Towards a framework for evaluating diversity in STEM outreach programs

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CONTEXT

In recent years, the Science, Technology, Engineering, and Mathematics (STEM) professions have been making significant efforts to attract and retain a broader cross-section of the community to study engineering, and in turn enter the engineering profession. This is often done through outreach programs with primary- and high-school students. However, there is no recognised framework for providers of these outreach programs to evaluate whether their activities are leading to the broadening of undergraduate intake or diversity in the profession.

PURPOSE

This study will consider existing professional inclusion and diversity frameworks and their potential application to STEM outreach activities. This will provide insight into and a potential platform to evaluate diversity initiatives in STEM outreach activities.

APPROACH

Diversity and inclusion frameworks created by business, government, and university bodies are analysed for common themes. These themes are considered alongside the literature around the attraction of students of diverse backgrounds into STEM to identify areas where STEM outreach may be able to learn from work done by professional bodies.

RESULTS

This review brings together the literature on early pathways to STEM and the best practice of professional bodies in regards to retaining people with diverse backgrounds. Areas that require further investigation for the creation of a full evaluation framework are highlighted.

CONCLUSIONS

It is currently challenging to objectively assess the value of STEM outreach activities. This review will provide a specific platform for a framework to evaluate STEM outreach activities, with a focus of attracting more students with diverse backgrounds cohorts into STEM professions.

KEYWORDS

STEM education, outreach programs, diversity, inclusion, framework

Towards a framework for evaluating diversity in STEM outreach programs

Introduction

The growth of the science, technology, engineering, and maths (STEM) workforce has been described as “critical” for Australia’s economy and prosperity (Office of the Chief Scientist, 2016). However, Australia is currently training fewer STEM professionals than it needs to stay competitive on the international stage (The Australian Industry Group, 2015). STEM-based educational outreach (EO) activities have been a long-term strategy to build awareness of tertiary study of STEM subjects, as an important step towards a STEM career.

There has also been popular recognition of the need to attract talent from diverse backgrounds into STEM careers. As a place of early exposure to opportunities in STEM, EO providers connect with children and young adults, who are already forming stereotypes about STEM careers (Frost & Diamond, 1979; Levy, Sadovsky, & Troseth, 2000). At this early decision point (Correll, 2001; X. Wang, 2013), EO activities play a key role in providing positive impressions of STEM fields to people from diverse backgrounds and currently underrepresented groups.

However, there is no recognised framework for EO providers to inform and evaluate their organisational strategy with respect to attracting people from diverse backgrounds into their programs and into further STEM-related studies. This paper investigates current benchmarking and diversity frameworks in governments, business, and universities and from this, highlights relevant factors for measuring diversity and inclusion in STEM EO activities.

Defining Diversity Groups

There are many definitions of diversity and underrepresented groups, each geared towards describing diversity in different contexts. For this review, diversity groups identified by the Diversity Council Australia (Diversity Council Australia, 2017), the Australian Commonwealth Government (Department of Employment Education and Training, 1990), and the UK’s Science Council and Royal Academy of Engineers joint Diversity Progression Framework (Royal Academy of Engineering, 2015) were considered. These were chosen to ensure the underrepresented groups were relevant to Australia, the higher education context, and STEM fields. The Diversity Progression Framework was chosen despite its UK context, as it was difficult to find an Australian counterpart who provided a similar holistic definition.

From these sources, five diversity groups were identified, and will be considered further in this review:

- Aboriginal and Torres Strait Islander peoples (Indigenous)
- Women in STEM
- People with disabilities
- People who identify as LGBTQ+
- People from minority race and ethnicity groups

Situating STEM Educational Outreach Programs

STEM EO includes activities which promote learning and engagement with STEM subjects, but operate outside of regular curricula and are typically run by an external partner or provider. STEM EO can be pitched anywhere on a spectrum of student interest and experience – from students who have had limited opportunities or interest and are experiencing STEM for the first time, to students who have shown an aptitude in STEM and are being extended in a specialist area. As such, EO is one way that students from diverse backgrounds who are not formally engaging with STEM subjects may interact with

professionals in STEM fields or STEM subject-matter. It is important, then, that these programs are attractive to students with diverse backgrounds and encourage further engagement.

The choice to adopt a STEM pathway can be viewed in relation to Rogers (2003) Innovation-Decision Process, where there are five stages of adoption: knowledge, persuasion, decision, implementation, and confirmation. These stages are explained and applied to the STEM EO context in Figure 1 below.

