific work) with methodological inquiry approaches. Of special interest for their framework was the use of socio-scientific inquiry-based learning, which incorporates the integration of citizenship education, socio-scientific issues, and inquiry-based education to enable students to ask authentic questions, conduct inquiries, and take action [20]. Linking STEM learning with sustainability involves girls in the consideration of a range of socio-scientific issues and places them at the heart of undertaking their own enquiries.

2.2. The Benefits of Industry-School Partnerships

Recently, the Australian report 'Girls' Future-Our Future' [9] highlighted the potential of alternative education pathways to engage girls in a wide range of rewarding STEM occupations. Research [21] has suggested that measures are needed to raise girls' understandings of what a future in STEM might look like. These include improving teacher learning, changes to curricula, public-awareness initiatives, and the significance of role modelling and mentoring and industry-related experience for girls. In Australia, years 5–8 (secondary school begins with year 7 in Victoria) are a critical time when girls tend to turn away from STEM offerings at school [22]. To increase the awareness and participation of

girls in STEM and entrepreneurship education, a focus of effort on these years of schooling is required. Obviously, this is not a uniquely Australian problem, as evidenced by indications of similar research in Europe. In 1996, Iredale [23] commented on the benefits of school-industry partnerships, whereas Joyce [24] p. 5 suggested that ‘students and teachers profit through gaining an insight into the world of work, learning through first-hand experience about the needs of industry and how it works’.

One of the five areas of the ‘National STEM School Education Strategy 2016 to 2026 is the facilitation of effective partnerships with tertiary education providers, businesses, and industry [25]. Connecting schools and teachers with industry and community partners is essential for improving STEM outcomes for students, as it provides real-world connections for students in the STEM fields (Office of the Chief Scientist (2016)). Tytler and Corrigan [16] indicated that connecting students to people from STEM industry can lead to an ‘appreciation of the STEM disciplines as important and worthwhile perspectives on the world’ (p. 180). Such collaborations can provide students with ‘the most up-to-date scientific methods and information’ [26]. Specifically for girls’ education, the recent ‘Women in STEM Decadal Plan’ [11] highlights strategies relating to strengthening STEM teaching and proclaims the importance of ‘real-world’ STEM scenarios and the vital role of industry in knowledge transfer into education.

Industry can provide role models for girls when schools engage with industry partners in the design and delivery of STEM programs. Depending on the level of involvement, industry partners may also become mentors for girls. Recent research highlights the importance of role models and mentors for developing girls’ interests and understanding of STEM careers [9]. In STEM, a role model might be a parent, teacher, or industry person who represents an inspirational ideal and inspires others by their behaviours and achievements [27]. This is slightly different to someone who is a mentor. A mentor commits time to another (mentee) by providing guidance, motivation, and support, as well as shares information about their career path [28].

2.3. Making Industry-Education Partnerships Work

Partnerships, such as those between schools and industry, have been part of the school landscape for some time [29], with teachers often drawing on their resources to develop links with industry. The Education Council [30] suggested that teachers need resources, access to contemporary workspaces, and expertise from industry in order to keep them up to date with STEM careers and new STEM developments. Marginson et al. [29] and the Australian Industry Group [31] recommend that advice about useful partnership practices is needed for schools, school authorities, and potential industry partners.

Industry-education partnerships can be difficult to establish and gain educational benefit because of ‘contrasting practices and language’ between partners [32]. Brokers can help to alleviate issues that arise from the limited understanding of industry knowledge and practices by educators, and the limited knowledge of curricula and pedagogy by industry professionals.

3. Research Methodology—Design-Based Research with a Focus on Co-Design Aspects

The GALS project arose from the implementation of recommendations from an extensive literature review on why fewer girls studied STEM and were less prevalent in STEM fields than boys or males [9]. The research led to a list of recommended actions, which were incorporated into the design and development of the GALS program. Specifically, the program aimed to develop the girls’ STEM capabilities by targeting factors that influenced societal, generational, and systemic change by:

- Exposing girls to the existence of alternative education pathways and a wide range of rewarding STEM occupations;
- Changing the culture of participating schools (leaders, teachers, and students) and of the broader community to acknowledge STEM pathways as potential alternatives for girls, and enable girls as leaders and entrepreneurs in STEM;

- Involving various stakeholders in education and industry;
- Strengthening STEM teaching and learning, using ‘real-world’ STEM scenarios, and involving industry partnerships in knowledge transfer into education.

