STEM Education in Practice
Case studies from three schools
A Bright Spots STEM Learning Hub Foundation Paper for SVA, in partnership with Samsung

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STEM Practices: what’s happening in schools?

STEM education is an increasingly important priority around the world; however, research on the broad topic is still emerging, with opinions varying on what STEM education can, and should, involve (English, 2017; Sanders, 2008). Unsurprisingly, educators encounter a range of challenges when implementing STEM programs. It can be overwhelming for teachers to know where to begin, especially when attempting to manage the seemingly different outcomes of achieving disciplinary depth and the breadth of boundary-crossing expertise.

The problem worth solving is... How do we equip young people with the knowledge, skills and values that enable them to achieve success—in the broadest sense—in a rapidly changing world? We argue that an approach to learning that we describe as STEM Practices offers teachers both a conceptual framework and a design lens for education that meets the needs of young people.
A STEM Practices approach focuses on the practices that underpin STEM, rather than content knowledge. A practice involves the use of an idea, method, and value to achieve a relevant outcome (Lowrie, Logan & Larkin, 2017), with the focus being on practices that underpin everyday uses of STEM.

In this paper we explore three schools’ STEM education programs through a STEM Practices approach, after conducting site visits, interviews and observations. The goal was to understand how schools in distinctly different contexts were progressing along their own STEM journeys.

This paper is part two of the paper ‘STEM education for all young Australians, A Bright Spots STEM Learning Hub Foundation Paper, for SVA, in partnership with Samsung’. That Foundation Paper provides an understanding of approaches to STEM education, focusing specifically on the needs of disadvantaged communities through the STEM Practices framework.

Before introducing the three schools, first we revisit some of the key elements underpinning STEM education, from the first Foundation Paper ‘STEM education for all young Australians, A Bright Spots STEM Learning Hub Foundation Paper, for SVA, in partnership with Samsung’.
STEM as a worldwide priority

STEM education is an important concern for governments, industry and education sectors nationally and internationally. School STEM education is an important component to any nation’s STEM plan.

In Australia, government interest in STEM has been described in a number of policy initiatives; including Australia’s National Science Statement, the National Innovation and Science Agenda and the National STEM Education Agenda. Unlike some initiatives, the importance of STEM education is highlighted from outside government, with industry bodies and professional organisations reinforcing the STEM agenda and the role education plays in STEM futures. By way of example, recent reports have been produced by The Australian Council for Education Research (Rosicka, 2016), The Australian Council of Learned Academies (Marginson, Tytler, Freeman, & Roberts, 2013), and The Australian Industry Group (AIG), (2017; 2015; 2013).

Unsurprisingly, Australia is not alone in its intense policy focus on STEM, with foundational alignment in Europe (Rocard, Csermely, Jorde, Lenzen, Walberg-Henriksson, & Hemmo, 2007), the United States (Committee on STEM Education, 2013), and much of the world (Marginson et al., 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 an important path to meet this need. The Organisation for Economic Co-operation and Development (OECD, 2014) 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.
STEM in schools

No two schools are the same, with each school possessing what Thompson (2000) described as ‘thisness’, the diverse combination of school, community and locale qualities. These case studies from schools around the world highlight diversity in context and approach to STEM engagement. The case studies demonstrate how STEM programs are always changing and evolving to meet students’ needs.

Although schools can, and should, approach their STEM journey differently, there is an emerging body of evidence identifying characteristics of successful STEM programs. Within the framework of STEM Practices, we suggest that teachers should consider these when designing their school STEM program:

- Learning needs to be authentic and meaningful for the students and focus on real-world problems (Rosicka, 2016; Sanders, 2012; Siekmann, 2016; Vasquez, 2014). This can incorporate activities that focus on allowing students to identify and solve problems. An example of this is an inquiry-based project (Rosicka, 2016).
- Approaches need to be designed around research about how students learn, classroom practice, and STEM education (Kelley & Knowles, 2016).
- School-wide support from teachers, administration staff, parents and students will assist with the implementation and success of a program (Kennedy & Odell, 2014; Sanders, 2012).
- Partnerships with external collaborators assist the development of STEM programs (Kennedy & Odell, 2014). These encourage students to see STEM in practice and connect students with mentors and resources.
- Programs need to be centred on what it is that we want students to learn, rather than assessment outcomes (Siekmann, 2016; Vasquez, 2014). Teachers can then connect this to assessment (Sanders, 2012) and curriculum requirements (Rosicka, 2016).

It should be noted that the focus in these key elements is not on STEM content knowledge per se, but rather a teaching mindset or even a pedagogical disposition. This is where the value of the STEM Practices framework lies. This framework asks teachers to focus on the practices that underpin STEM Education. The related Experience, Represent, Apply (ERA) heuristic (Lowrie, Leonard, & Fitzgerald, 2018) further helps teachers to start with their students’ experience to bring STEM into the classroom. This positions teachers as designers of learning activities that use different forms of STEM Practices in context.
STEM Practices

Teachers are faced with the challenge of equipping young people with the knowledge, skills and values that enable them to achieve success, in a rapidly changing world. STEM Practices offer teachers both a conceptual framework and a design lens for education that meets the needs of young people (see Figure 1).

As the name suggests, a STEM Practices approach focuses on the practices that underpin STEM, rather than content knowledge. A practice involves the use of an idea, method, and value to achieve a relevant outcome (Lowrie, Logan & Larkin, 2017), with the focus being on practices that underpin everyday uses of STEM.

![Figure 1. STEM Practices](image)

By teaching the underlying practices of STEM, teachers can address curriculum content, not just in STEM areas, but all curriculum areas such as English, languages, humanities and social sciences. This supports cross-curricula teaching, helping to alleviate common concerns about the fragmentation of curriculum and assessment requirements, while simultaneously increasing their confidence in teaching STEM.

