Informal spaces for STEM learning and teaching: STEM clubs

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Positioning the chapter

STEM clubs differentiate themselves from formal classroom-based, curricula-focused programming in several key ways. Firstly, they involve different dynamics between learners, as well as learners and their teacher, namely because of the freedom in not having to be aligned strongly with curriculum results in a more learner-driven and co-constructed learning environment. Largely due to the environment and the smaller learner-to-teacher ratios, the partnerships formed between learners, teachers, parents, volunteers, and others are often richer, more dynamic and have a more targeted impact than can be achieved in a typical classroom context with larger numbers and competing demands. And while STEM learning and teaching is increasingly finding its place in the classroom, STEM clubs continue to fill a niche by regularly exposing children to STEM concepts, enterprise skills and capabilities in exploratory and engaging ways.

In 2018, researchers from the University of Southern Queensland working with Inspiring Australia Queensland (IAQ), hosted by Queensland Museum, and STEM clubs across Queensland (a north-eastern state of Australia) to develop a framework for evaluating quality in STEM clubs. With funded support from IAQ, 47 STEM club providers took part in a pilot project, which included trialling the framework as a form of health check to understand the areas of strength and possible improvements in their programming. This project involved a range of different types of STEM clubs, which afforded a unique opportunity to consider the role of context in club development and operation, as well as impact on learning. The research component provided opportunities for the research team to engage directly with a number of educators, business owners and volunteers who operate STEM clubs in a variety of settings and capacities across the state. As a result of this work, this chapter presents a series of case studies exploring what STEM clubs look like along with developing an understanding the possibilities and challenges inherent in this informal approach to STEM education. The key question underpinning this chapter is: *How do STEM clubs support STEM learning and teaching?* By way of response, three different STEM club contexts are represented – private provider, school-based, and library- based – before teasing out the commonalities in the conditions they created to inform and enhance STEM learning and teaching. Then next section provides a nationally- and internationally-derived evidence base detailing what STEM clubs are and what purposes they intend to achieve.

Setting the scene

Increasing student participation and engagement in STEM learning continues to be a well-documented challenge (Timms, Moyle, Weldon and Mitchell, 2018). The STEM club movement is being driven, both nationally (in the Australian context) and internationally, by an identified need from policymakers, industry, and educators to encourage student participation in STEM-related activities (Gottfried & Williams, 2013; Lowrie, Downes, & Leonard, 2017). In this context, STEM clubs of differing configurations and visions are providing informal participatory learning opportunities for children and young people. These opportunities are showing signs of having significant influence on not only present day engagement and immersion in STEM, but future-oriented uptake of post-compulsory study and career paths in STEM-related fields (Behrendt, 2017; Gottfried & Williams, 2013). This approach is also having an impact on school-based achievement with Gottfried and Williams (2013) linking participation in extra-curricular STEM clubs with improvements across the four key learning areas that make up this construct. In further evidence of the wide reaching impact, Ozis, Pektas, Akca and DeVoss (2016)

discovered that STEM club participation has a significant impact on student attitudes towards STEM with the potential for this approach to reduce the gender and ethnicity gaps in relation to STEM perception and provide a more diverse student population for the STEM pipeline.

At their core, STEM clubs involve STEM-related content and skills delivered in informal learning settings. To focus on a key point of difference from school-based or formal contexts, learning environments can be defined as informal when they engage learners outside of the formalised school curriculum (Hofstein & Rosenfeld, 1996). An informal educational approach is typically underpinned by a different set of characteristics, goals, teaching approaches, and learning outcomes than those valued in formal, school-oriented settings (Stewart & Jordan, 2017). For example, school settings centre around structured, and often standardised, assessment of learning outcomes, while informal learning settings, in contrast, tend to be directed towards more open-ended outcomes that embrace serendipitous learning (Sefton-Green, 2013). It is important to note, however, that the operationalisation of informal learning contexts also has range of variation. This can include, for example, highly-structured formats through to more participant-led learning arrangements (Sefton-Green, 2013). Kotys-Schwartz, Besterfield-Sacre and Shuman (2011) suggest there are three main types of settings that characterise informal learning: (i) *everyday experiences*; (ii) *designed settings* (e.g. zoos, museums, environmental centres); and (iii) *programmed settings* (e.g. programs situation in schools, community-based, science organizations).

The project reported on in this chapter primarily focused on programmed settings that enabled participants to engage with a program of STEM-focused learning activities or events over a sustained period of time. We suggest, however, that there is some overlap with designed settings as a number of the programs we encountered took place within contexts such as libraries and museums. While informal in nature, programmed settings often "have structures that emulate formal school settings—planned curriculum, facilitators or mentors (taking a teaching role), and a group of students [or participants] who continuously participate in the program" (Kotys-Schwartz et al., p. 2). In practice, what we found this looked like in Queensland is STEM club learning that was situated in school hours (e.g., lunchtimes) or after-school programs (including weekends and holiday programs) at local schools, libraries, community centres, or with private providers (e.g. for profit, fee for service).