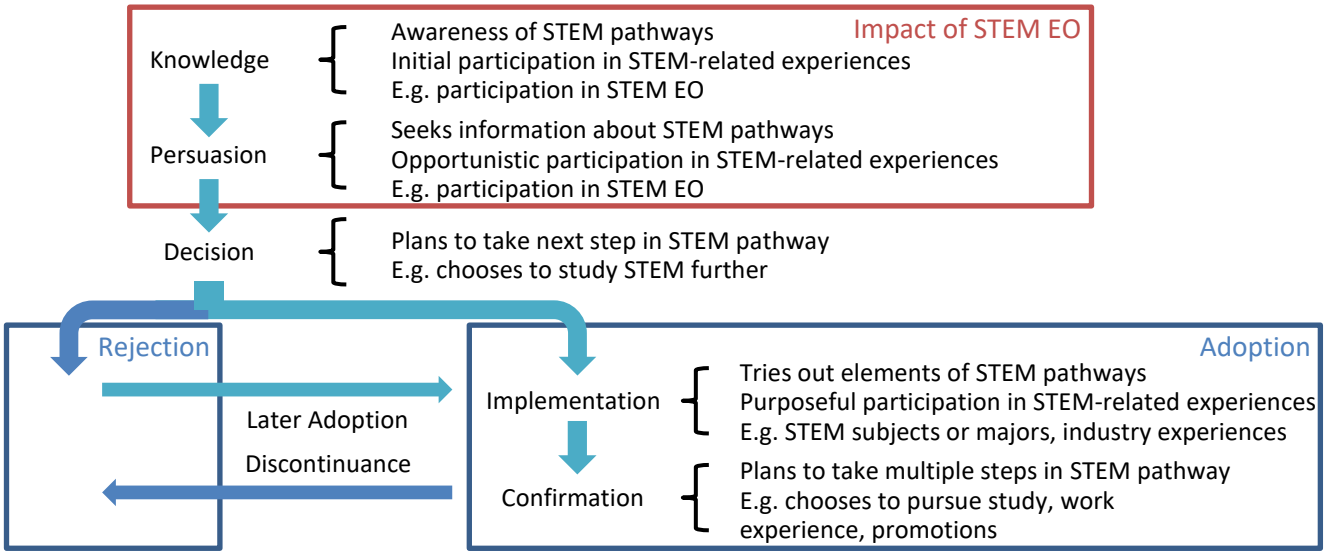

Figure 1: Innovation-Decision Process, Adapted to STEM Pathway

As an opportunity for exposure or extension, STEM EO offers a chance for students to engage with the initial two stages, knowledge and persuasion. This is particularly important for those students who are not gaining this experience through traditional pathways such as school.

Factors for attracting students to a STEM pathway

If STEM EO programs are to effectively provide students of diverse backgrounds exposure to and initial experiences in STEM pathways, they must be effective in both attracting and retaining students of all backgrounds to STEM. Key influences on a student's aspirations to a career in STEM include (Andersen & Ward, 2013; Bandura, Barbaranelli, Caprara, & Pastorelli, 2001; Dick & Rallis, 2017; M. Wang & Degol, 2013; X. Wang, 2013):

- achievement in STEM-related subjects
- self-efficacy in STEM subjects
- perceived relative advantage in a STEM career, such as perceptions of pay opportunities, job security, or opportunity to be challenged
- the influence of others, such as parents, teachers, peers, and STEM professionals

However, these influences are not uniform across all underrepresented groups, and each influence will be discussed briefly below.

Achievement in STEM-related subjects at high school level is a positive influence on a student's choice to choose a STEM career. Andersen & Ward's (2013) analysis of data from the High School Longitudinal Study of 2009 found that while the effect of science attainment was consistent across ethnic groups studied (Black, Hispanic, and White), Black students were more likely to consider mathematical attainment of importance. Ability in other areas affects career choice – mathematically capable students with high verbal skills are less likely to pursue STEM careers than those with high mathematical skills but moderate verbal skills

(M. Wang, Eccles, & Kenny, 2013). This has been linked to a higher number of women leaving STEM majors (Wai, Lubinski, & Benbow, 2005).

Self-efficacy refers to a student's belief about their own ability. Self-efficacy can predict career choice better than personality matching, thinking consequentially about potential difficulties, or outcome expectations (Bandura et al., 2001). However, the effect of stereotype threat often negatively affects self-efficacy; for example, causing women to perform more poorly in STEM subjects (Cadinu, Maass, Rosabianca, & Kiesner, 2005) and meaning women tend to feel more need than males to be prepared for the mathematical aspect of engineering before they will consider it as a feasible career option (Frehill, 1997).