A STEM Practices approach focuses on teaching practices that are key to helping children live in their world. Teachers start with the needs of each community; meaning, students can see STEM in practice in day-to-day situations and learn how 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.
STEM Practices by case study: methods, ideas and values

The three case studies presented in the following sections highlight STEM Practices in action around the world. These schools are committed to student learning and recognise the value of STEM in students’ development.

The first school we focus on is Mater Dei Catholic College in Wagga Wagga, Australia. Mater Dei Catholic College is a co-educational high school (years 7 to 12) in the early stages of its STEM journey. Teachers have a strong commitment to teaching the skills students will need for their future, using an integrated, inquiry-focused approach. This school broadens STEM to include the arts into all planning.

The next school we explore is Nurul Haramain Islamic Boarding School in West Nusa Tenggara, Indonesia. This school values their environment and has a strong commitment to sustainability and clean living, which the students enact through an entrepreneurship program. This program has been in action for several years now and is continually growing, based on students’ interests and ideas.

Finally, we explore the STEM programs in Anchorage School District, in Alaska, United States of America. Anchorage School District focuses on STEM programs that promote the native Alaskan culture. Their programs are supported by a dedicated team of teachers whose goal it is that every student will experience an inspiring STEM education. The program contains ideas relevant to in-school and out-of-school experiences, with particular relevance to local community needs.
In the first foundation paper we highlighted how a STEM Practices approach encompasses various aspects that influence the education of young people (see Figure 2).

![Figure 2. STEM Practices creating partnerships in STEM](image-url)
These aspects are:

- how STEM Practices link to policy (such as the curriculum)
- how educators can work with STEM Practices in the classroom
- how STEM Practices link to the students’ family and lives
- the role of industry in a STEM Practices approach
- the way students can use ideas, methods and values to learn STEM skills

This paper explores how schools are able enact each of these elements.

Each school, or school district, focuses on each of these elements in different ways (see Table 1 below).

Depending on the length of time their program has been operating, some schools may not have incorporated all elements yet. However, they each have plans for how they want to do this in the future as they continue to develop their program.

<table>
<thead>
<tr>
<th>Nural Haramain Islamic Boarding School</th>
<th>Mater Dei Catholic College</th>
<th>Anchorage School District</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Policy (curriculum)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integrating the entrepreneurial program with the school curriculum</td>
<td>Innovative assessment that focuses on skills rather than content knowledge</td>
<td>Incorporating meaningful local knowledges into the curriculum</td>
</tr>
<tr>
<td><strong>Educators</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Developing a program centered around the environment and clean living</td>
<td>Developing innovative integrated challenges for students</td>
<td>Accessing programs by local agencies and using their STEM kits</td>
</tr>
<tr>
<td><strong>Family</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Involving families in the supermarket and tree-planting program</td>
<td>Connecting the STEM Practices that students learn to real-life problems they may encounter; the involvement of families is still evolving</td>
<td>Encouraging students to explore STEM careers with volunteers for the STEM careers snapshot collection; This program is still developing</td>
</tr>
<tr>
<td><strong>Industry</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sponsorship of programs and provision of resources</td>
<td>Connecting with industry to provide role models for students. This is still developing.</td>
<td>Provision of STEM education that relates to local issues and environments</td>
</tr>
<tr>
<td><strong>Students</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connect with the values fostered by the school to develop the entrepreneurship program</td>
<td>Begin with STEM methods to explore their design challenges</td>
<td>STEM Ideas are crucial to work through problems students may encounter in their local community</td>
</tr>
</tbody>
</table>

*Table 1. Each school uses STEM Practices to connect with different elements that influence school education.*
The STEM ideas, methods, and values are addressed with varying levels of intensity in each school, and each school has a particularly strong positioning of one of these. Nural Haramain Islamic Boarding School has a particular emphasis on values, Mater Dei Catholic College has a particular focus on methods, and The Anchorage School District focuses on ideas.

Although we will turn to each of these schools in more detail in the case studies, Table 2 highlights the specific STEM Practices that are key in each school. Those highlighted in yellow are the focal point of each school’s program.

<table>
<thead>
<tr>
<th>Ideas</th>
<th>Methods</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nural Haramain Islamic Boarding School</td>
<td>• Problem finding</td>
<td>• Curiosity</td>
</tr>
<tr>
<td></td>
<td>• Proposing</td>
<td>• Persistence</td>
</tr>
<tr>
<td></td>
<td>• Designing and building</td>
<td>• Teamwork</td>
</tr>
<tr>
<td></td>
<td>• Thinking critically</td>
<td>• Creativity</td>
</tr>
<tr>
<td></td>
<td>• Generating ideas</td>
<td>• Integrity</td>
</tr>
<tr>
<td></td>
<td>• Using tools to produce artefacts</td>
<td></td>
</tr>
<tr>
<td>Mater Dei Catholic College</td>
<td>• Find and validate evidence</td>
<td>• Imagination</td>
</tr>
<tr>
<td></td>
<td>• Proposing</td>
<td>• Creativity</td>
</tr>
<tr>
<td></td>
<td>• Designing and building</td>
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<td></td>
<td>• Thinking critically</td>
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</tr>
<tr>
<td></td>
<td>• Encoding and decoding information</td>
<td></td>
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<tr>
<td></td>
<td>• Processing information</td>
<td></td>
</tr>
<tr>
<td>Anchorage School District</td>
<td>• Problem finding</td>
<td>• Curiosity</td>
</tr>
<tr>
<td></td>
<td>• Exploring and challenging</td>
<td>• Teamwork</td>
</tr>
<tr>
<td></td>
<td>• Finding and validating evidence</td>
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<tr>
<td></td>
<td>• Questioning</td>
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<td></td>
<td>• Thinking critically</td>
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<td></td>
<td>• Generating ideas</td>
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<td></td>
<td>• Processing information</td>
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</tbody>
</table>

Table 2. STEM Practices at each school, with area of concentration.

