UNIVERSITY OF CANBERRA

STEM Education for all young Australians

A Bright Spots STEM Learning Hub Foundation Paper for SVA, in partnership with Samsung

SVA Social Ventures Australia

SVA Bright Spots Schools Connection

SAMSUNG

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Overview

STEM education is currently receiving extensive policy and public attention, and is considered critical for the Australian economy. This Foundations Paper supports action to improve education for disadvantaged Australians in science, technology, engineering and mathematics (STEM). It outlines current approaches to STEM education internationally. A Framework for action for STEM education in disadvantaged communities is then presented.

Disadvantaged communities have lower levels of mathematical and scientific literacy, and fewer uptakes in STEM careers (Marginson *et al*., 2013). They typically have lower achievement levels in STEM subjects, as evidenced by assessment exercises such as Trends in International Mathematics and Science Study (TIMSS), and the Programme for International Student Assessment (PISA). Narrow views of what constitute STEM engagement, whether being discipline-content or productivity driven, are heightened in disadvantaged communities.

It is unsurprising that current approaches to STEM education are diverse. In some education jurisdictions across Australia, hundreds of different STEM programs are being implemented, sometimes simultaneously. In addition, numerous targeted initiatives and programs that aim to improve the situation in disadvantaged communities. Issues of time, resourcing, funding, and staffing often limit the effectiveness of these programs.

To respond to the diverse needs of disadvantaged communities, and to overcome these barriers, we propose a framework for STEM education that focuses on the practices that underpin STEM. By teaching STEM practices, content knowledge naturally follows, not just in STEM discipline areas, but all curriculum areas including English, languages, and social sciences.

In the Framework for Action, we outline what a STEM practice is (a method, value, and idea), the theoretical framing of STEM practices (practice architecture), an example of a STEM practice (spatial reasoning) incorporating the requirements of the Australian Curriculum, and recommendations for policy. In particular, we suggest that a national framework for STEM education is developed that includes STEM as a new general capability in the National Curriculum.

STEM education as a national priority

The current state of, and future needs for STEM education, is an area of interest and discussion for government, industry and education sectors across in Australia. School STEM education is seen as playing a crucial role in preparing individuals and economies for the future, and attention is paid to groups who are underrepresented in STEM education and the STEM workforce

Australian Government STEM education policies

In a world of technologically driven change and complex environmental and social challenges, the Australian Government has demonstrated a keen interest in the role and potential for STEM education.

In addition to the overarching initiatives of the Australian Curriculum which sets expectations for what all young Australians should be taught and the Australian Professional Standards for Teachers which make explicit the elements of high quality teaching, this interest is evident in various policies and initiatives. These include Australia's National Science Statement, the National Innovation and Science Agenda and the National STEM Education Agenda.

Australia's National Science Statement (Commonwealth of Australia, 2017) recognises the value of and demand for STEM-skilled employees, including the need to ensure the education system provides the broad base of STEM skills required for the future workforce.

One of the guiding principles articulated for government science policies and activities in the National Science Statement is the demonstration and promotion of leadership to actively address inequality in education, participation and employment, including for women and girls, Indigenous Australians, and those in rural and remote areas.

The *National Innovation and Science Agenda* (Commonwealth of Australia, 2015), also recognises STEM education making a key contribution to developing world-class professionals and preparing the future workforce. The National Innovation and Science Agenda Appendix of measures notes $AUD 84million of funding has been allocated to initiatives aiming to inspire Australians in digital literacy and STEM.

The goals of the *National STEM School Education Strategy* (Education Council, 2015) are focussed on ensuring all students acquire strong foundational knowledge and skills in STEM and ensuring students are inspired to take on challenging STEM subjects. The five areas for national action involve increasing teacher capacity in STEM, increasing student knowledge, participation and understanding of STEM, encouraging school system support for STEM education initiatives, facilitating effective partnerships, and building a strong evidence base.

The *National STEM School Education Strategy* recognises that inequities exist in STEM, particularly for girls, students from low socio-economic backgrounds, and

Aboriginal and Torres Strait Islander students and considers that a renewed national focus on STEM in school education is critical for supporting all young Australians.

Industry and professional organisations research and reports

In addition to the Australian Government interest in STEM education, industry bodies and professional organisations have also highlighted the importance of the STEM agenda, and recognised the role education plays in STEM futures.

Examples of this interest include reports from:

- The Australian Council for Education Research (Rosicka, 2016)
- The Australian Council of Learned Academies (Marginson et al., 2013).
- The Australian Industry Group (AIG), (2017; 2015; 2013).

These reports examine issues such as:

- Teacher capacity in STEM education
- How to raise student participation in STEM education and careers
- Approaches to STEM in schools
- Ways to work with STEM in the current school curriculum
- Industry, organisation, higher education, and government partnerships in STEM education
- Industry links with schools
- The importance of higher education and VET sectors in STEM education

Global perspective

Australia is not alone in its intense policy focus on STEM, with broad similarity in direction evident in Europe (Rocard *et al*., 2007), the United States (Committee on STEM Education, 2013), and much of the world (Marginson, Tytler, Freeman, and Roberts, 2013).

The global need for societies to adjust, transform, adapt and innovate is well established in political and policy discourse, and STEM has been identified as a path to meet this need. The Organisation for Economic Co-operation and Development (OECD, 2014), for example, has reported extensively on the role of STEM in leading innovation to recover from the 2008 economic crisis, and also on how STEM can enable countries to respond to environmental and social challenges.

Snapshot of current models of STEM education

Research on STEM education is an emerging field. Opinions vary on what STEM education should look like (English, 2017; Sanders, 2008). In this section we describe different approaches to STEM Education. We start focusing on key elements of STEM education, approaches to integrated STEM education, STEM and extra-curricular activities, and STEM schools.

In some instances, it has been suggested that STEM merely represents individual discipline areas (Sanders, 2008). More commonly, STEM is described as a way of teaching that integrates each of the four areas by removing subject barriers and making links to real-world learning experiences (Siekmann, 2016; Vasquez, Sneider, and Comer, 2013).

The shape this integration takes may vary, as STEM education does not always have to involve all four disciplines (Vasquez, 2014).

STEM education does not replace current education curriculums or standards (Vasquez, 2014). In fact, in Australia, there is no specific engineering curriculum, though engineering concepts can be found throughout other curriculum areas.

Key elements of STEM education:

- Enables students to engage in authentic, active, meaningful learning challenges (Siekmann, 2016; Rosicka, 2016; Sanders, 2012). Examples include inquiry-based learning (Rosicka, 2016), and problem solving that allows students to first identify a problem themselves (Marginson *et al*., 2013; Sanders, 2012; Vasquez, 2014).

- Allows students to put into practice the skills and knowledge they are learning in an authentic manner (Sanders, 2012; Vasquez, 2014). Students apply their learning outside the classroom.

- Includes planned learning experiences based on knowledge of learning theories, pedagogical approaches, and proven research in STEM education (Kelley and Knowles, 2016). Teaching is grounded in evidence-based practice.

- Takes a school-wide approach (Sanders, 2012) with all students and educators involved (Kennedy and Odell, 2014). Success requires support from teachers, administrators and students.

- Uses partnerships with external organisations, industry, universities, and associations to provide high quality STEM experiences for students (Kennedy and Odell, 2014). Through partnerships, students can access mentors and resources otherwise unavailable.

- Focuses on outcomes for students (Siekmann, 2016; Vasquez, 2014). That is, focus on what students will gain from the learning experience, rather than the content or assessment involved. Once this is decided, then teachers can make connections to assessment (Sanders, 2012) and curriculum in across areas (Rosicka, 2016).

The focus here is not on STEM content knowledge, but rather an approach to teaching. This is where STEM practices are useful, as they focus on the practices that underpin STEM and enable teachers to start with their students' experience to bring STEM into the classroom.

An integrated approach

The integrated approach to STEM involves teaching the disciplines in association with another, or teaching all four areas together. Taking the integrated approach even further, STEM can be integrated with other subject areas such as art, language and social science. This is referred to as STEAM (science, technology, engineering, arts, and mathematics).

Integrated STEM education involves linking and combining at least two or more of the discipline areas of STEM (Sanders, 2008). Depending on the level and degree of integration, the approach can increase in complexity (Vasquez *et al*., 2013).

One of the aims of integrated STEM education is to demonstrate how STEM can be applied in real-life, rather than how it is separated into disciplinary content knowledge (English, 2016; Honey *et al*., 2014; Kelley and Knowles, 2016). Considering the context is important to keep content authentic (Kelley and Knowles, 2016). Using the example of technology, Sanders (2008) argues that a technology-focused project cannot be separated from its context without losing authenticity (Sanders, 2008).

The nature of the integrated approach varies depending on the structure of STEM education at the school. For example, in primary schools, integration can occur throughout the school day. In high school, it may need to occur across different subject classes and over several lessons. It may involve a whole-school approach, or only be occurring in some classes. All these approaches involve different resources, considerations, timeframes, challenges and opportunities (Honey *et al*., 2014). Teachers have found it more difficult to implement an integrated approach in high school than primary school (Shernoff, Sinha, Bressler, and Ginsburg, 2017).