Perceived relative advantage in a STEM career can include a student's assumptions or stereotypes about the job, their perception of pay, security, and prestige, and other future benefits of studying STEM. The "Draw a Scientist" test has uncovered that students across ages, gender and ethnic groups have a perception of scientists as Caucasian and male, working with technology in a laboratory (Finson, 2002). Cheryan et al. (2011) suggests that aspects of these stereotypes may keep students, particularly those who do not fit the stereotype, away from STEM. Andersen & Ward (2013) found that Hispanic students considered STEM utility—the perception that a STEM subject or major will benefit the student in the future—to be more important than students of other ethnicities.

As with the previous factors, the influence of others in a decision to pursue STEM careers varies across demographic groups. For example, women are more likely to draw their self-efficacy from social persuasions such as encouragement from family members, teachers, and peers, while men's self-efficacy is more likely to be influenced by their interpretations of their achievements (Zeldin, Britner, & Pajares, 2008; Zeldin & Pajares, 2000).

Beyond the individual factors for attracting students to a STEM pathway, students of diverse backgrounds also face additional challenges after entering a STEM environment. Cutts-Worthington (2017) explores key factors impacting representation in engineering for underrepresented gender and ethnicity groups, Indigenous students, students from low socio-economic backgrounds, students with disability, and LGBTQ+ students in an Australian context. Cutts-Worthington identified five key factors impacting retention of students of diverse backgrounds: sense of belonging, academic preparation, perception of engineering, stereotype threat, and financial burden. Other, less-significant factors of note were representation, career concerns, and discrimination and bias.

It is important to note that areas of diversity cannot be simply considered separately. Students at the intersection of two or more areas of diversity may be influenced in a way that is not a direct addition of the research concerning the two areas separately. It is also important to note that there is a range of diversity within each area of diversity, as identified in this paper. For example, students with physical disabilities may experience these factors in a very different way to those with learning disabilities or mental illness. Lastly, the research so far focuses much more on differences across gender and ethnicity than it does on LGBTQ+, Australian Indigenous, and people with disability.

Existing frameworks for diversity

For each of the five diversity categories selected for this review two peak bodies were chosen that:

- demonstrate representation of that diversity category
- have a defined framework, benchmark or award program
- demonstrate influence or impact in one or more sectors

Impact was measured on an adapted Impact Management Planning and Evaluation Ladder (IMPEL) (Department of Education and Training 2016). Only frameworks from organisations demonstrating Level 5 impact—narrow opportunistic adoption were considered. Preference was also given to frameworks pertinent to STEM or educational contexts, or aimed at an

Australian audience. These were then analysed to provide insight into the potential usefulness of these frameworks in a STEM EO context.

Table 1 outlines the 10 frameworks chosen for the review. The organisation's purpose or vision is listed alongside their membership or reach as an indication of their influence.

Table 1: Organisations providing Frameworks

Equity Group	Organisation	Purpose	Membership/Reach
Indig-enous	Universities Australia [a]	Represents Australian universities	Universities in Australia
	Council of Australian Governments (COAG) [b]	Coordinates strategic policy on education	Educators in Australia
Women in STEM	Workplace Gender Equality Agency (WGEA) [c]	Promotes gender equality in workplaces	Workplaces in Australia
	Science in Australian Gender Equity (SAGE) [d]	Supports gender equity in STEM and medicine	Australian universities and workplaces
Disabilities	Australian Local Government Association (ALGA) [e]	Serves as national voice for local councils	Local government across Australia
	Australian Network on Disability (AND) [f]	Advances the inclusion of people with disability in business	Workplaces in Australia
LGBTQ+	Pride in Diversity (PiD) [g]	Reducing exclusion, and homophobia in the workplace	Workplaces in Australia
	Beyond Blue [h]	Provides information and support for mental health	Health services, schools, workplaces
Minority ethnicity	Equality Challenge Unit (ECU) [i]	Support ethnic diversity in higher education institutions	Universities in the UK
	Business in the Community [j]	Building a fairer society and more sustainable future	Businesses in the UK

[a] (Universities Australia, 2013) ; [b] (Education Council, 2014); [c] (Workplace Gender Equality Agency, 2017); [d] (Science in Australia Gender Equity, 2017); [e] (Australian Local Government Association, 2010); [f] (Australian Network on Disability, 2017); [g] (Pride in Diversity, 2015); [h] (Beyondblue, 2016); [i] (Equality Challenge Unit, 2017); [j] (Business in the Community, 2017)

Major themes, or attributes, found across the frameworks were identified through a thematic analysis. The frameworks were then mapped against these themes to give an understanding of the importance and prevalence of these attributes.