Each school is at a different developmental and implementation stage of their STEM journey (see Figure 3). For example, the program at Nural Haramain Islamic Boarding School has been operating for several years now. With support from the community, they continue to advance program operations. Mater Dei Catholic College is in the early stages of developing their program; with a team of dedicated teachers, they are developing initiatives that develop relevant 21st century skills for their students. The Anchorage School District has a wide range of schools who are at different stages of their STEM journey. The district has great support from external agencies to implement their programs.
Figure 3 demonstrates the different stages each school is at in their STEM programs with reference to each of the STEM Practices. The respective pie charts demonstrate the intensity of the respective practices being undertaken at each site—in relation to the ideas, methods, and values in their STEM programs. For all schools this is a point-in-time indicator. Each school has their own plans to further develop their STEM programs; these programs are not at their end point. The time a program has been operating is not necessarily an indicator of where each school is at with each STEM Practice. Other factors such as the availability of resources, support, and time are all factors that influence STEM programs. The journey of every school is different.

Regardless of the stage of the journey they are at, all schools are committed to continually developing their programs based around their students’ interests with the aim of helping them develop skills they will need throughout life.
In this paper we also develop a reflective lens to examine each school’s STEM journey. This approach is based on the work of Borton (2000) and Gamble (2002) and supports a developmental disposition that is based around three framing questions: What?, So what?, Now what? (Leonard, Fitzgerald, & Riordan, 2016).

Figure 4 (below) sets the reflective questions within a broader action-learning cycle that might be found in medical practice. It begins with the ‘do it’ and asks what were the events that trigger the reflection. The ‘so what?’ asks about the significance of the outcomes and their implications. The role of the practitioner is particularly relevant in this stage. The ‘now what?’ asks about lessons learnt, future actions, how this could be improved (e.g. even better if...), and broader professional development needs.

This lens is widely used in education (and medical education) and helps move us beyond the ‘descriptive trap’ of much educational reflection work. That is, we tend to do the ‘What?’ very well, the ‘So What?’ a little less well and the ‘Now What?’ infrequently. As we know from the evaluation literature, especially the field of developmental evaluation (Patton, 2010), our evaluation evidence must be forward looking and support next-practice innovation and development in dynamic and complex environments.

The schools highlighted in this paper have elements of STEM Practices throughout their programs. Of interest is that the schools started their journey with different elements of STEM Practices—the ideas, methods, or values. We will now introduce each school and their STEM program.
Case Study 1

Mater Dei Catholic College
Wagga Wagga, Australia
Mater Dei Catholic College is located in the regional Australian city of Wagga Wagga, New South Wales. Wagga Wagga is located approximately five hours drive south-west of Sydney, on the banks of the Murrumbidgee river on traditional Wiradjuri country. Wagga Wagga has a population of approximately 62,000 people (Australian Bureau of Statistics, 2018). The town is a base for the Royal Australian Air Force, as well as a service centre for surrounding agricultural industry and small towns.

Mater Dei Catholic College opened in 2004, as the second Catholic College in Wagga Wagga. Although newly established, it builds on the long history of more than 130 years of Catholic education in Wagga Wagga. The school has approximately 800 students from year 7 to 12 and approximately 60 teaching staff.

What: it’s not just what you learn, but how you learn—21st century skills, inquiry-based integrated STEAM challenges

At Mater Dei Catholic College, they take an expanded view of STEM, focusing not just on STEM, but STEAM. Here they recognise the value of the Arts as contributing to STEM skills. The STEAM journey at Mater Dei is in its early stages; with the program being developed by teachers who identified a need for students to develop skills that would benefit them in our changing world.

Although still focusing on the curriculum, teachers diversified from thinking about what students learn, to how they learn. Teachers used this to develop a vision for STEAM education.

This vision is centered around the skills teachers want students to develop, and how teachers wanted them to develop these skills. In particular, they chose to focus on developing 21st century skills, a growth mindset and resilience in their students through real-world applications of the curriculum content (Figure 5).

It’s not just what you learn, but how you learn.”
(Year 8 teacher, Mater Dei Catholic College, 2018)

STEAM is an inquiry-based subject that focuses on engaging students through collaborative complex problem-solving activities and draws upon the latest real-world experiences.”
(Year 8 teacher, Mater Dei Catholic College, 2018)

![Growth Mindset](Mater Dei Catholic College, 2018).
This approach was also guided by the success of programs of integrated learning already in operation at the school.

Integrated learning at Mater Dei

In 2017, a ‘challenge week’ was held with year 10 students. Students were asked to volunteer to participate; the majority of students elected to be involved. Students had a week to design a ‘tiny house’, and local primary school students were invited to attend the final presentation of these houses. Students were very dedicated to this task, with some even contacting local trade companies to research their task.

Students in year 7 participate in an integrated learning unit, known as a TED class. This unit combines English, history, geography and religion. Students responded well to this combined class and felt it changed the way they thought about their learning.

Feedback from these units was positive, and the majority of students would like to do something similar again.

Student feedback, and the recognition to teach students how to apply skills in real-life situations, were a driving force behind the development of the STEAM program.

“If you don’t teach us in this way now, how will we ever learn these skills?”

(Year 10 student challenge week participant, Mater Dei Catholic College, 2018)
Inquiry based STEAM projects

2018 saw the beginning of an integrated STEAM program for students in year 8. Each term, students participate in a different STEAM unit. The 2018 units are a Makerspace Sandpit, an Mbot Golfing Tournament, a Design Challenge and a Solar Car Challenge (see Figure 6).