Advantages of integrated STEM education include:

- Increases in student interest in STEM and STEM-related careers (Becker and Park, 2011; Honey *et al*., 2014; Sanders, 2008). The increased interest in STEM may also increase student motivation and interest in continuing with STEM education (Honey *et al*., 2014).

- Improved learning outcomes and achievement in STEM subjects (Becker and Park, 2011; Honey *et al*., 2014).

- Students are able to see and understand links between discipline areas, rather than seeing each discipline area individually and separated from each other (English, 2017). They can understand the relevance of STEM (Honey *et al*., 2014).

- Students are able to see how STEM applies in the world, which adds meaning to what is taught in the classroom. They have a greater understanding of real-world problems and how to solve them (English, 2017).

- Students can understand how knowledge across each discipline combines in different careers (English, 2017).

Integrating STEM education leads to the following challenges:

- Time required for teachers to learn a different pedagogical approach.

- Applying STEM across all school levels.

- Hindering learning outcomes.

- Issues with separating content knowledge and assessments.

- Problems with finding a balance between all discipline areas.

Some suggest that an integrated approach means the focus on each disciplinary area can be lost (English, 2017; 2016; Honey *et al*., 2014). Mathematics and engineering are often neglected (English, 2017; 2016) while technology is becoming more prominent (English, 2017).

An integrated approach requires new ways to teach STEM, which means finding time and resources (Becker and Park, 2011; Shernoff *et al*., 2017). How STEM is implemented will also depend on how teachers view the new approach (Becker and Park, 2011) as well as support from school administrators (Becker and Park, 2011; Clark and Ernst, 2009). It is more likely to be successful if there is a strategic approach to implementation (Kelley and Knowles, 2016).

Different year levels face different challenges. An integrated approach to teaching STEM in the younger years appears easier (Becker and Park, 2011), as higher year levels are more confined by standardised assessments, structural limitations in schools, and issues of collaboration among teachers (Shernoff *et al*., 2017). Teachers in primary school also have more opportunity to implement an integrated approach because they can be more flexible and are not teaching in siloed subject areas (Shernoff *et al*., 2017). Another approach is needed to suit students in higher levels of schooling.

Integrated STEM education takes different forms in schools. It is currently being delivered in day-to-day school lessons, through additional extra-curricular activities, and in enrichment and outreach programs. These approaches are usually based on a constructivist approach to learning, using research from the cognitive sciences (Sanders, 2008). It generally incorporates problem-based approaches, project-based approaches, or inquiry-based approaches to learning, which enable students to explore and come to their own understandings and solve their own problems.

Project-based learning

Project-based learning involves students investigating a particular problem, question, or challenge for an extended period of time. These often in the form of design challenges. Key features include students engaging with authentic problems where students can make connections to real-world contexts (Estapa and Tank, 2017) and apply the concepts they are learning (Dierdorp, Bakker, van Maanen, and Eijkelhof., 2014).

There are benefits and disadvantages to a project-based approach. In STEM specifically, these benefits include:

- Increased student understanding of connections between discipline areas (Estapa and Tank, 2017).
- Increased performance in STEM activities (Fan and Yu, 2017; Han, Rosli, Capraro, and Capraro, 2016; Hudson, English, Dawes, King, and Baker, 2015; Knezek, Christensen, Tyler-Wood, and Periathiruvadi, 2013; Sahin and Top, 2015).
- Improved perceptions of STEM careers and disciplines (Knezek *et al*.,2013; Sahin and Top, 2015).

Project-based education also has benefits outside STEM. Students felt that what they had learned could be applied to other discipline areas (Dierdorp *et al*., 2014) and they started seeing STEM lessons as developing skills rather than just content knowledge (Estapa and Tank, 2017). Students also increase their higher-order thinking skills (Fan and Yu, 2017) and creativity (Knezek *et al*., 2013).

In terms of the difficulties teachers faced, one area that teachers struggled with was the how to make connections between the content during lessons. Professional development can help effectively implement an integrated approach to STEM education (Estapa and Tank, 2017) and has been shown to be successful in assisting teachers with project-based STEM learning (Stearns, Morgan, Capraro, and Capraro, 2012).

Inquiry-based learning

Inquiry-based approaches invite students to pose problems, ideas, or questions to be investigated, rather than presenting them with an activity to complete. Students' interests guide the investigation and learning. Questioning and creativity are key to this approach (Hathcock, Dickerson, Eckhoff, and Katsioloudis, 2015), along with hand-on, practical activities (Perrin, 2004).

Benefits to an inquiry-based approach include:

- Increased student knowledge and skills in STEM subjects (Cotabish, Dailey, Robinson, and Hughes, 2013; Duran, Hoft, Lawson, Medjahed, and Orady, 2013; Kim, 2016).

- Increased positive attitudes about STEM and STEM careers (Duran *et al*., 2013; Kim, 2011; Kim, 2016).

- Increased understanding of how STEM activities apply to day-to-day life (Perrin, 2004) .

- Increased problem solving ability (Hathcock *et al*., 2015).

Problem-based learning

In problem-based learning, students work to solve an open-ended problem. These are usually problems that students can relate to in real-life, and aim to challenge them to think differently to find solutions (English and Mousoulides, 2015).

An important component of problem-based learning is ensuring that the problems have multiple solutions that can be determined through creative and critical thinking (English and Mousoulides, 2015). Students have the opportunity to design, make, and test their solution, and then improve the design if it doesn’t quite work (English and King, 2015).

Some teachers feel a problem-based approach will not work in the classroom due to discipline-specific classes, organisation of school, and changed pedagogical practice (Asghar, Ellington, Rice, Johnson and Prime, 2012). Others felt constrained by the discipline specific nature standardised testing (Asghar *et al*., 2012).

Extra-curricular STEM activities

STEM experiences may also be available to students through competitions, school clubs, or holiday programs.

STEM competitions usually involve a design-based challenge, where students compete to solve a problem. School clubs usually occur at lunchtime or after school, and are in addition to the school curriculum. Holiday programs involve students attending an intensive program that focuses on STEM projects for several days outside school-based programs.

These approaches also incorporate STEM enrichment and outreach programs, as external organisations and institutions host many of the programs.

Benefits to students include:

- Increased interest in STEM careers (Goonatilake and Bachnak, 2012; Moreno, Tharp, Vogt, Newell, and Burnett, 2016; Sahin 2013; Yuen, Boecking, Tiger, Gomez, Guillen, Arreguin, and Stone, 2014).
- Increased performance in STEM subjects (ChanJin Chung, Cartright, and Cole, 2014).
- Increased knowledge and understanding of STEM concepts (Barker, Nugent, and Grandgenett, 2014; ChanJin Chung *et al*., 2014; Moreno *et al*., 2016).
- Increased STEM dispositions (Christensen *et al*., 2015).
- Increased likelihood of studying STEM after secondary school (Sahin, 2013).

These positive indicators suggest students' interest and engagement with STEM increased after the participation in extra-curricular activities. However, there are limitations. Despite the benefits, in one program students' attitudes towards STEM disciplines did not necessarily improve (Moreno *et al*., 2016).

There can be issues around the program leader's ability to implement a STEM program. Limitations may include a lack of STEM knowledge, confidence, and self-efficacy in teaching STEM for those who were implementing the programs (Barker *et al*., 2014).

A lack of STEM knowledge can make it difficult for the program leader to perceive the difficulty of the activity, and tailor activities to the age of students (Barker *et al*., 2014).

As programs such as these are usually provided by external providers, access to such programs for disadvantaged students may be limited. This may be due to issues around the proximity of a school to providers, and the cost of such programs.

STEM schools

STEM schools have a particular focus on STEM education and STEM discipline areas. In the United States, inclusive STEM schools focus on targeting underrepresented student in STEM. These schools aim to change the profile of STEM professionals, and encourage students to develop positive attitudes towards STEM education (Peters-Burton, Lynch, Behrend and Means, 2014).

STEM schools do this by providing a high-level STEM curriculum taught by teachers who are experts in STEM discipline areas, and making links with industry through internships (Erdogan and Stuessy, 2015). Students often have opportunities to undertake courses to prepare them for college with access to practical, real world, engaging STEM lessons (Means, Haiwen, Young, Peters, and Lynch, 2016).

As with STEM education, there are multiple views of what a STEM school should do (Laforce *et al*., 2016). Laforce *et al*. (2016) identified key features that STEM high schools focus on:

- The nature of the learning experiences and pedagogy.
- Incorporating links to real-life skills.
- The community.
- Careers.
- Considerations around staffing and school factors.

Discipline knowledge was not a consideration in these elements (Laforce *et al*., 2016). This suggests that it is not the content that is important, but a combination of pedagogical approaches, partnerships, and a focus on real-life connections.

Other key features of STEM schools are that they motivate students to work together (Morrison, Roth McDuffie, and French, 2015), allow students to be in charge of their learning (Tofel-Grehl and Callahan, 2014), provide opportunities to develop reasoning, questioning, and argumentation (Tofel-Grehl and Callahan, 2016), and an inquiry-based approach (Morrison *et al*., 2015; Tofel-Grehl, and Callahan, 2016).