3.1. Design-Based Approach

While the GALS project was essentially funded to provide girls and teachers with STEM education regarding knowledge, understanding, and the development of capabilities, it was also embedded with a robust research agenda. As the program involved four cycles, a design-based research approach was initiated that engaged in iterative designs to develop knowledge to improve educational practices. Our purpose was to generate new understandings about STEM practice and to conceptualise girls’ learning using design processes, while engaging with industry partners.

According to Anderson and Shattuck [33], design-based research is founded on a number of aspects inherent to the approach:

- It is situated in a real educational context that adds validity and ensures that the results can be used to inform the practice.
- It is focused on the design and testing of a significant intervention, considering ‘frameworks for learning, the affordances of the chosen instructional tools, domain knowledge presentation, and contextual limitations’ [34].
- Uses mixed methods with a variety of research tools and techniques, selected for their particular application and/or need.
- Involves multiple iterations—design practice evolves through multiple, iterative refinements.
- Involves a collaborative partnership between researchers and practitioners. The partnership helps negotiate meaning from the perspectives of multiple viewpoints.

Tytler et al. [35] (p. 41) commented that design-based research is aimed at ‘developing optimal design solutions to complex educational problems’ where the relationship between theory and practice ‘is layered and complex.’

3.2. Co-Design with Teachers, Industry Partners, and the University

Campbell [36] indicated that there is an increased demand by governments, industry, and commercial groups to form collaborations with others in the co-production of knowledge. Zamenopoulos and Katerina [37] highlighted that the co-production of knowledge ‘builds on a deep and powerful research tradition that dates back beyond the recent emergence of calls for ‘co-produced’ knowledge’. Given the complexity of our world, with its social, political, environmental, educational, and technological sustainability issues, it is recognised that no one person or group has the knowledge or skills to solve these issues [37]. A collaborative approach is needed to bring together the diversity of skills and knowledge to solve problems to incorporate the views of multiple groups and empower a broader cross-section of society to invest in the future of all humankind. A variety of models of collaboration can be found in both national and international research literature, each with their own arrangement for partnerships, approaches, objectives, and outcomes [38]. In particular, partnerships between universities and schools have produced their own unique approaches [36]. An emerging collaborative practice can be found in organisations that have an aspect of service to broader communities. In these collaborative practices, the participation of the end-user is important for the effective development of a new service or product. The term ‘co-design’ is often used to describe a collaborative team approach to designing innovative solutions in response to end-user feedback. In a co-design process, end-users are considered as experts of their own experience. Co-design seeks to use the expertise of the team members to clarify and develop solutions. Collaboration between designers, researchers, developers, and end-users enables the final outcome to be theory/research informed, valuable, utilitarian, and well designed. In the project described below, a human-centred, participatory approach of co-design was used with industry partners, teachers, and university academics for developing support materials for teachers and students that were informed by theory, and were meaningful, useful, and impactful.

4. Research Design

This study was designed to elicit information about the program and participants' perspectives and contributions to the program. The research design underwent ethical consideration by the University Research Ethics committee and was approved to proceed (HEA 19-202). Ethical considerations included the signed voluntary involvement of all participants to contribute to the research data collected as well as the option to be removed from the project should they wish.

4.1. Participants

The GALS program, in its first year, involved the participation of forty-six girls from years 5–8 (aged 11–15 years old) and 13 teachers. The girls and teachers came from 12 different schools—six government-funded primary schools, three government-funded secondary schools, one Catholic primary school, and two Catholic secondary schools. The teachers and schools self-selected into the program, whereas the girls were selected by the school. In some schools, this was undertaken as an expression of interest from the girls, while at other schools, the selection was based on practical aspects of the schools' routines.

4.2. Research Instruments

The research tools used in this study included surveys, interviews, and portfolios/artefacts. Formative and summative evaluation processes drew on data generated through a mixed method research design [39,40] to describe and measure changes in student practices, attitudes, and engagement in relation to STEM and leadership as a result of connecting to industry problems. The combination of measurement techniques provided qualitative and quantitative data sources to ensure the reliability and validity of the data and their interpretations. For example, the use [41] of detail in the survey as well as the use of mechanical recording allowed for the improvement of the reliability of the data. According to Cypress [42], reliability can be insured by care and consistency in the application of research practices—the visibility of practices, analysis, and conclusions, with an awareness of the limits of the research findings.