![Figure 6: Interface of the online portfolio of student work (Mater Dei Catholic College, 2018).](image)

During these challenges, students work in groups and take responsibility for their own learning using an online portfolio of work to guide them through the process. Throughout the challenges, students take on assigned roles to encourage group participation; these roles include technology manager, group leader and scribe, and mathematician/engineer. In the online portfolio, students complete activities and reflections about their progress and the process of their challenge. Some activities in the portfolio are optional to extend students’ thinking if they are interested.

The Makerspace challenges have been varied, and include a water vessel challenge, paper plate challenge, inventors challenge, oobleck challenge, and straw bridge challenge.
In the paper plate challenge, students were faced with a variety of scenarios where they had to achieve a goal with paper plates. They had a set number of paper plates and a small number of resources such as scissors and a measuring tape. Students participated in challenges including: determining how long they could make a paper plate, creating a plate that could fly the furthest distance, creating a roller coaster, and creating a tower.

In the water vessel challenge, students were asked to create a vessel that could hold as much water as possible. They were able to use a cup, tin foil, three skewers and four marshmallows. An important part of this challenge was reflecting on what skills the students were using, and how these are useful in everyday life. They were not only learning about the processes used in the challenge, but also about their own strengths and weaknesses and the strategies employed when working collaboratively to solve problems and come up with new ideas.

In the straw bridge challenge, students were asked to construct a free-standing bridge from straws, rubber bands and sticky tape. Part of the brief was that the bridge had to be a certain length, width, and hold a certain amount of weight. Students also had to research different bridges around Australia, including those that have had construction issues. Students needed to draw their bridge design as well as research design factors such as compression, tension, suspension cables, trusses, and arches.
In the oobleck challenge, students had to make oobleck from cornflour and water, without instructions on how much of each to mix together. Students all had oobleck of different consistencies and used this to experiment with pitch. Music was played at different pitches and students explored how high the oobleck moved, as well as how oobleck of different consistencies moved differently. Students were experimenting with pitch, volume, ratios, solids and liquids throughout this process.

Although there was a focus on skills in these challenges, each of these challenges covered the content knowledge required in STEAM subjects. Students were, for example, learning about speed, distance, ratios, friction, solids, liquids, and pitch in these different activities.

One of the keys to success of the Makerspace challenges has been flexibility. This program is constantly evolving as teachers and students learn more and respond to new challenges.
STEAM assessment process

Part of the STEAM journey has been changing assessment practices. Instead of assessment that focuses on the curriculum content of each subject area, students are assessed on the skills they are developing. In the term one projects, for example, skills such as complex problem solving, critical thinking, creativity, collaboration, communication and technology use were assessed (see Figure 7). It is through these skills that students learn the curriculum content.

![Mater Dei Catholic College Year 8 STEAM student assessment template](Mater Dei Catholic College, 2018).

Figure 7. Mater Dei Catholic College Year 8 STEAM student assessment template (Mater Dei Catholic College, 2018).
One challenge with this approach to assessment is recognising how integrated assessment works. Teachers learnt to recognise that their students were still learning all the same content and skills they would have learnt in individual subject classes—they were just learning it in different ways.

Students participate in a self-assessment process where they reflect on their skill development throughout the unit. This encourages students to be self-aware about their learning and assists teachers to plan for future challenges. One of the focuses of student assessment is on what is working well and what students can improve on—described as ‘even better if...’.” Students provide feedback to teachers about what they think would make the unit even better.

One challenge with self-assessment is students’ understanding of the language of assessment, and their self-ratings. Students rarely assessed themselves in the top or bottom band of achievement.

STEM Practices at Mater Dei Catholic College

The STEAM journey at Mater Dei Catholic College starts with STEM methods and expands out to the ideas and values. Students begin their challenges by generating ideas, thinking critically, and encoding and decoding information as they explore real-world applications of STEAM. These are all key STEM methods that lead into STEM ideas. Students question the information they are presented with, find and validate evidence to develop their strategies, propose solutions, and design and build the final product as they work through the challenges. These challenges are team based, which provides an environment in which they develop STEM values. In their teams, the students used their imagination to come up with creative solutions, guided by their curiosity and eagerness to find a solution. Table 3 identifies the main STEM Practices in the programs at Mater Dei Catholic College.

<table>
<thead>
<tr>
<th>Ideas</th>
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<th>Values</th>
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<td>Thinking critically</td>
<td>Creativity</td>
</tr>
<tr>
<td>Designing and building</td>
<td>Encoding and decoding information</td>
<td>Curiosity</td>
</tr>
<tr>
<td></td>
<td>Processing information</td>
<td>Teamwork</td>
</tr>
</tbody>
</table>

Table 3. STEM Practices at Mater Dei Catholic College.
So what: positive student feedback and outcomes, strong leadership, time and space

Although the STEAM program at Mater Dei is in its early stages, student feedback and outcomes have shown it is successful. Student feedback has been positive, with suggestions for improvement focusing on issues of time management. Students have also indicated that they greatly enjoy the program and would like to see it continue.

The success of the STEAM program is underpinned by strong leadership and committed teachers who are not afraid to try new things. The teachers work together as a team to make their STEAM vision a reality.

Development and introduction of the STEAM program has required a great deal of planning and researching of resources. Teachers are not thrown by any obstacles that come their way, instead they use these to enhance the challenges posed to their students. However, while the dedication of the STEAM team is a strength, it could potentially pose a challenge for program sustainability if there are staff changes in the future.

Time and space have been both enablers and constraints in the STEAM education program. Students have four timetabled periods per week for the integrated STEAM classes, which replace some of the individual STEAM classes. Although this time assists in achieving the STEAM vision, having more time to spend on each challenge would be advantageous.