The common element in all of these features is a focus on the student, and developing skills and capabilities, not content knowledge.

There is differing evidence about the impact of STEM schools. Some suggest that students attending STEM schools performed better than those who did not (Scott, 2012). Others argue that outcomes between students attending STEM schools and non-STEM schools are no different (Erdogan and Stuessy, 2015) especially after accounting for different student characteristics that may influence performance (Wiswall, Stiefel, Schwartz, and Boccardo, 2014).

Despite these discrepancies, attending STEM schools was seen to have an impact on students' interest in STEM and STEM careers. Students were more likely to complete STEM subjects in high school, participate in STEM activities outside of school, express interest in STEM careers (Means *et al*., 2016), and participate in a STEM related post-school course or career (Franco, Patel, and Lindsey, 2012).

Setting up a STEM school is challenging because there is uncertainty about what these schools should involve, particularly in primary schools (Sikma and Osborne, 2014).

There are also challenges associated with planning and assessment. Teachers may not feel confident with the content (Sikma and Osborne, 2014), or feel uncomfortable with what is expected of them (Teo, 2012). Professional development can help (Tan and Leong, 2014).

Real life links: Programs and partnerships in STEM Education

Current situation

As mentioned, there is growing interest from industry and professional organisations in school STEM education and is often demonstrated through the provision of extra-curricular activities and experiences. With research organisations, universities and science centres and museums also involved in such initiatives, there are now more than 250 STEM education and engagement programs offered for Australian schools (Office of the Chief Scientist and the Australian Industry Group, 2016). This is an indicator of how quickly and broadly interest in STEM is growing.

A focus area of the National STEM School Education Strategy (2015) is to facilitate effective partnerships with tertiary education provides, business and industry and schools with a national STEM Partnerships Forum convened in May 2017.

Programs range across a variety of formats and include professional development for teachers, events and competitions, with examples of these evident in the STEM Programme Index (Australian Industry Group, 2017; Office of the Chief Scientist and the Australian Industry Group 2016). Partnerships such as these are also particularly prevalent in disadvantaged communities (Marginson *et al*., 2013).

Benefits

Programs and partnerships play a key role in STEM education, both in Australia and internationally (Marginson *et al*., 2013). They can expose students to STEM education, engage them in STEM, increase their understanding of STEM, and increase their interest in STEM careers.

Enrichment and outreach programs provide students with many benefits. Students are able to make connections to STEM beyond the classroom and access mentors in the field of STEM education (Quagliata, 2015).

There are also changes in student knowledge and interest in STEM. Students showed increased STEM knowledge (Kim, 2016 and Kim, 2011), increased interest in STEM careers (Reid and Feldhaus, 2007; Quagliata, 2015), increased interest in STEM (Pecen, Humston, and Yildiz, 2012) more positive attitudes towards STEM (Kim, 2016; Kim, 2011; Nadelson and Callahan, 2011) and increased motivation (Vennix *et al*., 2017). These positive outcomes suggest STEM partnerships have an important role in developing students' interest in STEM education.

Challenges

There are challenges involved in STEM partnerships, enrichment and outreach programs. Teachers may face challenges related to implementing a new approach. This is because they need to adapt their teaching practice, which involves a shift in thinking, and time to occur (Rogers and Portsmore, 2004; Reid and Feldhaus, 2007). It can be made more difficult by a lack of training in the areas the program is being implemented in, which means they may need training and support to change their practice (Rogers and Portsmore, 2004). This may prevent programs from continuing after the support of an external provider ends.

There may also be difficulties making connections in the curriculum with project-based industry examples (Australian Industry Group, 2017) and this can limit a program's authenticity. Programs that involve borrowed resources such as technological tools or equipment may face issues with maintaining them (Rogers and Portsmore, 2004). Most importantly, programs often rely on financial support (Australian Industry Group, 2017; Rogers and Portsmore, 2004; Reid and Feldhaus, 2007). This may influence the sustainability of programs provided by external providers. As such, action needs to be taken to ensure STEM education is embedded in day-to-day teaching, rather than implemented in short-term programs.

Programs are often usually aligned to the main function of the provider and occur in locations similar to the provider. This is potentially an issue for disadvantaged regions as they are not always located near providers (Australian Industry Group, 2017).

Additionally many programs on offer currently focus on specific subject areas rather than taking an integrated approach (Australian Industry Group, 2017). They are also usually voluntary, which means they are often organised by one enthusiastic person in the school and are not always sustainable. A more coordinated approach to such activities is needed (Australian Industry Group, 2017; Education Council, 2015).

Factors contributing to partnership and program success

There are many recommendations for successful partnerships between industry/organisations and schools and outreach and engagement programs. Broadly speaking, they focus on working effectively with stakeholders and participants, and considering curriculum and teaching practice.

Successful partnerships have a shared vision, benefits for all involved, trust and enthusiasm about making the partnership work, and foster student autonomy and responsibility (Watters and Diezmann, 2013).

Outreach providers need to consider how programs fit with curriculum standards and use pedagogical approaches that are evidence-based (Kesidou and Koppal, 2004). This is particularly important as the success of programs is largely due to the teaching method (Vennix, den Brok, and Taconis, 2017). Effective approaches are those which:

- Consider students thinking (Kesidou and Koppal, 2004).
- Are problem-based (Vennix *et al*., 2017).
- Teach students how to find solutions, consider the validity of evidence, and foster curiosity, self-confidence and enthusiasm for learning (Rogers and Portsmore, 2004).

STEM education in disadvantaged communities

Access to and participation in STEM has been, and continues to be, highly socially structured. In disadvantaged regions students are achieving lower results in national and international testing in the subjects of science and mathematics (as evidenced by TIMSS, PISA and NAPLAN), lower mathematical and scientific literacy, and they have lower participation rates in STEM careers (see for example Marginson *et al*., 2013). This has broad implications for both the economic future of disadvantaged communities and for students' capacity to participate in democratic decision-making around the many STEM issues facing us in the 21st Century.

There is a clear need to address the specific needs of students in these regions to ensure they have access to high quality STEM education. This is also a priority internationally (Marginson *et al*., 2013).

Creating a path forward for these communities means understanding the challenges faced by disadvantaged students, and what is currently happening to overcome those challenges.

Challenges

There are many factors that influence student interest, achievement, and careers in disadvantaged regions. Broadly defined, these factors can be described as school factors, home factors, and personal factors.

School Factors

- Teachers often expect less of disadvantaged students, which therefore influences their engagement with school. It also influences the classes they are allocated and therefore their opportunity to experience STEM (Banerjee, 2016; Williams, 2013)

- Access to resources is a problem in disadvantaged schools. This includes a lack of funding, poor access to new equipment and limited experiences provided by others (Williams, 2013).

- Staff are often less qualified to teach STEM, and schools have higher staff turnover rates, and younger, newer teachers (Williams, 2013).

- Students are not exposed to STEM in the younger years of school, which influences their engagement with it in the later years of school (Williams, 2013).

- STEM is not taught in a way that allowed students to make connections between school and their lives. STEM taught in way that reinforces traditional stereotypical views about STEM limits students interest in STEM careers (Sharkawy, 2015; Williams, 2013).

Home Factors

- Parent education levels are often lower, which influences students' participation in STEM subjects in high school (Banerjee, 2016; Miller and Pearson, 2012).

- Families are less involved in school activities, and communicate less with the school, factors which influence STEM subject achievement (Banerjee, 2016).

- Parent awareness of STEM is low. Students often have less opportunity to see STEM careers and STEM knowledge being put into practice (Sharkawy, 2015).

- Students' own perceived ability to communicate with their parents about future careers in STEM (Sharkawy, 2015; Zhang and Barnett, 2015).

- Parent expectations and communication about STEM careers influence students' interest in STEM careers (Dika, Alvarez, Santos, and Suarez, 2016).

Personal Factors

- Students do not have very positive attitudes towards STEM, school, and learning generally (Banerjee, 2016). They also felt they lacked ability in STEM compared with other students (Finkel, 2017).

- STEM is often perceived to be irrelevant to the students' future careers and lives. Students with traditional, stereotypical views of STEM education feel that a STEM career wasn't for them (Sharkawy, 2015).

- Students often lack engagement and interest in their STEM learning at school because they haven't been encouraged to develop interest and efficacy in it (Banerjee, 2016; Sharkawy, 2015)

- Information about STEM careers is lacking, which means students are misinformed or do not know about STEM careers (Sharkawy, 2015; Yerdelen, Kahraman, and TaS, 2016; Zhang and Barnett; 2015).

- Students have not been encouraged to take up STEM, or to develop an interest in STEM (Sharkawy, 2015).

Many of the challenges students experience relate to differences between their lives and what is happening at school. For example, students and their families have very different experiences, understandings and expectations in STEM compared to what is being taught in the classroom. Therefore, STEM education becomes challenging and students do not engage or feel they can participate in a STEM career.