The validity of the data was improved by having multiple sources of data; hence, the use of both surveys and interviews. In qualitative studies, it is very important to have quality data. In this study, a number of strategies were in place to ensure that the data were of high quality. We engaged in embedding data in context, having prolonged contact with participants, collecting rich descriptions (using photographs and text), and having a sufficient data base that others could make judgements by. In addition, the research team met frequently to debrief the data and engage in intellectual discussion in relation to the data.

At the commencement of the project, an anonymous survey of each teacher and an anonymous survey of each student were undertaken. The survey instruments for the teachers and students were developed for government research projects and were validated at that time by trials with teachers and students, which are recounted through non-disclosed government reports.

Focus group interviews with students and teacher interviews were developed specifically for this research project and were modelled to aspects of the research questions. They were reviewed through the university's project ethics process.

4.3. Procedure

The data included in this paper were generated by the teacher pre-program survey, the post-program interview with six teachers from five schools, and student focus group interviews. All participants were approached to contribute and self-selected into the process. The student focus group interviews were held with available students from each of the six schools who self-selected into the research. Reported here is the data from the first year of the program. All participants in the interviews provided written permission as outlined in the ethical research procedures of the university.

Data components 1, 3, and 4 (see Table 1 below) were drawn on for this paper. Other data components were not reported in this paper. An anonymous survey of all teachers ($n = 13$) using a Likert scale occurred prior to the commencement of the GALS program, which required teachers to comment on their STEM practices in relations to student engagement as well as the representation of real-world industry problems. A semi-structured 30-minute interview of teachers was undertaken at the conclusion of the girls' projects to gather in-depth opinions to determine how the program affected girls' engagement with industry partners and their understanding of STEM and STEM-related career paths. The semi-structured nature of the interviews permitted teachers the opportunity to broaden their comments and responses.

Table 1. Data components in GALS program.

Component	Data Source	Research
Ongoing collaboration GALS project team, industry representatives, and teachers	1	Anonymous survey of teachers
	2	Anonymous survey of students
	3	Semi-structured 30 min interview of teachers to determine how the program affected students' engagement with STEM
Student/teacher/mentors		Student focus group interviews to determine the impact of this industry-sourced problem solving and university-based mentoring program on girls' awareness, attitudes, and engagement in STEM-related subjects and leadership
	4	

Student focus group interviews ($n = 24$) were undertaken to determine the impact of this industry-sourced problem solving and university-based mentoring program on girls' awareness, attitudes, and engagement in STEM-related subjects and leadership. All interviews were audio-recorded and transcribed professionally.

4.4. Data Analysis

The analyses of each research method initially occurred independently of each other. First, the quantitative data from the survey were analysed. Then, a thematic analysis of all qualitative data was undertaken. For the survey, statistical analysis was not possible due to the small number of participants; instead, it was analysed as interval data, where the mean is the best measure of central tendency. For the qualitative data, the interview transcripts were proofread and checked for accuracy. Data cleaning was then carried out—this included the removal of 'off-topic' discussions, repeated words, and hesitations. Summaries were compiled from each interview and were used to identify common themes. A separate coding of each transcript was undertaken where the research questions guided the development of themes. The initial coding used a systematic open, selective, and axial coding to ground ideas and identify discrepancies, rich details, and other connections [43]. Data related to more than one code were double-coded.

4.5. Description of the GALS Project

From 2019–2022, the Deakin University School of Education initiated a program for girls from years 5 to 8. It is offered as a four- to five-month involvement of teachers and students across different regions of Victoria, Australia. Each separate program involves up to 16 schools, 64 students, and 16–32 teachers—this varies with each region. The aim of the program is to develop girls' STEM capabilities by targeting factors that influence societal, generational, and systemic change. A schematic of the program is provided below

to clarify the components and the order of the delivery of the program. Figure 1 describes the stages of this program; the focus of each stage, including the participants involved; and the key outcomes generated from each stage.