Common attributes across frameworks

Twelve common themes, or attributes, derived from the frameworks listed in Table 1 are listed and described in Table 2 below.

Table 2: Attributes derived from Frameworks

	Attribute	Framework principles coded to this attribute discussed…
Standard Operating Activities	Policy/ Accountability	• Development of procedure, policy, or strategy to make the organisation more diverse or inclusive • Transparency or accountability throughout the organisation
	Formal Structures	• Creation of positions, committees or other groups, or feedback systems to improve diversity and inclusion
	Evaluation /Review	• Collecting data or information about the current state of the organisation • Review of initiatives or actions taken towards increasing diversity and inclusion • Reporting mechanisms or processes
	Training Staff/ Students	• Training for staff or students about diversity and inclusion • Ensuring that staff or students have the skills they need to be inclusive • Development or training given to diverse staff or students
	Representation/ Recruitment	• The representation of equity groups within the organisation, sometimes at different levels within the organisation • Attracting and recruiting people from equity groups into the organisation
Organisational Attitudes	Leadership Support	• Inclusive statements or policy created or signed off by the organisation's upper leadership • Actions or embodiment of framework principles by the organisation's upper leadership
	Seeking/ Using Best Practice	• Pursuing or reading research to understand and implement new ideas pertaining to diversity and inclusion • Commitment to innovative activities or "doing better" • Concepts that take diversity and inclusion beyond compliance
	Welcoming Culture	• Encouraging, promoting, or incentivising inclusive behaviour • Creating physical environments that acknowledge or celebrate diverse groups
	Support Diverse Groups	• Initiatives designed to promote diversity and inclusion, such as ensuring resources are sensitive and accessible, adjustments being made, or policy being changed
	Acknowledgement of Intersectionality	• Understanding the interplay between equity groups, and that they cannot be considered as completely separate • Acknowledge that an individual may not belong to only one equity group
External Relationships	Community Links/ Consultation	• Seeking input or looking for feedback on diversity and inclusion actions from the local community or other organisations • Seeking input or looking for feedback on diversity and inclusion actions from people who identify with the equity group in question
	Impact Outside the Organisation	• Choosing or influencing suppliers and customers to adopt a similar value of diversity and inclusion • Considering the organisation's ability to serve customers in equity groups

Table 3 (in the appendix) maps between the attributes identified in Table 2 and the frameworks that they occurred in. The spread of attributes across the frameworks concerned with different equity groups suggest that at least some of the attributes of a good diversity and inclusion framework are shared across the different types of diversity.

Application to STEM Educational Outreach

In this paper, three areas of concern relating to diversity in STEM EO have been identified:

- the people in diversity groups
- the factors that influence a decision to explore a STEM pathway
- the organisational attributes which promote diversity

These have been summarised in Figure 2.