It is also important to note that disadvantaged students face other challenges that relate to geography, cultural and linguistic diversity, and poverty, all of which influence their schooling. It is beyond the scope of this report to provide an overview of the research in these areas, however they have an important role in students' education and should be considered when planning educational programs.

Current approaches

While many of the approaches described earlier in this report occur in disadvantaged communities, there are additional programs to overcome the barriers experienced by disadvantaged students.

In STEM education, programs for disadvantaged students usually aim to increase aspirations, participation, understanding of STEM and STEM careers. They often take the form of short-term outreach initiatives that involve partnerships between higher education institutions, or organisations that work in STEM. The approaches can be grouped as in-school initiatives, out-of-school enrichment programs, or longer-term holiday programs.

In-school programs

In-school programs occur during school hours and are usually part of the school curriculum.

An example of an in-school program is where a unit of work is developed and implemented (see for example Duffin, Starling, Day, and Cribbs, 2016 and Han, Capraro, and Capraro, 2015) or a short-term program of work where STEM is showcased (see for example The Robot Roadshow Program, Matson, DeLoach, and Pauly, 2004).

Key features of such programs are inquiry, project or problem-based approaches (Duffin *et al*., 2016; Han *et al*., 2015; Han, Rosli, Capraro and Capraro, 2016) that provide opportunities for students to make authentic connections to real life examples of STEM, and consider links to careers in STEM (Duffin, *et al*. (2016). These are all key features of STEM education described earlier in this report.

Such programs have both positive and negative outcomes. The positives relate to student understanding of STEM. For example, programs increase student knowledge and outcomes in STEM subjects (Duffin *et al*., 2016; Han *et al*., 2015; Han *et al*., 2016) as well as their understanding of STEM outside school (Duffin *et al*., 2016). However, the long-term outcomes of such programs has not yet been tracked (Matson *et al*., 2004).

Most of the difficulties relate to sustainability. While most approaches incorporate teacher professional development, they are organised by outside providers. This means they rely on external funding and staffing, so once these resources end, the programs can no longer continue (Matson *et al*., 2004).

Out-of-school enrichment programs

Many enrichment and outreach programs operate outside school hours. These can be after-school programs run on a regular basis, or one-off workshops. Examples include after-school clubs where students have the opportunity to participate in STEM activities. They usually aim to increase participation and interest in STEM (Marginson *et al*., 2013).

Many of these programs involve an inquiry, project, or problem-based approach where students had the opportunity to engage in hands-on activities (Cutucache *et al*., 2016; Finkel, 2017; Moreno, *et al*. 2016). Other crucial factors include opportunities to feel successful, build confidence, engage in teamwork, and enjoy new opportunities (Denson *et al*., 2015).

With the involvement of external providers comes the opportunity for students to work with mentors in STEM fields. These are often university students, which means students could both see STEM in practice, and ask questions about STEM (Cutucache *et al*., 2016; Denson *et al*., 2015; Finkel, 2017).

The programs were seen to have both advantages and disadvantages. The advantages include increases in STEM knowledge, and career interest (Cutucache *et al*., 2016; Denson *et al*., 2015; Moreno *et al*., 2016).

However, there were issues that related to teachers, students, and the authenticity of the STEM activities. In some programs, it was difficult to get teachers involved, and to understand the programs, their purpose, and how to teach them after the program ended (Finkel, 2017). For students, there was little opportunity to make connections with prior knowledge and work on long-term units of work (Gupta, Hill, Valenzuela, and Johnson, 2017). This was also influenced by unpredictable attendance and student enthusiasm (Gupta *et al*., 2017). Programs are also limited by factors such as time, and ease of use of the materials involved (Moreno *et al*., 2016).

Holiday programs

Many enrichment programs are school holiday programs and camps where students attended organised activities for a series of days, usually a week or more. They are usually provided by universities, or organisations that work in STEM. These programs may also involve professional development for teachers with the aim of them applying their new knowledge about STEM teaching in the classroom (Elam *et al*., 2012).

Holiday programs generally include inquiry-based approaches, (Gilliam, Bouris, Hill, and Jagoda, 2016; Oyana, Garcia, Heagele, Hawthorne, Morgan and Young, 2015), hands-on activities (Elam, *et al*. 2012; Mohr-Schroeder, Jackson, Miller, Walcott, Little, Speler, Schooler, and Schroeder, 2014), collaborative projects (Elam *et al*., 2012) and mentoring (Elam, *et al*., 2012; Gilliam *et al*., 2016).

Successful programs consider socio-cultural factors. This includes the students' family background, their academic background, and their previous exposure to STEM activities (Oyana *et al*., 2015). This suggests an approach that considers the student first, rather than focusing on content knowledge, is important.

Holiday programs increase students interest in STEM (Elam, Donham and Solomon, 2012; Gilliam *et al*., 2016; Oyana *et al*., 2015), increase their knowledge of STEM, and many students indicate that they may consider a STEM career (Oyana *et al*., 2015). Students are able to build connections between STEM and real-life applications (Oyana *et al*., 2015).

However, one issue with holiday programs is their location. Programs usually occur near an external provider of such programs, which may limit access (Oyana *et al*., 2015). This is particularly a problem for disadvantaged students in rural or remote areas.

Key components

When planning for future education programs, it is important to look at what is working and what current approaches have in common. In the literature, it is evident that the provision of enrichment and outreach programs are the most common approach to improving STEM education in disadvantaged areas. These programs usually involved the following key features:

- Partnerships between school students and industry professionals and university students.
- Mentoring for students by STEM professionals.
- Inquiry, project, and problem-based approaches.
- Connections with STEM to real-life examples.
- Short term programs.
- Access to resources.
- Aim to increase participation in, and exposure to STEM.
- Involve teacher professional development.

While these programs have benefits for students, they usually rely on the availability and support of external providers.

Schools are then dependent upon the resources and mentors provided by the external provider, which impacts sustainability. While some programs also incorporate teacher professional development to allow learning to continue in school, this is not always the case. This may influence the sustainability of programs provided by external providers. As such, action needs to be taken to ensure STEM education is embedded in day-to-day teaching, rather than implemented in short-term programs.

Current needs

Students in disadvantaged communities require an approach to STEM education that considers their needs and overcomes the barriers they encounter. These approaches must be evidence-based practice, and designed specifically to assist in overcoming the novel challenges they face.

There are several key features of STEM education in disadvantaged areas that need to be considered:

- Students need to see the relevance in what they are learning. That is, to apply their learning outside the classroom and make links to STEM careers and uses in day-to-day life. This includes authentic learning experiences that connect to real-life applications of STEM, examples of STEM in possible careers, and starting lessons with what the children know and examples in their day-to-day lives and building outwards from there. This takes students beyond the basic mastery of curriculum content, and enables them to participate and contribute in an effective manner.

- Approaches need to be grounded in evidence-based practice and what is working for students in disadvantaged regions. Most approaches to STEM education incorporate principles of inquiry learning, problem-based learning, or project-based learning. They enable students to participate in authentic, active, meaningful learning, where they have the opportunity to design their own problems, consider possible alternatives and decide on a course of action.

- Opportunities to see STEM in action and to work with local industry mentors are beneficial. School students also need to be able to involve their family and community to encourage awareness in the value of STEM education. Partnerships can allow access to resources, information, and opportunities to experience STEM in action.

- School-wide support is needed to increase the value on STEM education and increase the chances of students participating. This includes support from school administrators, support staff, teachers, students, and families.