The college recently opened a new space for students to work in; the classrooms are separated with glass dividers which can be opened to enable different class groups to work together. These rooms are also fitted with smart TVs that connect across rooms to enable students to work concurrently on the same projects. As this space and the STEAM classes are new, one challenge teachers faced was organising the space. Delays in the delivery of resources also posed challenges for the program, however the teachers were fantastic at improvising and working around challenges such as these. Students worked in open spaces outside and found new resources to work with.

“Our team leader] would come in and see us and say “ok, where are you up to with this, are you ok, how are you going?” and that communication was so important.”

(Year 8 teacher, Mater Dei Catholic College, 2018)
Now what: reshaped challenges, renewed assessment, community

With the STEAM Program in its early stages, the teachers and students have many ideas for where they would like to take it in the future (see Figure 8).

Teachers and students would like to have more time dedicated to the STEAM project to extend the time students spend on each project. Although the initial stages of the project were interrupted with issues of space and time, it is hoped that more timetabled lessons can work with the STEAM projects, and a greater focus on integrated assessment.

Currently the teachers are working to develop connections with local industry, particularly through the involvement of parents at the school. They would like to see parents and community members showcase their STEAM skills, and how these can be applied outside the classroom.

The teachers would like more opportunities to incorporate the STEAM program across the school, not just in one year level. This would require more teacher involvement and training to understand the way each STEAM subject can be incorporated. A challenge for the school has been accessing professional development opportunities. Being a rural school, access to professional development for teachers is more difficult (time, travel, resources). However, the leadership team are always looking for opportunities for their team and the students.

Teachers recognise that the self-assessment process for students may need to be amended to incorporate self-assessment throughout the challenges. Students may also need more scaffolding to develop an understanding of the language of assessment, and the purposes behind this.

We have the ability to let it grow, sustainability is important—but it’s a long journey!“
(Year 8 teacher, Mater Dei Catholic College, 2018)

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Figure 8. Mater Dei Catholic College Future Directions for STEAM Teaching (Mater Dei Catholic College, 2018).
Case Study 2

Nurul Haramain
Islamic Boarding School
West Nusa Tenggara, Indonesia
Nurul Haramain Islamic Boarding School is located in Narmada district, West Lombok regency, West Nusa Tenggara (NTB) Province, Indonesia. It is around 11 km from Mataram, the capital city of West Nusa Tenggara province. The Narmada district is a mountainous region with a total area of 112.77 km² and a population of approximately 100,815 people (as at December 2017). The economy in this region is mainly agricultural with some fruit plantations, animal husbandry, and fisheries.

The residents in the Narmada district are mostly Muslim (90%) with a small number of Christian, Hindu or Buddhist (10%). Most of the citizens come from the Sasak tribe, with the Sasak language used as their daily language.

The school opened in 1992 and caters for all school age students. It covers approximately 5 hectares and has nearly 2200 students and almost 200 teachers and educational staff. In the early years of the school students only came from Lombok island; now students come from many different areas of Indonesia and Malaysia.

What: entrepreneurship and clean, healthy living at Nurul Haramain Islamic Boarding School

The educational philosophy at Nurul Haramain Islamic boarding school focuses on developing the potential of each student by valuing their individual skills, interests and expertise. There is a strong belief in the capabilities of every student, and teachers work hard to ensure their capabilities are developed. Students’ interests and ideas are key, with programs and resources developed around these. Students and teachers work together to plan strategies to achieve their goals.

STEM is covered both in day-to-day subject areas as well as in their entrepreneurship program. School leaders prioritise STEM education by focusing on programs and resources that students identify as needed. The school prioritises the computer literacy of teachers and was one of the first in the region to encourage all teachers to learn to use technology to enhance their students learning. The school also uses technology to solve problems and increase the use of resources.
The approach to education at the school is influenced by educational practices from around the world. School leaders have had the opportunity to visit and work with schools from different countries and use this to inform their practices. In particular, the school is influenced by Japan’s teaching style and healthy living.

Clean healthy living

Valuing and promoting a clean, healthy lifestyle is at the centre of the school’s philosophy. A central part of this involves being as self-sustainable as possible within their community. This has influenced the school’s approach to the environment, as well as their entrepreneurship program.

Students are encouraged to keep the environment as clean as possible and the school maintains a rubbish-management program that the students and teachers work on together. Waste is collected from the school, transported to their incinerator and burned. Students manage the roster for the roles involved in this, as well as participating in cleaning their school.

Students are also involved in an environmental tree-planting program in their school which is supported by community members.

The community provides tree seedlings for the program, and students work with non-government organisations to run community events centred on environmental awareness.

Caption 5. Students participating in the tree-planting program.
Entrepreneurship program

The entrepreneurship program brings together many elements of STEM education through different projects inspired by the students’ interests.

Currently the school manages a catfish farm, mushroom cultivation, brick production, tree plantation and a shop to sell the goods that are produced.

Catfish farming

Students involved in this program raise and then sell catfish to the public. Students take on different roles through the process including catfish treatment (feeding and caring for them), environmental management, marketing and finance.

The program begins with students caring for baby catfish and feeding them every day. The schedule for feeding them is important as otherwise the fish will eat each other in their quest for food.

Students need to clean the fish’s habitat, keep track of the Ph balance of the water and harvest the fish. Harvesting the fish is a big job and students who are not normally involved in the program are asked to assist. Once the fish are harvested the boarding school keeps enough for their needs, then sells the remaining catfish to the public.
Mushroom cultivation

Students in the mushroom cultivation program start by making the tubes needed to grow the mushrooms, then they treat the mushrooms and harvest them. When making the tubes students learn mathematics and science concepts as they mix sawdust, bran, pumice powder and water. Once the tubes have been made, the students work to prepare them for combustion and then inoculation, this occurs in a hut where the temperature is monitored. The mushrooms are watered every day until they are ready to be incubated and inseminated, the mushrooms are then ready for students to harvest. This process takes approximately four to five months. Students harvest the mushrooms twice a day, in the morning and afternoon. In one harvesting session, a student can collect approximately 4 kg of mushrooms. The mushrooms are used both for the boarding school and sold to the public in the school shop.
Brick production

This program developed after external workers were producing bricks to build the school. Students are now learning how to make the bricks from sand, water, and cement. The aim is for students to produce as many bricks as possible for the benefit of the community. Anyone who is using the bricks for the community’s benefit may have the bricks at no cost. For example, anyone involved in building shelter, schools, toilets for a community may access the bricks.