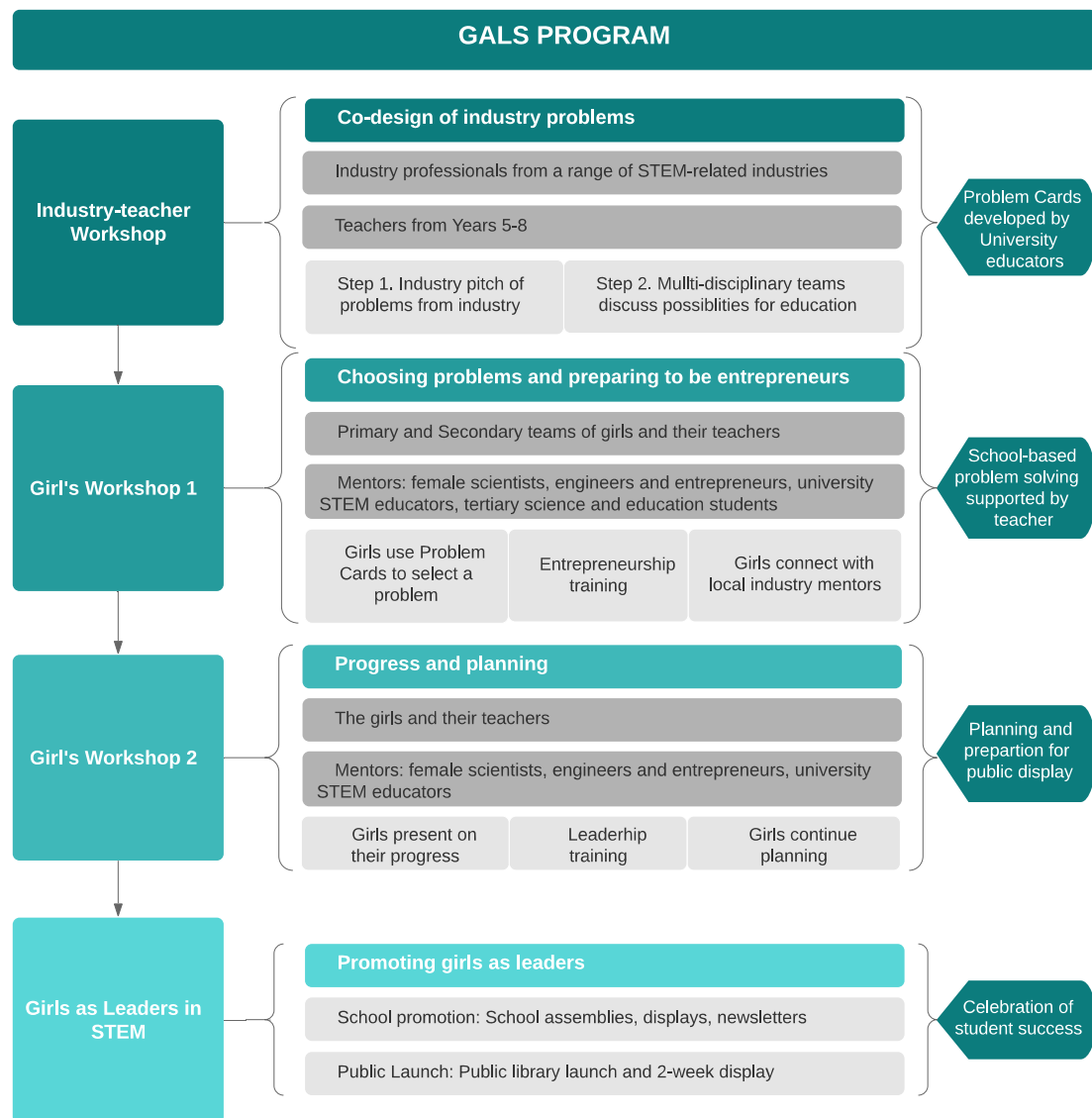


Figure 1. Stages of the GALS Program.

Stage 1. The Industry-teacher Workshop—A Pitching Event

In Stage 1, teachers and industry partners are brought together in an industry-teacher workshop facilitated by university educators to discuss the potential industry problems that can be translated into curriculum for the girls. A range of local industries is canvassed for their participation in the industry-teacher workshop. To date, the project has engaged representatives from thirteen industries as diverse as the fashion industry through to a hydrogen technology hub. As an outcome of the teacher/industry workshop, 'Problem Cards' were developed for each industry. The problem cards use the concept of newspaper stories that provide a context to the industry's challenges, presenting science as a real-world translation of technical STEM work [43]. Each card is a two-sided A4 sheet that maintains the same structure and targets components to provide continuity for the girls, with three interspersed textboxes to scaffold student exploration of the stories. The 'Scoping Statement' gives the girls a broad sense of the industry problem. Four to six 'Stimulus Stories' provide details about various aspects of the industry in focus. A set of 'Stimulus Questions' prompt

thinking around the solution to the industry problem. The problem cards are sent to the industry professionals to ensure that the key ideas are represented.