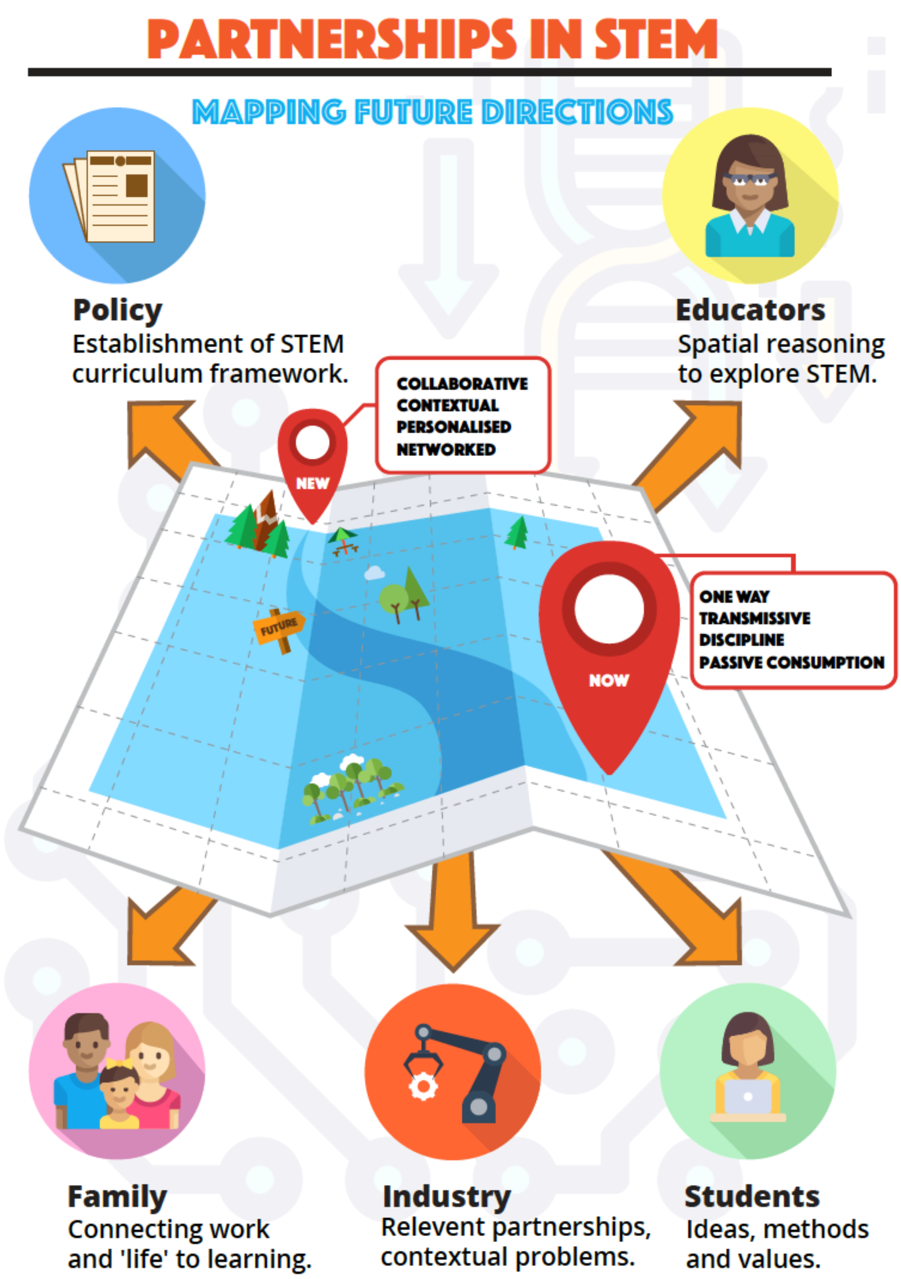
- Teachers need an understanding of evidence-based pedagogical approaches. Support with curriculum and assessment requirements and access to professional development is important for this.

- A sustainable and embedded approach that can continue to be implemented in the classroom that does not rely on funding, the provision of external resources, or external knowledge. While these things can be included as part of a STEM education program, it is important to consider how the program can be continued after access to these resources ends.

- The focus needs to be on the students first and content knowledge later. That is, focus on what students will gain from the learning experience, and their learning needs, before content or assessment. While these are important considerations, they follow from an understanding of the overall learning experience.

Framework for Action: STEM education in disadvantaged communities

STEM education in disadvantaged communities needs an approach that actively responds to the needs of the students and their communities, drawing on the key points identified in the previous section. This is where the approach we describe as STEM practices is crucial. STEM practices responds to the needs of families, students, industry and educators, while providing a way forward for STEM for schools in Australian policy.



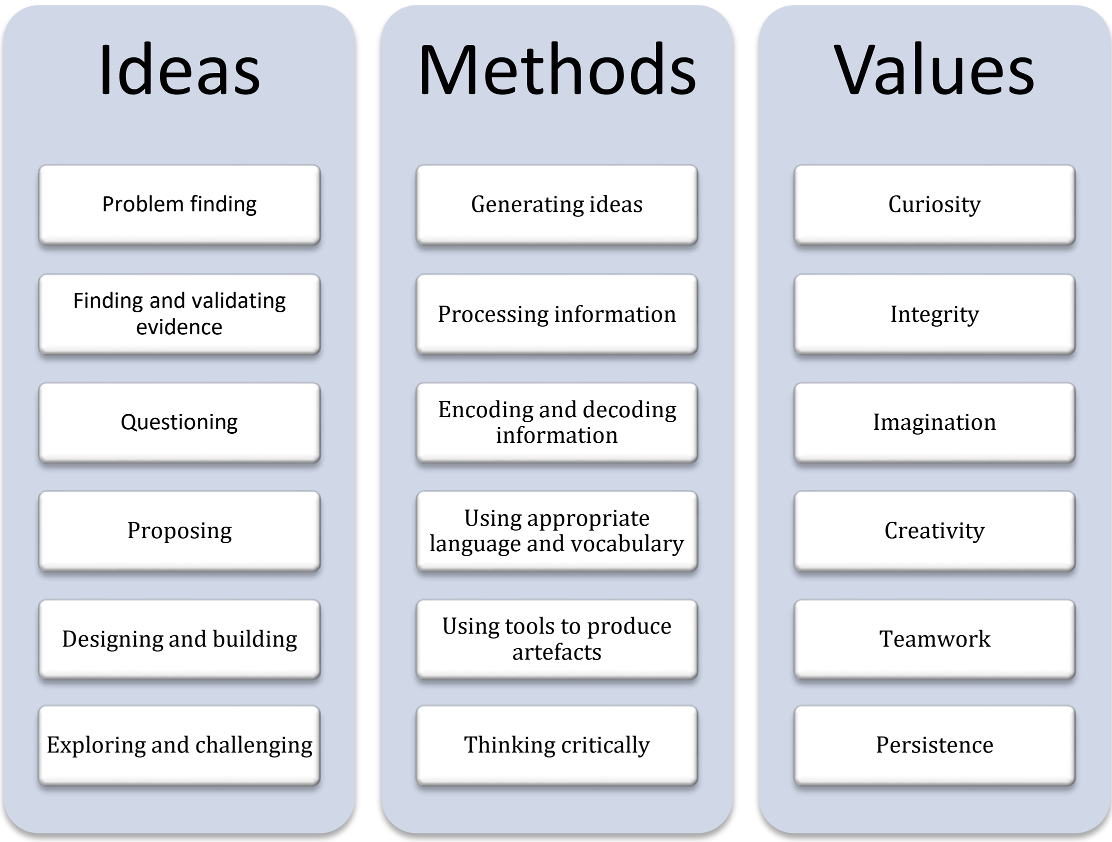
In the framework for action, we outline what a STEM practice is (a method, value, and idea), the theoretical framing of STEM practices (practice architecture), an example of a STEM practice (spatial reasoning) meeting the requirements of the Australian Curriculum, and recommendations for policy.

STEM practices

As the name suggests, a STEM practices approach focuses on practices, rather than content knowledge.

A practice involves the use of an idea, method, and value to achieve something (Lowrie *et al*., 2017), with the focus being on practices that underpin everyday uses of STEM. Ideas, methods, and values, can look different depending on what is involved.

Figure 5: STEM Practices approach involves an idea, method, and value



The crucial part of this approach for disadvantaged communities is that it focuses on ensuring that systemic factors, such as curriculum and policy, work with students rather than against them.

In a STEM practices approach, consideration is given to the practices students need to live in their world, and what the students and their community need from school education.

Considering these factors aligns with the practice architecture theory of Kemmis and colleagues (2014), which will be explored in more detail in the next section. Focusing on the practices rather than content also has the advantage of disrupting the traditional content-based approach to schooling (Sanders, 2008).

This does not mean the curriculum content is ignored. Content is addressed through the STEM practice. This approach avoids disciplinary arguments about what STEM involves, and alleviates any concerns about confidence in teaching STEM.

Practice architecture

The STEM practices approach is grounded the work on ‘practice architectures’ of Kemmis *et al.* (2014). The work on the professional practice of teachers argued that practices are socially-established forms of human activity. They are held together by practice architectures, which are characteristic arrangements of actions and activities (doings), ideas and discourses (sayings), and arrangement of people and objects (relationships). Practices are influenced by the architecture of the context, cultures and infrastructure around them.

As set out in Figure 6, the practice architecture supports educational designers to see the connections between the sayings, doings and relatings. The approach draws attention to the connections between language, activity and, crucially when considering disadvantage, power.

Figure 6: Practices and practice architectures

	Practices	Medium	Practice Architecture	
Individual world	Sayings	Language	Discourse	The world we share
	Doings	Activity	Material-economic, spatial	
	Relatings	Social	Social-political	

Figure 7 shows the arrangement of some basic STEM ideas, methods and values using this framework.

Figure 7: Some STEM practices and practice architectures

<table>
<tr><th></th><th>Practices</th><th>Medium</th><th>Practice Architecture</th><th></th></tr>
<tr><td rowspan="3">Individual world</td><td>Questioning</td><td>Language</td><td>Vocabulary of science and design</td><td rowspan="3">The world we share</td></tr>
<tr><td>Processing information</td><td>Model making</td><td>Representations</td></tr>
<tr><td>Communicating</td><td>Social space</td><td>Social choices</td></tr>
</table>

Educational design built on this framework seeks to provide an education that supports the individual to live well, while also supporting the development of a world worth living in.

On the individual side, the framework brings attention to the cognitive, psychomotor and affective domains; while on the world side it brings attention to language and ideas, to objects and spatial arrangements, and to the relationships between people.