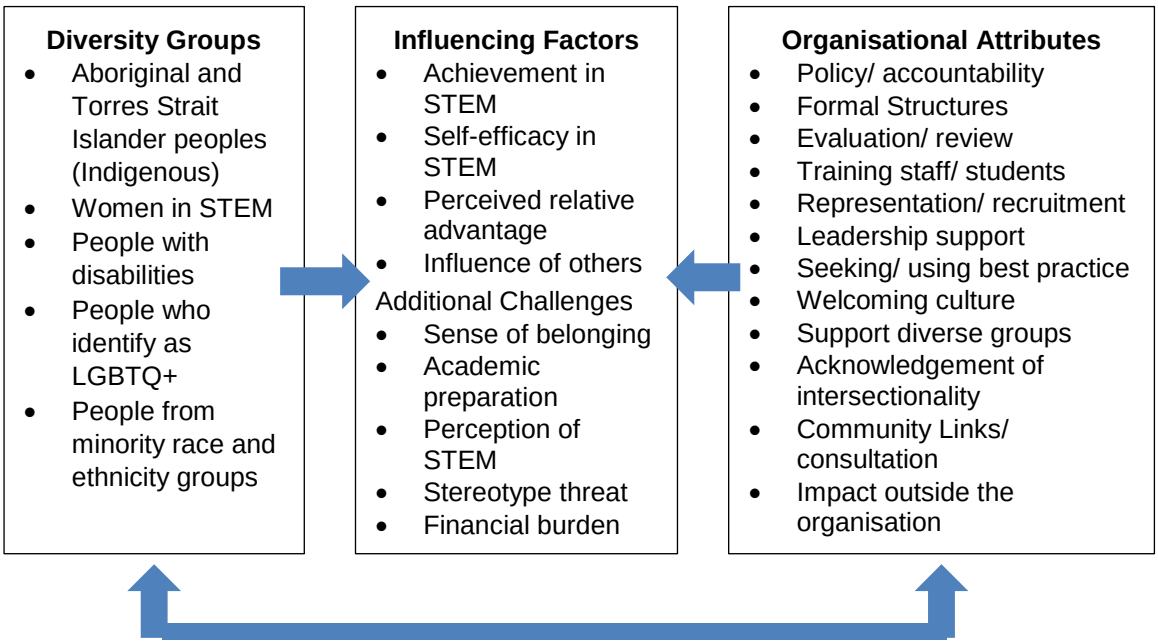

Figure 2: Summary of Diversity Groups, Factors, and Attributes

Understanding the relationships between these three areas (represented by the arrows in Figure 2) is a key area of further work for reducing the barriers for a STEM career for diverse people.

It is important to recognise the nuances in how the different diversity groups experience and perceive the factors that encourage students to explore the STEM pathway. As evidenced in this review, not all factors apply equally to all groups of students, and this becomes even more complex when considering individuals who may fit in multiple groups. Each person's individual characteristics and identities will affect how they see and react to the activities of STEM EO.

Organisational attributes describe the implicit and explicit actions both within and outside of an organisation. It is here that STEM EO organisations can make systemic change to affect diversity. However, initiatives at organisational level may affect multiple influencing factors in different ways. Understanding the relationship between organisational attributes and the factors that influence students along the STEM pathway will allow STEM EO organisations to make informed decisions about their diversity policies and strategies.

The strong commonalities between frameworks directed at different diversity groups suggest that some measures may lead to better inclusion for all groups; however, the differences between the emphases of frameworks suggest that different groups are also likely to require tailored support. Understanding how initiatives targeted at one diversity group may affect other diversity groups is also of importance.

A further consideration when looking at STEM EO organisations is the broad variety of activities that make up EO. The STEM Program Index 2016 (SPI) (The Australian Industry Group, 2016) lists a wide range of STEM EO activities, including after-school clubs and holiday programmes, competitions, excursions, in-school programmes, mentoring, school

visits, out of school programmes, and residential programmes. These programs are delivered by a wide variety of organisations, including universities, museums, not-for-profits, foundations, and both small and large businesses. The recent interest in STEM also suggests there may be a number of start-up groups delivering outreach activities. These groups may have an entirely different organisational structure to the groups targeted by the frameworks used in this review. Understanding the different organisational contexts is an important factor for investigating diversity in the STEM EO sector as a whole.

Conclusions and Future Work

If the STEM field is to increase diversity at industry level, it must consider how diversity can be increased at earlier stages in the STEM pathway. It is important, then, to consider how diversity can be improved in the first impressions that STEM EO provide at the early stages of the innovation-decision process.

This review has investigated the frameworks used by businesses, government and universities to improve diversity across five underrepresented groups, and considered how these may be useful for the STEM EO context. From this, 12 common attributes were identified. In addition, nine key factors and challenges that influence students to adopt STEM pathways were identified from the available literature.

Having identified these attributes, further work in this area is required to assemble these considerations into a coherent framework which can be applied to the niche area of organisations working in STEM EO. This review and its findings form only preliminary work in understanding what must be done to measure and affect participant diversity in STEM EO organisations. Future work will require a considerable understanding of how diversity groups and organisational attributes influence the decision of individuals into a STEM pathway.

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Appendix

Table 3: Framework-Attribute Mapping

		Standard Operating Activities					Organisational Attitudes					External Relationships	
	Attributes / **Organisation**	Policy/ Accountability	Formal Structures	Evaluation/ Review	Training Staff/ Students	Representation/ Recruitment	Leadership Support	Seeking/ Using Best Practice	Welcoming Culture	Support Diverse Groups	Acknowledgement of Intersectionality	Community Links/ Consultation	Impact Outside the Organisation
Indigenous People	Universities Australia	■	■	■	■	■	■	■	■	■			
	COAG Education Council			■		■		■	■	■		■	
Women in STEM	WGEA	■		■	■	■			■	■			■
	SAGE	■		■	■	■	■		■	■	■		
People with disabilities	ALGA	■	■	■	■	■	■	■				■	
	AND			■		■		■		■			■
LGBTQ+	PiD	■	■	■	■		■	■	■				
	BeyondBlue	■		■			■	■	■				
Minority ethnic groups	ECU			■	■	■	■	■		■	■	■	
	BiTC		■	■	■	■		■		■			■
Instances (/10)		6	4	10	7	8	6	8	6	7	2	3	3
Instances across Diversity Groups (/5)		4	4	5	5	4	5	4	3	4	2	3	3