Shop

The school runs a shop that sells products to its students and the general public. The shop is called Haramain Mart, and many of the products that are being sold are grown or produced by the students, such as the catfish and mushrooms. The shop is operated by students and staff and run as a business. Students, parents and community members are regular consumers. The profit from the shop is returned to the school and used to buy more resources.

Caption 8. Product storage at the Haramain Mart.
At Nurul Haramain Islamic Boarding School their approach to STEM begins with the STEM values they want to develop in their students, and to prepare them for a successful life after school. Programs originate from students’ and teachers’ curiosity and desire to learn. These programs are developed through their creativity and imagination as they start from scratch. Students and teachers are supported even when things might not go to plan, encouraging them to develop persistence.

Students and teachers propose possibilities for their learning and identify problems they want to focus on when developing the entrepreneurship program. These are all key STEM ideas. Students are encouraged to achieve their goals by proposing approaches, questioning their approaches, and exploring and challenging their ideas; all key STEM methods. Table 4 identifies the main STEM Practices in the programs at Nural Haramain Islamic Boarding School.

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<tr>
<th>Ideas</th>
<th>Values</th>
<th>Methods</th>
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<tbody>
<tr>
<td>Problem finding</td>
<td>Curiosity</td>
<td>Thinking critically</td>
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<tr>
<td>Proposing</td>
<td>Persistence</td>
<td>Generating ideas</td>
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<td>Designing and building</td>
<td>Teamwork</td>
<td>Using tools to produce</td>
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<td>Creativity</td>
<td>artefacts</td>
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<td></td>
<td>Integrity</td>
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Table 4. STEM Practices at Nural Haramain Islamic Boarding School

Community involvement is central to the entrepreneurship program. Community businesses, non-government organisations, and local councils all provide support via financial means and by hosting educational events. This enables the programs to continue and expand, while supporting the sustainability of the region. Student values are also developed by considering their community and responsibility to those who have supported their programs.
So what: student and community interest, role models and leadership

The school believes in building a strong foundation for students to be successful later in life. Programs at the school develop religious knowledge and values, a good mentality and good management skills which enables them to achieve their goals in life once they leave school. Students are encouraged and supported to build confidence and independence, which underpins their success. The alumni of the school are very successful, with many developing careers in their area of interest, completing higher education and contributing to their community.

The success of the entrepreneurship program is evident in the continual interest of students, and support from external stakeholders. The school is very grateful for the support they are provided and believe in repaying this with productive outcomes from their programs.

These programs are achieved by a strong belief in teachers’ leadership ability and a focus on nurturing students’ ideas and interests. Students and staff are supported to achieve their vision and provided with support through learning opportunities, resources and opportunities to try new ideas.

The school leaders support teachers and encourage them to try new ideas, without concern about failure. They believe that there is always a way around things if at first things do not go to plan.

Although the school is well on its way to managing its own waste, there are varying levels of enthusiasm among the students. Some students are not as enthusiastic about cleaning up after themselves and this has influenced the program. However, the school believes it can do more to encourage students to focus on this. An important part of this has been role modelling for students.

“The trust we give teachers builds their confidence. We give teachers and staff a chance to do what they love. Often we find, after school hours, teachers will be in the place where it is related to their interest, some in the science lab, library, multimedia room, workshop room, on the plantation field, and many other locations of their interest.”

(Vice Chairman of Nurul Haramain Islamic Boarding School, 2018)

“What I believe is giving full trust, which means, even when the staff make a mistake we still support them, it’s okay to make a mistake, we can fix them.”

(Vice Chairman of Nurul Haramain Islamic Boarding School, 2018)
Now what: towards sustainability and student led projects

The school will continue to model good environmental practices and provide incentives for students to keep their environment clean. It is hoped these changes will increase student motivation and interest in maintaining a clean environment.

The school would like to extend its program so it can eventually make its own products. This will reduce the carbon emissions and decrease the environmental impact of the program.

The entrepreneurship program is always expanding in response to student and teacher interests and the desire to develop new skills.

The leadership team at the school is open to suggestions and will assist in any way they can. The school is looking to return to Japan to learn more about its clean living and teaching styles.

Caption 9. Students assisting with the rubbish program.

“I will listen to the students and teachers. What is it that the students need? We will maximise anything that students need.”

(Vice Chairman of Nurul Haramain Islamic Boarding School, 2018)
Case Study 3
Anchorage School District
Alaska, United States of America
In this case study we focus on the STEM program in a school district in the USA. The Anchorage School District is located in Alaska, in the south-eastern corner of the state.

The Anchorage school district is one of the largest in Alaska with approximately 130 schools that service nearly 47,000 students. This includes preschools, elementary schools, middle schools, high schools, and charter schools. The district has a diverse student population with more than 50% having diverse cultural backgrounds. In the district there are over 100 languages spoken, with many of these being native Alaskan languages (Anchorage School District, 2018).

What: culture, community and connected real-life STEM experiences

The native Alaskan culture is a central focus of the STEM programs in the Anchorage School District. Participating in outdoors activities with the community and understanding the environment is a key part of this. Students are encouraged to learn about interacting with their local waterways, animals, preparing for the colder months, reading maps, navigating and subsistence activities. Students are very connected to nature.