From this practices standpoint, the key outcomes are not about how much knowledge about science, technology, engineering and mathematics a student can reproduce on an exam paper. Rather, the outcomes are allowing students to develop practices that involve sayings, doing and relatings. It is concerned with how forms of understanding are connected to individual and collective self-expression, how modes of action are connected to individual and collective self-development, and how ways of relating to one another are connected to individual and collective empowerment and self-determination.

A further point to be made here is that because practice architectures are socially and historically developed, what is authentic in one context may not be authentic in all contexts. Most curriculum planning calls for STEM to be taught in context. This is answered with an abundance of project-based learning. Too often, however, these responses are not authentic and do not link to the real world, nor to the cognitive, psychomotor or affective needs of the learners.

Spatial reasoning as a STEM practice

A key aspect of our own use of the practice architecture framework is that we start at a very clear point within the matrix, and to ensure that all design decisions can be justified from that point. For example, because STEM is fundamentally concerned with understanding and working with the physical world, spatial reasoning is a key 'doing' within STEM.

Spatial reasoning involves the process of being able to mentally consider and manipulate spatial properties of objects and consider how these objects relate to each other. It involves being aware of space, being able to represent spatial information and applying reasoning to interpret the spatial information (National Research Council, 2006).

Spatial reasoning comprises three constructs, namely: spatial visualisation; mental rotation: and spatial orientation. Engaging in these constructs requires visualising "in the mind's eye"; using mental imagery; locating and arranging objects; orientation shapes and objects; understanding structures; interpreting visual and graphical arrays; navigating maps and reading timelines; and the sequencing of pictures. We will return to these in a later section of the paper.

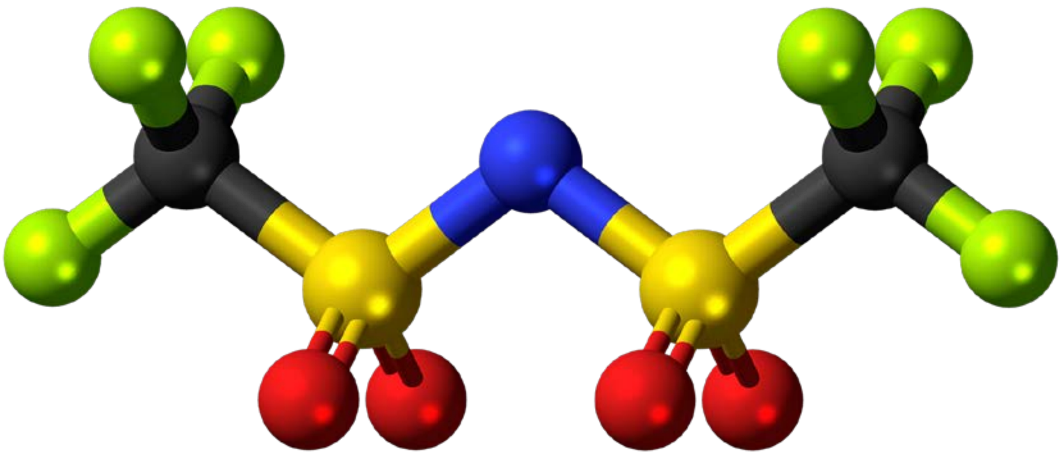
Figure 8: Spatial reasoning skills are used in everyday life, in situations such as driving

Spatial reasoning is not only about mathematics. It applies to all areas of life. We apply spatial reasoning in our daily routines, usually without thinking about it. It is part of adjusting to the physical and social environment around us. For example, when driving a car, you need to be aware of the objects around you, make a judgement about distance and space, and direction, in order to drive without hitting an object.

There are a number of advantages in teaching spatial reasoning and developing spatial skills:

- Young adults with highly developed spatial skills are more likely to pursue STEM careers (Wai, Lubinski and Benbow, 2009).
- Many STEM careers involve spatial skills (Uttal, Miller and Newcombe, 2013). For example, the use maps, or chemistry models (Hegarty, 2010).
- People working in STEM fields are more likely to be successful if they have well-developed spatial skills (Kell *et al*., 2013).
- Students develop the skills they need to participate in STEM careers (Uttal *et al*., 2013).
- Spatial skills can be developed and taught, with improvements continuing later in life (Uttal *et al.,* 2012).
- Developing spatial skills makes it easier for students to learn STEM knowledge (Uttal *et al*., 2012).

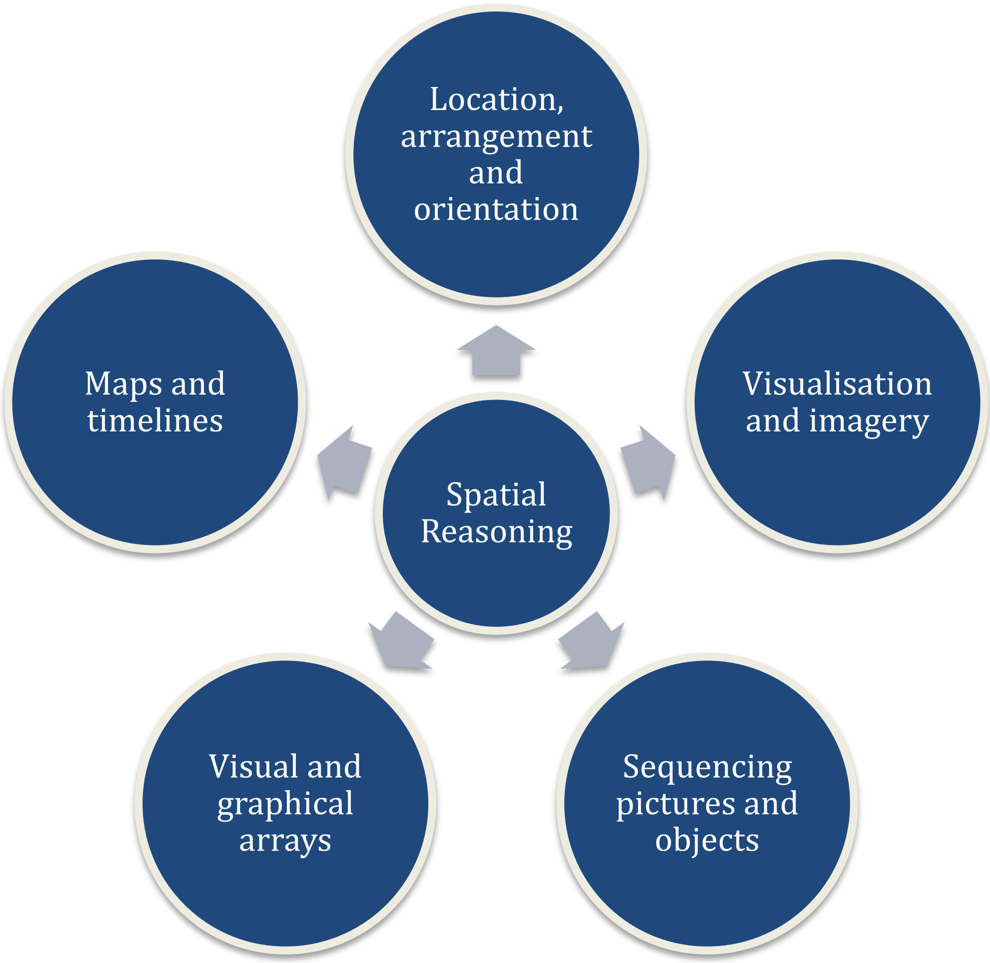
Figure 9: An example of a chemistry model (a bistriflimide anion) where spatial reasoning skills need to be applied to create and interpret.



Elements of Spatial Reasoning

Spatial reasoning involves several elements which we describe here to involve visualisation and imagery; location, arrangement, orientation, and structure; visual and graphical arrays; maps and timelines; and the sequencing of pictures.

Figure 10: Elements of spatial reasoning



Location, Arrangement, and Orientation

Location and Arrangement involves considerations about your own position, movements you may take, the direction these may be in, and the ability to use appropriate spatial language to communicate this to others (Lowrie *et al*., 2017). Examples of this include giving directions such as 'turn left in 300 metres', planning and performing a dance, being able to plan a sequenced path to get from one location to another, and navigating an obstacle course or navigate a children's playground.

Figure 11: Navigating a children's playground involves considering your location and the movements you need to make to successfully use the equipment.

Spatial orientation involves the ability to consider your own perspective, and transform that perspective. So for example, you need to imagine an object from another perspective to the perspective that you can see (Hegarty and Waller, 2005). You also need to use your own position to consider the analysis of the object (Ramful *et al*., 2016). For example, deciding whether an object is above or below you. It is also needed when reading maps.

Figure 12: Using a map requires spatial orientation skills to navigate, through for example, matching north on the map with north on your physical location

Visualisation and Imagery

Spatial visualisation and imagery involves mentally manoeuvering and manipulating spatial information in a complex manner. It usually involves multiple manoeuvers and steps when manipulating the object or information (Ramful *et al*., 2016) and it involves considering the way an object changes when it is manipulated (Sorby, 1999). So for example, imagining what an unfolded piece of origami may look like when folded back into shape, or the change in a packing box from when it is flattened to when it is 3D form. The focus here is on the transformation of the object, and the multiple steps involved.