Stage 2. The Girls' Involvement in Design-based Learning

The schoolgirls from years 5–8 were engaged for four months in a series of two workshops and mentoring activities that facilitated a collaborative design-based learning experience where they explore the creative possibilities of STEM. During the two workshops, the girls were mentored by female scientists, engineers and entrepreneurs, Deakin University STEM educators, and tertiary students to foster the girls' interests in STEM and entrepreneurship, develop STEM skills and knowledge, and build their professional networks. In between workshops, the girls were mentored and guided by teachers at their schools and the school liaison officer.

During the first workshop, the girls were introduced to the industry problems through the problem cards, and to the engineering design-challenge process. The outcome of the workshop was to prepare them to proceed with designing their solution, and where desired, make links with their industry partner to follow up in coming weeks (for example, through ongoing contact/support/mentoring or for an excursion to the local business). In the second workshop, the girls presented their progress to each other and participated in leadership training. The teams were supported to plan for a public launch that showcased their solutions to their industry-related problem. The outcome of this workshop was to develop plans for finalizing their solutions and developing posters or prototypes of their solutions.

A number of showcase events were held towards the end of the program that helped to establish the girls as leaders at their school and in the community. In the school-based event, the girls established themselves as school leaders by reporting their project outcomes to their schools at a school assembly, and through displays and/or school newsletter acknowledgements. To raise awareness of the possibilities of girls' involvement in STEM careers, a public launch of the girls' projects was held in a local public library, where certificates of participation were presented to the girls by the local federal member of parliament and other dignitaries. In addition, the girls' projects were placed on display across a two-week school holiday period and were available for public scrutiny and to raise further community awareness of Girls as Leaders in STEM.

The girls' project topics varied, not just in how the topics related to the problem cards, but also from school to school. Interestingly, the majority of the topics and projects had a sustainability element or focus. The following table (Table 2) provides an overview of the ten projects and indicates the link to the associated problem card.

Table 2. School Project Topics.

1.	<i>Education campaign—raising community awareness of waste through a project wall. Links with problem card—managing waste.</i>
2.	<i>Interchangeable car pods—designing new interiors for family cars. Links with problem card—automotive industry.</i>
3.	<i>Designing new measurement devices—repurposing plastic. Links with problem card—managing waste and new materials.</i>
4.	<i>Community education campaign—designing a campaign to educate on recyclable materials. Links with problem card—managing waste</i>
5.	<i>Minimising packaging—considering new material suitable as packing for the clothing industry. Links with problem card—managing waste and fashion industry</i>
6.	<i>Recycling. Links with problem card—managing waste.</i>

Table 2. *Cont.*

7.	<i>Designing an inclusive playground. Links with problem card—inclusive society.</i>
8.	<i>Packaging of clothing in fashion industries. Links with problem card—managing waste and fashion industry.</i>
9.	<i>Inclusive playground—designing play items for an outside playground that encourages inclusive play. Links with problem card—inclusive society.</i>
10.	<i>Designing and creating effective writing grips for students with casts—linking to OHS. Links with problem card—inclusive society.</i>

5. Results

Data contributing specifically to the focus of the benefits of industry partnership to girls' understanding and aspirations of STEM career pathways were selected for discussion.

5.1. Teacher Surveys

At the start of the project, the anonymous pre-program teacher survey asked teachers to rate the strategies they used for student engagement from 'Never' to 'Very Often' using a Likert scale. The following statements (Table 3) were used.

Table 3. Likert statements used in teacher pre-program survey. As a teacher I ask my students to.

	Statement	Very Often	Often	Sometimes	Rarely	Never
1	Work in teams to solve problems					
2	Plan and carry out investigations					
3	Obtain, evaluate, and communicate information					
4	Relate to contexts drawn from STEM industries					
5	Model with mathematics					
6	Ask questions and define problems					
7	Represent data in a variety of modes					
8	Use design software to output to a 3D printer					
9	Undertake learning activities drawn from innovations and advancements in science and technology					
10	Use video and image capture and manipulation					
11	Use mathematics and computational thinking					
12	Construct explanations and design solutions					
13	Use appropriate mathematics tools strategically					
14	Generate questions to investigate					
15	Solve problems they have generated					

In general, the responses indicated that teachers used a range of strategies 'often' or 'sometimes'. Considering the central tendency of the data, two statements (4 and 9) related to connections to industry and STEM innovations and the teachers' responses are provided in Table 4 below.

There was a slightly skewed result towards the negative for these two factors, highlighting that linking to STEM industries or the use of innovative science and technology ideas were of low priority in the teachers' practice or focus.