Vision for STEM education

Program leaders in the Anchorage school district are passionate about ensuring that every student has access to STEM education in a way that is relevant, engaging and connects students to real-world problems and experiences. They focus on the skills students will need to contribute to the world they live in, such as problem solving, innovative thinking and communication.

The vision for learning is that students will be able to see STEM beyond the classroom, in real life situations, with themselves at the centre.

Educators recognise that the world is changing at such a rate that they cannot begin to imagine what

[students are] learning the things that you actually need to know in the real world. You need to move beyond a bunch of content standards that we can look up. It has to be what you are doing with the information—what problems are you solving, what skills are you developing.”

(Anchorage School District Leader, 2018)

Whatever it is we are doing I want it to be authentic and applied, and I want to give these kids a vision of what they could be when they grow up and to understand that anything is possible.”

(Anchorage School District Leader, 2018)
will be in these students’ futures. Nevertheless, they appreciate the importance of skill development, while helping them see that they can be anything they want to be if they work hard.

**STEM kits**

One benefit of the STEM kits is that they are organised by the district, rather than individual teachers in schools. This means teachers have more time to plan how to use the lessons and resources, rather than spending their time finding resources. This also assists schools located in more geographical isolated areas as the cost of delivery for individual resources would reduce the amount of resources they could afford.

*Caption 10. One of the activities enabled by the STEM kits.*
Community support for STEM

In Alaska, community organisations and government agencies play a key role in supporting STEM initiatives. These government agencies provide community education which involves working closely with schools to involve teachers and students in local environmental initiatives. Some of the areas these agencies focus on include fishing, gaming, biological resources forestry and land management.

Volunteers from the government agencies have an education background as well as expertise in their field. This enables them to work with teachers to incorporate the lessons into the curriculum and provide professional development for teachers.

One of the initiatives organised by a government agency is the watershed program for fourth grade students. In the district there are eight small watersheds that run into a local estuary. Students in fourth grade in nearby schools learn about water quality and looking after their waterways. Volunteers from the government agency visit the school to run two lessons about water quality, then they organise a fieldtrip for students to visit their local estuary.

Another initiative focuses on growing and releasing salmon into lakes. The government agency provides schools with the resources they need to raise salmon in tanks and then release them into lakes when they are big enough. Students learn how the salmon grow, how to take care of them, and why they need to be released into the lake.

Some agencies also run free community education programs outside school. These are aimed at educating the general public about environmental issues that are important for the local community. Teachers encourage attendance as they believe there are many benefits for the students and their families.

Caption 11. Students participating in the release of salmon.
The expertise these agencies provide is invaluable and provides a connection to real-world experiences as well as showcasing potential careers for the students. The agencies also provide the necessary resources, funding and organisation of these programs—taking the pressure off teachers.

However, there is also a sustainability risk since these programs rely on a continued connection between the school and government agencies. If this connection was to break, or funding was discontinued the programs would be jeopardised. And although school staff receive professional development, it would still be difficult to continue the program without the support of the external agency.

STEM for girls

Teachers and external agencies also recognise the need to encourage the interest of students that are traditionally underrepresented in STEM. An extra-curricular activity aimed at providing girls with the opportunity to participate in engineering activities is held each year. Girls are given the opportunity to learn about different types of engineering, including topics such as robotics, fluid mechanics and chemical engineering.

Students experience engineering in their local region, learning about things such as the equipment that engineers wear on the icy slopes, issues of heating and cooling, and temperature pressure for pipelines.

They ask more, learn more, and be curious.”
(Anchorage School District Leader, 2018)

It’s place-based and meaningful, so the kids can connect.”
(Anchorage School District Leader, 2018)
Middle school STEM education

Educators at Anchorage school district believe middle school (years 5 to 8) is a crucial time for students to receive STEM education. STEM education during this period needs to be something that will challenge students and encourage them to think about STEM as a career path.

In middle school, students participate in multidisciplinary units that span the entire year. In year 8, students study chemistry, earth and space science and computer science. Students use their coding knowledge to conduct physics experiments with robots and learn about remote sensing and work on Mars.

This program is also supported by resources and funds supplied by external organisations. This assists the sustainability of the program; however, it also highlights more challenges around staffing, resources and the location of the school district. For example, teachers would like to involve NASA in this program, but this relies on funding, time and the development of a partnership with NASA.

One of the motivations behind the districts’ vision to involve NASA is to encourage students to see STEM in practice.

Teachers in Anchorage School District want students to be able to see opportunities for STEM careers beyond the traditional notions of scientists working in laboratories.

“It’s really important for STEM to be engaging and accessible.”
(Anchorage School District Leader, 2018)

“Connecting what we are doing to really cool, exciting, motivating and inspirational real people.”
(Anchorage School District Leader, 2018)
STEM Practices at Anchorage School District

The STEM program in Anchorage School District is underpinned by a dedication to the local community and native Alaskan culture. Students can see STEM in a way that is meaningful to their lives and their future. The program involves local community members who work in STEM careers, exposing students to role models they can relate to.

Students begin their explorations of real-world problems in their community with STEM ideas. They explore problems and challenge themselves to work towards a solution. Through these explorations, they find and validate evidence to propose solutions to real-world problems.

The connection to their community encourages students to be curious about their world and work together with integrity to understand more about their lives, their community and their contribution in the future. STEM methods are also crucial to work through the problems they are exploring. Thinking critically, generating ideas, processing information and using tools to produce artefacts are all necessary elements in working through their community projects and challenges. Table 5 identifies the main STEM Practices in the programs at Anchorage School District.

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Table 5. STEM Practices at Anchorage School District
The place-based STEM learning initiatives in Anchorage School District have shown the programs are successful through student engagement, and the continual support of external organisations and government agencies.