Stating a case(s) for STEM clubs

Informal learning opportunities and environments seem to be making some real progress in invigorating STEM education in the wider community. Yet what is actually happening in STEM clubs to effectively support quality STEM learning and teaching? The answer to this question is largely unknown with much research focused on detailing the logistics and outcomes of individual STEM clubs rather than taking a more holistic perspective. As part of a larger study conducted by the authors, the stories of several STEM club providers were documented. For this chapter, to ensure the representation of the diversity of STEM club operations identified in Queensland (as well as evident in literature worldwide), three cases are showcased: (i) private provider; (ii) school-based provider; and (iii) library-based provider. The insights shared are from interviews with educators, who were involved in the development and delivery of their specific STEM club, and have been crafted into stories by the research team. These stories capture the intent underpinning the establishment of the featured STEM clubs before highlighting the opportunities and challenges experienced in this space.

CASE STUDY 1
Private STEM club provider: *Building Block Studio*

Building Block Studio, located in suburban Brisbane, draws on the talents and interests of a dynamic husband and wife team to create an environment where children are inspired by and empowered in their use of technology. With a background in electronic and software engineering, Daniel had transitioned from two decades of working with consulting companies to the e-learning team at Education Queensland for a number of years. While he was gaining inspiration from this work, Rebecca was finding her work as an accountant not as invigorating as she would like and was craving an opportunity for more creativity. Their lives are also intertwined with the goings-on of their three sons, who were becoming increasingly involved in technology use. From this place, *Building Block Studio* was born at the start of 2016.

Children as young as six years old participate in the *Building Block Studio* programs, which cater for a variety of skill levels and interests under three broad umbrellas: Coding Club, YouTube Club, and Robotics. There are typically 4 to 12 participants per group and their attendance is stable. The programming for both the ongoing weekday/weekend sessions and holiday offerings consistently book out in advance. Daniel and Rebecca do face challenges in terms of the cohorts they attract to their programs. They struggle to reach teenagers and would like to engage this group as they have a significant amount of technical depth to offer in comparison to other STEM clubs in the market. Encouraging girls into the clubs is also a challenge with the current male-to-female breakdown at 70:30. Participants and their families typically become aware of these STEM programs through word of mouth, Facebook and the business' website. They tried advertising their programs through campaigns and paid ads, but did not enjoy this process or find it beneficial. This approach has enabled Daniel and Rebecca to grow their business at their own pace and essentially keep up with the evolution in a manageable way.

Building Block Studio is a multi-faceted business, which started off focusing on activities relating to LEGO before moving into technology-focused activities and competitions and is now branching off into running incursions in primary schools. This new school-based avenue is very much where the revenue is made, but Daniel and Rebecca's hearts are with the regular participants who have the passion to turn up regularly to participate in the clubs. One of the biggest challenges in maintaining the business and ultimately attracting interested children and schools is developing new programs and content. While *Building Block Studio* does have a huge content bank, Daniel and Rebecca are continuously considering how they can improve what they do. Rebecca tends to generate the ideas, while Daniel works out how to enact them in terms of the technology. The interests of their boys and the STEM club participants also informs content development. For the club-based programs, they have fallen into a planning pattern that focuses on skills development, such as solving everyday problems and seeking innovative/creative solutions. They use the clubs as a space to trial activities and approaches before taking them into a school context. The business is entirely reliant on Rebecca and Daniel's time and energies, which raises questions about sustainability and the notion of succession planning.

With sustainability front of mind, Daniel and Rebecca are taking several steps to address this issue. In the last year, they have been in a position to employ casual staff to assist with the clubs. They currently have three staff members – a female Year 11 student and two male 3rd year engineering students. They feel very fortunate to have found great staff who connect with children, are relatable, good role models, and provide insightful feedback on how activities are received to drive improvement. Daniel and Rebecca consider their staff to be high-quality resources. They are also at a point in terms of their business development of considering where to next. One key idea, connected with their current experiences in schools, is developing a STEM subscription service for teachers. This service would provide access to the *Building Block Studio* content and they would seek to develop purchasable kits to support activity implementation. Another aspect of this would be the ability for schools to hire technology equipment for a period of time and then return when finished or swap for other resources. Daniel and Rebecca see this prospect as offering innovative STEM content and resources to schools for an affordable price. Another aspect to assist with sustainability is for *Building Block Studio* to seek out partnerships with STEM industry professionals to leverage their expertise and knowledge as well as to further inspire the children they work with.