Figure 13: Origami requires the ability to manipulate paper and imagine what it should look like from beginning to end.

Visual and Graphical Arrays

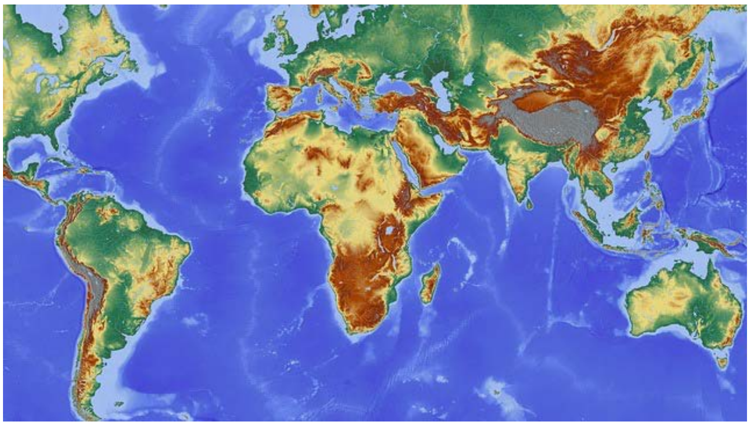
An array is a visual representation that involves congruent units that do not overlap or leave gaps. It is usually rows and columns that are aligned in a rectangular shape, and have equal numbers of units in each side (Outhred and Mitchelmore, 2004). They are an example of spatial structuring, where you mentally construct and organize the form of a set of objects (Battista, 1999). They are often used as a multiplication strategy. An example is considering the number of cupcakes you have, and how you will divide them evenly into rows and columns to fit in a rectangular container.

Figure 13: Considering how to fit a certain number of cupcakes into a rectangular cake container is an example of an array

Maps and Timelines

Maps as a STEM idea involve the display of spatial information (Hegarty, 2011), and require the manipulation of spatial information to interpret them. They usually involve pictorial or symbolic representations and have a specific orientation that needs to be interpreted (Presson and Hazelrigg, 1984) and are usually used to assist with navigation somewhere new (Xiao, Lian, and Hegarty, 2015). Maps usually require spatial knowledge, such as directions and locations to understand and interpret (Xiao *et al*., 2015). An example of a map is a street directory of a city or town; however, it can be more complex such as a weather map.

Figure 14: Interpreting a map involves considering and interpreting spatial information



Spatial timelines involve considering sequences to understand the way things come together and how they are ordered. For example, the days of the week, months of the year, and time all follow particular sequences and orders. Another example is identifying and describing the way the sun moves from sunrise to sunset.

Figure 15: Understanding sequences of days, weeks, months and years requires you to interpret spatial timelines

Sequencing of Pictures and Objects

The sequencing of pictures is an example of patterns and relationships. It involves the ordering of pictures to understand and predict things such as what may come next; discovering what is missing from a repetitive series of pictures; and making inferences, predictions, generalisations, and drawing reasonable conclusions from the information in a sequence of pictures (Lowrie *et al*., 2017). An example of this is figuring out what comes next in the sequence of traffic lights.

Figure 16: Understanding and predicting the sequence of traffic lights involves interpreting patterns and relationships

STEM practices in action

By seeing spatial reasoning as a ‘doing’ in the practice architecture, it is possible to design activities that work through the framework.

Spatial reasoning requires certain cognitive skills (sayings) such as patterning. It requires a certain language and vocabulary (near, far, bigger, smaller). The choice of contexts can be driven by identifying where students can really use these sayings, doings and relatings. A context will engage the learner when they can see it as a reasonable place to use patterning, or vocabulary such as bigger and smaller.

In this section, we describe examples of spatial reasoning as a STEM practice, focusing on how it may link to the Australian Curriculum across all subject areas, not just STEM, and an example of a unit of work that involves spatial reasoning as a STEM practice that can be adapted across all Year levels.

Curriculum and assessment

A common concern teachers have with teaching STEM is how it influences their ability to meet curriculum and assessment requirements. Requirements are usually discipline specific, with no connection between each discipline area such is expected in an integrated approach to STEM education (English, 2016).

By teaching the underlying STEM practices, teachers can addresses curriculum content, in all curriculum areas including English, languages, and humanities and social sciences, to meet assessment, and curriculum requirements. The difference with this approach is that teachers start with the practices and then incorporate the content. This avoids disciplinary arguments about what STEM involves, and alleviates teachers’ concerns about their confidence in teaching STEM education.

A STEM practices approach also aligns to the philosophy of the curriculum, focusing more on capabilities rather than content knowledge. This means students are also developing the general capabilities outlined in the Australian curriculum, including critical and creative thinking, personal and social capability, and ethical understanding.

Examples of spatial reasoning can be found across all areas of the curriculum and helps with concepts and content knowledge in each subject across STEM and other subjects in the Australian curriculum. This is one of the advantages of teaching STEM practices rather than STEM content; teachers do not have to feel concerned about making links to the curriculum, or missing content. The table on the following pages details where examples of spatial reasoning can be found in each area of the curriculum, along with illustrated examples, to help understand how STEM practices can assist in all areas of teaching.

Spatial reasoning as a STEM practice in the Australian Curriculum

Science

From Foundation, students are exploring size, shape and movement (ACSSU005) and this is an opportunity for them to visualise and use spatial language.

Graphs and visual arrays can be used throughout Year 3 (ACSIS057), and maps can be useful in Year 6 to explore Earth sciences (ACSSU096).

By Year 8, the location and arrangement of structures in cells is a rich way to encourage spatial reasoning (ACSSU149), while diagrams of DNA and inheritance do the same in Year 10.

Technology

By Year 2, students are sequencing steps for making designed solutions (ACTDEP009). Using pictures when sequencing helps develop spatial reasoning.

In Years 5 and 6, storyboards involve sequencing and timelines (ACTDIP019). Visualising data and using graphs is enhanced in Years 7 and 8 (ACTDIP026).

In Years 9 and 10, students can refine their skills by producing technical drawings in two and three-dimensional representations (ACTDEP049).

Engineering

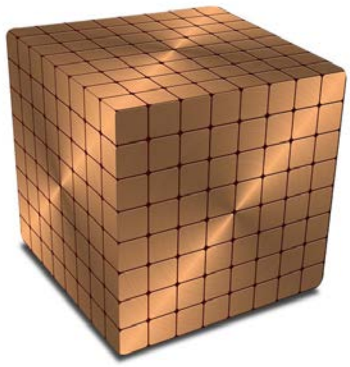
Although engineering is not a specific area in the curriculum, it shares many similarities with Design and Technologies (above).

Students can explore big ideas in engineering by applying mathematics and science to invent, design, build and improve all kinds of things. Spatial reasoning is at the heart of this process. In primary school, students use visualisation to develop design ideas, and communicate these by drawing and modelling (ACTDEP006 and ACTDEP015).

In high school, these designs become more nuanced (ACTDEP036) and designs are tested and refined (ACTDEP050).

Mathematics

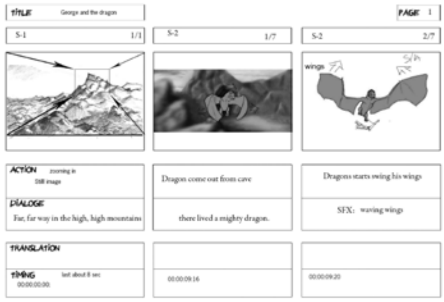
Spatial reasoning has always been recognized as an important component for the teaching and learning of geometry. For instance, describing position and movement (Foundation-ACMMG010); describing the features of 3D objects (Year 2-ACMMG043); connecting 3D objects with their nets and other 2D representations (Year 5-ACMMG111); identifying relations between patterns on the net; investigating combinations of translations, reflections and rotations, with and without the use of digital technologies (Year 6-ACMMG142); and calculating the areas of composite shapes (Year 9-ACMMG216).



Spatial reasoning is beneficial in solving non-geometric problems. For example, in algebra, it is utilised in describing patterns with numbers and identifying missing elements (ACMNA035) and investigating, interpreting and analysing graphs from authentic data (Year 7-ACMNA180).

English

In Foundation, children start learning about rhyming patterns, syllables, and sounds in words (ACELA1439). Year Four students begin to make their own storylines, characters and settings (ACELT1794).



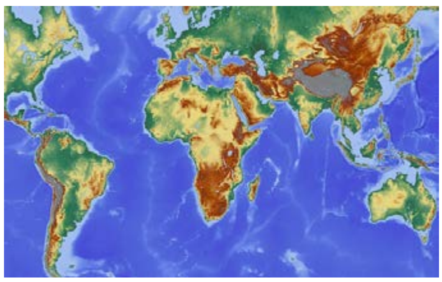
In Year Seven, students focus on planning, rehearsing, and sequencing information to promote a point of view that is delivered in a presentation (ACELY1720).

By Year 10 they focus on analysing and evaluating text structures and language features to understand how authors' have constructed their text and make comparisons between texts (ACELT1774).