This year there was no formal school-based assessment specifically targeted at these initiatives. Through anecdotal feedback from the teachers, however, district leaders reocognise the programs are engaging students. Currently the government agencies have their own way of assessing the success of the programs; their continual involvement indicates that they see the benefits to continuing the program.

The success of this program is influenced by the dedication of a strong district leadership and teachers, and continued community involvement by external agencies. District leaders and teachers are passionate about ensuring every student has access to STEM education in elementary and middle school, and access to STEM education that is place-based, integrated, and connected to real-life experiences and careers.

“We need to sweep away the veil of ‘what is scientist?’, ‘what is STEM’. We have these visions and it’s usually a white male in a lab coat. We need to take that all aside and demystify STEM, to understand that you can be whatever it is that you want to be, but it takes hard work and the work is what you are learning in school. It would be really unfair to give these students this vision, then to give them a bunch of menial, unapplied tasks. We need to give them something that is real, that involves the skills they are going to need, and to help them get that motivation to dream so they are actually motivated to do that work.”

(Anchorage School District Leader, 2018)
Now what: every student engaged with STEM, community roles, and program analysis

Program leaders have a vision to expand their programs so that all students in the district have access to STEM.

One challenge will be resourcing such a goal. Funding for programs through the district is a challenge, and at present many of the programs rely on support from external agencies. Implementing more STEM initiatives will require more funding, staff time, training and access to resources.

Leaders believe that one way to encourage such initiatives to continue is to promote the value of STEM and encourage people to see how STEM is applied in everyday life. The district is currently applying for a grant to enable them to build on a current project where they are making short recordings of community members involved in STEM related careers.

This is part of their vision; to connect student education to the skills they need for the future. One challenge they currently face with this is their focus on females in STEM careers.

Another goal of the district is to focus on assessing the effectiveness of the programs. Developing an assessment of the program is in the early stages of development, with plans to implement this next year. This will involve a comparison of the results of students who had access to the external agency provided programs, and those that did not access these programs. This will be used both for teachers to assist in designing future programs, and also to provide data that may assist with the continuation of the programs. This assessment will also align with some of the assessment the external agencies incorporate into the program.
STEM education for ALL young citizens

Every child around the world has a right to an education that meets their needs and enables them to develop their full potential. This is a basic human right. Education needs to meet the needs of students who live in an ever-changing world, while being connected to their everyday lives. We have seen three diverse examples of this in STEM education from schools around the world. These schools have an expansive view of education where students’ learning is connected, integrated and applied in real-world situations. Students are developing 21st century skills while learning more about themselves and becoming strong, capable citizens who can contribute to shaping the future.

Although each of these schools are at different stages of their journey in STEM education, there are several common features in their approaches. These programs are led by a dedicated team of teachers who are committed to making STEM education a key part of their students’ education. Teachers at these schools have a vision for what they want their students to achieve and are not afraid to experiment with new ideas to achieve this. Student learning is connected to the world outside school, and student learning is not siloed into individual content areas. Teachers are more focused on the skills and practices that students are learning than on the content of the individual subject areas. Although the curriculum is crucial to teachers’ planning, it is only one aspect that comes together to shape students’ learning.

These approaches align with a STEM Practices approach to teaching and learning. The crucial part of a STEM Practices approach is that it focuses on ensuring that all factors that influence a student’s education are engaged with. It responds to the needs of families, students, industry and educators, while providing a way forward for schools to navigate STEM in Australian policy (see figure 2). Teachers can respond to the diverse needs of their school and community, and connect students’ learning to problems and issues that are relevant to them. There are opportunities for schools to link with community groups, industry groups and students’ families which provides students with access to inspiring applications of STEM Practices. From a policy perspective, focusing on practices rather than curriculum content aligns to the philosophy of curriculum which emphasises capabilities rather than content knowledge. Bringing all these together, students use the ideas, methods, and values in their day-to-day life and learn content knowledge through this.
Conclusion

Education must meet the needs of students who live in an ever-changing world, while being connected to their everyday lives. The importance of STEM in preparing us for the future is recognised around the world; however, approaches to STEM education are diverse and teachers are faced with many challenges in implementing programs.

In this paper we have explored the STEM journey of three schools through the reflective lens of three framing questions: what, so what, now what, from the work of Borton (2000) and Gamble (2002). This framework encourages schools to focus on the broader action-learning cycle and provides a focus for working through and developing their STEM journey. It provides a way for teachers to focus on implementing their STEM program—to consider the significance of the outcomes and their implications, lessons learnt, future actions, how this could be improved, and their broader professional development needs.

Our case study schools are at various stages of their STEM journey and each of their approaches is different. They involve in-school programs, extracurricular activities, whole school sector approaches, individual projects, community and industry. What they all have in common is a commitment and dedication to student learning and recognition of the value of STEM in students’ learning.

These schools all have an expansive view of education where students’ learning is connected, integrated and applied in real-world situations. Students are developing 21st century skills and learning more about themselves as strong, capable citizens who can contribute to shaping the future.

Elements of the STEM Practices framework were evident in each of the schools’ approaches, highlighting the diverse ways that STEM Practices can look, depending on each school’s individual needs. When thinking about these schools’ STEM journey with the question, ‘How do we equip young people with the knowledges, skills and values that enable them to achieve success in a rapidly changing world?’, it is our contention that the STEM Practices framework offers a golden triangle for success in STEM education when designed around the three arms of ideas, methods and values.

In this paper we have seen how three schools from diverse locations have overcome challenges to implement successful STEM programs in their schools. Although starting on a STEM journey may seem daunting, schools should consider how STEM Practices may meet the needs of their school and community. The reflective framework of ‘what, so what, and now what’ can be used to assist with evaluating this journey.
References