There was only one other statement that indicated a 'rarely' (or 'never') response, and that was in relation to the use of a 3D printer. Bearing in mind that at least half of the teachers were from primary school settings, it is understandable that a 3D printer may not be available at the school for teaching purposes.

Table 4. Teacher responses to connections to industry approaches.

	Very Often	Often	Sometimes	Rarely	Never
Relate to contexts drawn from STEM industries		(4) 33%	(5) 42%	(3) 25%	
Undertake learning activities drawn from innovations and advancements in science and technology		(4) 31%	(6) 46%	(3) 23%	

5.2. Teacher Interviews

At the conclusion of year one of the project, teachers were interviewed for feedback on the program about different aspects of the process and, in particular, the role of industry in relation to the girls' attitudes. Interview data from the teachers highlighted some of the benefits gained in the GALS project associated with girls and teachers engaging with industry. The teachers articulated aspects of the effects of industry engagement on the girls. They also identified the nature of the experience that was most impactful. Based on the analysis of codes, three specific themes were identified:

- Relevance and connections to girls' lives.
- Authenticity of the learning context.
- Novelty of the learning experience.

These are discussed below using the teachers' statements to offer evidence for each of the themes.

5.2.1. Relevance and Connections to Girls' Lives

Teachers highlighted the importance of the connection with industry for the students to see the relevance of these problems to their own lives.

"They just connected. As soon as they saw an industry that they were interested in or related to, it was more about something that's part of their lives. The hook was that link to industry because it's where the kids can start to actually connect with it. Unless they start to hear about it, some of them had never heard that, because they don't have that exposure."

(Teacher 1)

"I also think the industry connections clearly are really important. The students need to be able to see this as a real-life problem and they need to be able to understand that there are industries who work within those particular spaces and it's really important for them to be able to see and read about those industry connections."

(Teacher 4)

"We actually had people from the community and people that were linked to our school community. If they were intrinsically sort of motivated by someone that they knew, they went with something that connected."

(Teacher 3)

5.2.2. Authenticity of the Learning Context

A second aspect highlighted by the teachers was the authenticity of the learning context for the girls. One teacher commented that the industry involvement helped to make the context real for the girls.

"Something like that needs to have an authority and be believable, that this is not made-up stuff, this is real because of the nature of what it's about because that's about that real context anyway. The main idea of how to meet the needs of someone in the society in a STEM way."

(Teacher 2)

5.2.3. Novelty of the Learning Experience

The final aspect indicated by the teachers was the novelty of the learning experience for the girls. For Teacher 1, this experience created new possibilities for the girls and helped to broaden their horizons. For Teacher 2, on the other hand, this experience presented something new for the girls that they had not experienced before.

“Well, I think it broadened their horizons in the case of our kids, just because of their personal circumstance, a lot of them don’t have that wider view of what’s going on in the world. It just helps to put it in a context as well for them and present different opportunities. It sort of opens up what might be possible.”

(Teacher 1)

“It was that it was something new to them, they had not considered the fact that the clothing that they wear day in day out could actually be causing an environmental issue. It engaged them because it was something they hadn’t seen before”.

(Teacher 4)

5.3. Student Interviews

Focus group interviews with the girls also provided useful reflections on aspects of the program, and in particular their developing understanding of STEM career pathways, though engagement with industry. The girls were asked what new things they had found out about the STEM industry. The girls identified several aspects that were ‘new’ to them (Table 5), including the following:

- An understanding of what STEM is or could be.
- An appreciation of the breadth of STEM career options.
- How a STEM career is achievable.
- How their involvement in STEM can make a difference.

Table 5. Girls’ comments about their STEM experiences.