Humanities and social sciences

In Foundation, students start by exploring maps, texts , and pictures (ACHASS1008). In Year 4 they start to look at recording and representing data that they have collected that can also involve locational data (ACHASS1075)

In history in Year 7 students look at physical features of ancient civilisations and how these influenced civilisation (ACDSEH002)



In geography in Year 8, students are expected to represent geographical data such as maps, graphs, population data, field sketches and diagrams, with and without the use of digital and spatial technologies (ACHGS057)

In civics and citizenship in Year 9, students look at Australia's identity and how it is influenced by global connections and mobility (ACHCK081)

In economics and business in Year 10 students are required to consider economic reasoning and decision making processes, focusing on cost-benefit analysis and economic events (ACHES058)

Health and physical education

Spatial reasoning is a key part of movement and physical activity across all year levels. In Year 1 and 2, students work with movement skills in sequences and situations (acpmp025).

In Years 5 and 6 they work to manipulate objects, space and people to perform movement sequences (ACPMP064).

In Years 9 and 10 their involvement with manipulating objects, space and people moves into the more complex level of analysing the impact of movement, space, objects and people (ACPMP103). An example of this would be planning moves in a basketball or football game, and predicting where players may be and the outcome of this.

Arts

In media arts in Foundation to Year 2, students create and present media artworks that communicate ideas, such as through comic book representations (ACAMAM056)

In music, Years 3 to 4, students create compose and perform music using their own way of recording it with symbols on paper and performing it (ACAMUM086).

In drama, Years 5 to6, students need practice and perform scripted performances that involve considerations of narrative structure, representations through body, and interactions and use of props to tell their story (ACADRM037)

In art, Years 7 to 8, students focus on planning for art works which involves considering spatial representations of the design and space used for art (ACAVAM120)

In dance, Years 9 to 10, students structure dramatic performances by manipulating elements and form and style to meet a purpose (ACADRM050)

Language

Linguistic structure is vital to all communications (verbal and written), and the understanding of these structures can be thought to be a spatial representation of language conventions.

The decoding of sequence in sentence construction, directionality in written language and symbolic representations require a spatial scaffold with which to alter one's frame of reference from their first language.

In Foundation to Year 2 Arabic, students are expected to locate and organise information from texts (ACLARC106) which requires spatial knowledge.

In Years 3 to 4 Auslan (second language learner) students are expected to understand hand movements and combinations of hand movements that form signs and meaning (ACLASFU156)

In Years 3 to 6 of the Aboriginal Languages and Torres Strait Islander Languages (second language learner), students focus on stories, paintings, songs and dances that have particular language features and meanings throughout (ACLFW101)

In Year 9 to 10 French (Year 7 entry), students explore how language has changed over time and in response to cultural changes. This involves creating timelines of change and mapping differences (ACLFRU124)

Integrated Learning

Each of the curriculum links described in this section can be combined into larger units of work that cover more curriculum content. For example, when teaching spatial reasoning skills through a unit about maps, graphs or data linking to the humanities and social sciences curriculum area, it is likely that this could also cover content around countries, history of different locations, scientific evidence and many other examples. This is one of the advantages of a STEM practices approach; it underpins many day-to-day learning experiences across all areas of the curriculum.

A way forward: A sustained, embedded approach to STEM Education

Educators need a way forward that emphasises a focus on STEM in day-to-day teaching. Currently STEM education is not incorporated in schooling in a sustained way. Curriculum and assessment expectations do not allow this as STEM is not highlighted as a priority. This is despite many documents outlining the importance of STEM and the role of schools in Australia's future prosperity. Changing the current approach is crucial given the importance of STEM to Australia's future.

To increase the emphasis on STEM education, Australia needs a recognised national framework for STEM education. A key part of this would be to include STEM as a general capability to the National Curriculum. This will enable schools to incorporate STEM in a more sustained way in day-to-day practice. Such an approach responds to calls to increase the focus on the general capabilities to meet the future needs of Australia's workforce (Torii & O'Connell, 2017). This addition is not asking teachers to add more content, it is to indicate how STEM can be incorporated across everyday school practice. Without the addition of STEM as a general capability, it is unlikely that the growing need for STEM in schools will be addressed.

A STEM practices approach provides a guide to how a national framework may look in schools. STEM practices is an approach that focuses on the underlying practices of STEM; including the use of an idea, method, and value to achieve a goal (Lowrie *et al*., 2017); rather than teaching specific content knowledge. By focusing on practices rather than content, teachers are able to respond to the diverse needs of their school and community. This aligns to the philosophy of the curriculum, focusing more on capabilities rather than content knowledge.

Drawing on the example of spatial reasoning as a STEM practice, the capacity to reason spatially, is becoming increasingly important for tomorrow's professions and workforce. Some STEM practices have particularly high associations with today's STEM professions. That is, if you are good at these practices, you are more likely to go into one of these professions. Developing these practices are therefore crucial to Australia's future. In disadvantage communities, this is particularly important because students have lower achievement rates in STEM, and less participation in careers traditionally perceived as STEM careers (Marginson, Tytler, Freeman, and Roberts, 2013). An approach such as this Is crucial to meet the needs of Australia's future workforce in all communities.

STEM FOR ALL YOUNG AUSTRALIANS

A FRAMEWORK FOR ACTION

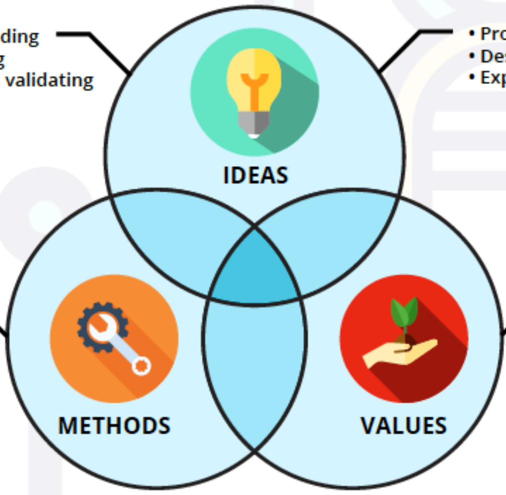
Helping children live in their world, by responding to the needs of their community.

STEM PRACTICES

Improve education for Australians in science, technology, engineering and mathematics.

- Problem finding
- Questioning
- Finding and validating evidence

- Proposing
- Designing and building
- Exploring and challenging



- Generating ideas
- Processing information
- Using appropriate language and vocabulary
- Thinking critically
- Using tools to produce artefacts
- Encoding/Decoding information

- Curiosity
- Integrity
- Imagination
- Creativity
- Teamwork
- Persistence

The biggest predictor of success in STEM: Spatial reasoning

- Location, arrangement and orientation
- Visualisation and Imagery
- Visual and Graphical Arrays
- Maps and Timelines
- Sequencing of Pictures and Objects

Conclusion

The increasing focus on STEM education comes from recognition of the crucial nature of STEM for Australia's future. It is linked to economic productivity, innovation, and future workforce needs. School education needs to be responsive to these needs and prepare children for the future they will live and work in. It is important to consider the needs of disadvantaged communities to ensure they can participate in such a future, so disadvantage is not further increased.

Current approaches to STEM education are diverse, and teachers are faced with many challenges in implementing programs. This is further complicated in disadvantaged communities where achievement, participation and interest in STEM is lower than the average Australian community. While there are many targeted initiatives that aim to assist disadvantaged communities in STEM education, these are often limited by time, resources, funding, and staffing issues. To respond to the diverse needs of disadvantaged communities, and overcome barriers, teachers need an approach they can implement in their day-to-day teaching.

At a policy level, we recommend that a recognised national framework for STEM education is developed. A key part of this would be to include STEM as a general capability to the National Curriculum. By doing this schools will have more scope to incorporate STEM into day-to-day teaching. This is not adding new content, or more pressure to teachers, it is to highlight the importance of STEM and how it can be incorporated across everyday school lessons. A STEM Practices approach is a perfect example of how an addition such as this can be incorporated into day-to-day teaching.

By teaching the underlying practices of STEM, and relating this to STEM general capabilities, teachers can address curriculum content, not just in STEM areas, but all curriculum areas such as English, languages, and humanities and social sciences. This alleviates teachers' concerns about curriculum and assessment requirements, and increases confidence in teaching STEM. It also addressed the growing need for STEM in Australia's future.

In the STEM Practices framework for action, we have outlined what a STEM practice is (a method, value, and idea), the theoretical framing of STEM practices (practice architecture), an example of a STEM practice (spatial reasoning) and how STEM Practices aligns with the requirements of the Australian Curriculum. This framework aims to guide teachers towards understanding what STEM Practices look like so they can use this approach in their school.

For disadvantaged communities a STEM practices approach is effective as it focuses on teaching practices that are key in helping children live in their world. Teachers start with the unique needs of each community, which means students can see STEM in action in day-to-day situations. They can see that they can actively contribute to the future of their community in a meaningful way. School education needs to be responsive to these needs and prepare children for the future they will live and work in. Without an approach such as this, disadvantaged communities are at risk of being further left behind in this ever-changing world.

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