School	Students’ Comments
A	There are options ... is not only one specific topic, you can do STEM in ... different areas and things. you can choose to if you want to start a stem career yeah If we didn’t do this program, then I probably ... be less excited ... and now I know lots more about STEM. ... if I didn’t do GALS I would still think that stem is all about building ... there’s actually ... more options that you can do I would focus on stem education in school, first, before going on to a job that I would want to do ... creative jobs, like designing stuff.
BP	it’s a lot easier to get a steady job than I thought and it’s a lot more well paid. ... I would really want to be ... biologists ... dad keeps saying that it’s a bit unrealistic.
NS	... the fashion industry ... it’s something that everyone is a part of ... so it’s a problem that affects everyone. ... visit ... when we went into the microplastics and did that that was really interesting about all the jobs and ... the research. being able to go to ... that was really good, and it was a really clear ... of how to go about starting and how they run their business and, ... they design everything and all the technical things behind the store. excursion and we got to go there and talk ... about the designing processes.
SH	on the excursion today ... some of the talks and we had a tour around ... she was talking about how she researches all the things and so I was interested and intrigued in what she does, and I think that’s just a really fun part that we kind of focused on, how we can also make a difference.
StA	And at first I didn’t know what STEM was ... It means science, technology engineering and I kind of understood more ... and that ... helped me when we were doing a project ... just to remember that ... that engineering is involved. ... and I think technology is sort of ... being part of STEM.
TC	There were a lot more jobs, incorporating STEM than I thought there were. I’ve just learned, I thought STEM was only like coding to you, but it’s such a lot more ... I’d like to do some more training ...

What was particularly interesting about the girls' responses was the increase in understanding about what STEM actually meant in terms of their lives and interests. Many of the groups of girls had undertaken an excursion to an industry of interest and their comments reflected their engagement with the issues and problems of the industry. An arranged tour of some of the university's STEM facilities also provided stimulus in terms of their developing understanding of the diversity of STEM pathways.

6. Discussion

The aim of this paper was to discuss how the GALS program impacted girls' awareness of and engagement with STEM, as well as to consider how industry collaboration in school-based projects, such as GALS, can address sustainability goals.

What is the impact of an industry-sourced problem solving and university-based mentoring program on girls' motivation in STEM?

The data clearly identified how the various connections with industry provided opportunities for girls to engage with STEM in various ways that differed from their in-school experiences. For example, according to the teachers, the industry engagement in the GALS project offered examples of enthusiastic people who presented key STEM ideas aligned to the teachers' curriculum. This way, the girls were exposed to a variety of role models, types of work, and opportunities. Similarly, according to the girls' responses, the connection to industry role models and to key STEM ideas through the use of the problem cards raised their awareness of the diversity of STEM occupations and increased their engagement with STEM-related ideas. In particular, the authenticity of solving a 'real' problem or issue was a clear motivational factor, according to the teachers' comments, but was also a factor in how the girls reacted to their involvement in industry sites. Figure 2 shows a graphic depiction of the effect of industry engagement on girls' STEM awareness, attitude, and engagement.

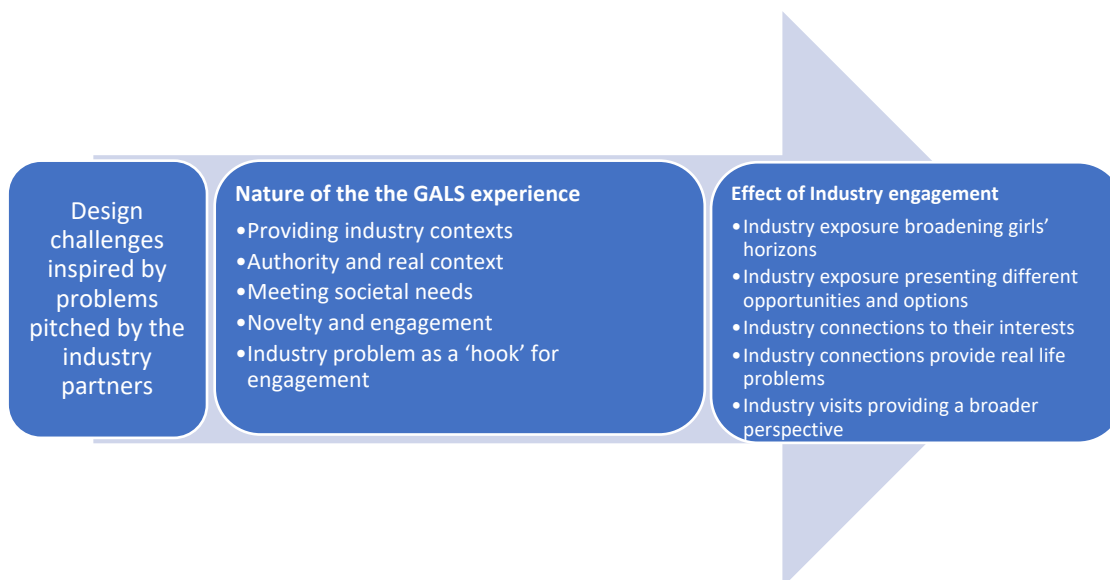


Figure 2. Girls' STEM awareness due to industry engagement.

As indicated by the surveys and interviews, schools and industries are different. Each has its own values, purposes, and cultures. In addition, taking students into workplaces is challenging. There are risks and legalities associated with taking students into potentially dangerous workplaces. However, as shown above, there is real advantage in engaging girls in experiences where they are exposed to STEM knowledge and the practices of local industries; it helps to raise their awareness of career opportunities.

How does the GALS program of collaboration between industry, university, and schools facilitate ESD and SDG4?

The data clearly suggest that the industry elements of the project influence girls' perception in a positive way about what STEM is and their aspirations for STEM careers. This confirms previous research by Tytler and Corrigan [16] that highlighted how connections with industry can provide a better understanding of STEM as important and worthwhile, and that of Finkel [26] who commented on students gaining up-to-date scientific methods and information.

When considering whether the GALS project aligns with Sustainability Development Goal 4, which advocates for quality education that is inclusive and promotes learning opportunities, the development of student/industry links provided opportunities to expose girls to STEM industries. We suggest that these elements clearly address SDG4.

If we consider the principles suggested by Pahnke et al. [8], there is further evidence in the structure of the GALS project and in the data obtained from the teachers and girls that many of the guiding principles of STEM for sustainable development have been met. For example, the GALS project:

- Promoted inquiry-based learning and scientific thinking and practice thorough authentic projects. Pahnke et al. [8], guideline 1.
- Encouraged interactive, learner-centred teaching that enabled exploratory, action-oriented, reflective, and transformative learning. Pahnke et al. [8], guideline 2.
- Fostered independent thinking and responsible action that took place in the learner's context, sometimes involving the girls' own school as the recipient of their project solutions. Pahnke et al. [8], guideline 4.
- Was compatible with the goals of sustainable development through the choice of project. Pahnke et al. [8], guideline 5.
- Empowered the girls to use science, technology, engineering, and mathematics (STEM) skills and reflective reasoning to solve complex sustainability problems. Pahnke et al. [8], guideline 7.

While some of the guidelines were not met, such as the reinforcement of a whole institution approach, the teachers involved may have future opportunities to broaden the STEM education at their schools. The project did not attempt to collect data on all aspects of sustainability education as perceived by the guidelines, as the focus was on the engagement of girls with STEM and on raising their aspirations for STEM pathways.

In conducting this project and the associated research, we found that the girls were attracted to undertaking projects that had a 'social good' element to them, as suggested by Kim et al. [13]. It can be seen from Table 1 that the projects chosen were clearly linked with sustainability, and the girls used their STEM projects to enhance life for others. In addition, we observed first-hand the girls' involvement in their projects, and during presentations to the wider group, the girls demonstrated a deep understanding of their projects, the STEM knowledge underpinning them, and their connection to broader industry needs.

Future Research

The GALS program is continuing until the end of 2022, and depending on COVID-19 restrictions, data collection may be able to be continued. If data collection is enabled, then the results achieved here will be tested through the collection of subsequent data. Based on the results to date, the survey and questions can be changed to better represent the findings and to elicit greater understanding and depth in relation to the two research focus questions.

7. Conclusions

This study set out to demonstrate that one way to address Sustainability Development Goal 4 is to raise girls' aspiration for STEM careers and to promote STEM learning opportunities to ensure a more inclusive and equitable approach to STEM education. Industry partnerships were leveraged in a way to stimulate girls' interest in STEM, and in undertaking industry-related projects, girls were able to see the potential of a STEM career. Using a series of principles of STEM for sustainable development (STEM4SD), proposed by

Pahnke et al. [8], this research demonstrated that the girls' project work did align with most of the principles, demonstrating the links between sustainability and STEM education.

The university educators acted as brokers by bringing together people from education and industry, and supporting the translation of industry ideas, processes, and problems for teachers and students. The problem cards developed by the university educators and informed by discussions between industry and teachers proved to be successful in presenting real-world STEM scenarios. Furthermore, involvement with industry mentors and visits to industry workplaces were considered highly motivational. This model of enrichment (GALS) for girls has therefore made some headway in positioning girls as the job makers (entrepreneurs) rather than the job takers in STEM.

8. Limitations

Unfortunately, as with many research projects conducted over the last few years, this project was affected by the COVID-19 pandemic. This caused cancellations part-way through the second offering, changes to offering the program in a blended mode (with less access to the girls and their teachers), the partial cancellation of the third program, and an embargo on the collection of any research data since 2021.

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