The vision underpinning why Daniel and Rebecca started *Building Block Studio* is simple: to create a place where children, who might not fit into mainstream extracurricular activities (e.g. sports), can be with like-minded peers and feel like they belong. Secondary to this is supporting children to develop the skills to actively participate in team situations. Daniel and Rebecca gain an enormous amount of satisfaction from making a difference in the lives

of the children they work with. While *Building Block Studio* doesn't have a formal evaluation process, as a paid service if participants don't return to a club or if they are not invited back to a school this is considered as powerful feedback. Daniel and Rebecca do engage in self-evaluation and use informal feedback process such as comments from teachers and parents to inform what they do. Knowing that the participants are enjoying the activities and wanting to continue participating is also part of this more informal feedback loop.

CASE STUDY 2
School-based STEM club: *The STEM Shack*

Located in regional Queensland, this school prides itself on the quality of their technology curriculum and extracurricular opportunities offered to all students. In 2015, Jay, a motivated early career classroom teacher with a keen interest in digital technologies, noticed that during lunch time supervision some students with autism spectrum disorder (ASD) struggled to socialise which often resulted in conflicts between students. He decided to utilise his lunch time supervision to provide an alternative for these students. As a result, library lunch time coding activities were offered. Initially students with ASD and other disabilities engaged in independent computing coding programs utilising Scratch and Coding.org where they moved through levels and attained certificates of completion. The positive participation within these activities was noticed by school staff and students and as participation increased an informal STEM Club emerged. The school principal and Jay saw the growing potential of the club to complement the implementation the new digital technologies curriculum and the club was formalised and renamed the STEM Shack. Jay's formal lunch time supervision allocation was utilised to offer the opportunity to all students during two 40-minute lunch breaks per week.

The *STEM Shack* profile grew through the school's participation in a digital technology launch project, which encouraged Jay to identify issues that may prevent the club from moving forward. From this he identified that technology within his school community was viewed as the enemy of physical activity; that kids were going to be sitting on computers not being active. Jay decided to dispel this myth and initiated a formal communication strategy through the school newsletter and information sessions to help the community understand what technology is and why it is important and enjoyable to the students. This strategy increased the club profile and highlighted the positive engagement and learning that was occurring through the *STEM Shack*. The community saw the value and parent helpers approached the school to volunteer their time. This was quickly followed by other schools visiting the club to observe the positive student engagement, structure and informal STEM learning outcomes. As outside interest in the club grew, staff within the school began to visit the club, often returning to build their own professional knowledge by participating in the coding courses. In 2016, student interest exceeded the available resources which resulted in formalising student participation into two semester intakes. Students who had not participated in the previous semester were prioritised with a maximum of 27 students participating per intake.

With a focus on positive participation, socialisation and coding skill development, the structure of the STEM club has adapted to meet student interests and engagement needs. As a result, the *STEM Shack* structure and offerings have changed. Jay described it as a *"space where kids can work on a variety of different things related to what we do in school and what they're interested in".* This is reflected in the structure of the *STEM Shack* that now, with the assistance of parent helpers, offers two simultaneous areas: (i) coding skill development and (ii) programming through programs such as Minecraft: Education Edition, drones and Lego robotics. In addition to this, Jay has established two afterschool programs. This first program is *Code Red* where students engage in collaborative construction-based activities using Minecraft: Education Edition and programming using Scratch or Code.org. The second program targets older students and is focused on learning to fly drones. Jay and his parent helper (who is a programmer) have created their own program where students are taught the basics of flight with small challenges to complete. The club has a flight simulator that students use to obtain their drone licence. Once obtained, students are equipped with the skills to fly nano-drones for fun.

Jay's positive approach to resourcing the *STEM Shack* has resulted in a large variety of coding and programming kits being utilised. By beginning small and continually reflecting on how the students engage and what they are

interested in, Jay was able to utilise free coding resources, access government grants and strategically align the STEM club resources to the school's technology curriculum needs to utilise school funds. As a result of this, the resource bank has grown significantly to include a range of robots and programming kits that cater for a diverse range of students. Jay sees this as a great opportunity for other teachers in the school to include some simple programming activities into the classroom and has observed a positive shift in in the way other staff see the technology curriculum area as well as how supportive they are of the STEM clubs.

Aligning the STEM club with the school's technologies curriculum has allowed the *STEM Shack* to be a more student-centred space, where students have opportunities to use what they know, to be creative and create their own things. Jay acknowledges that the formal technology curriculum learning with the classroom provides that scaffolded learning, which allows the STEM club teacher to be more of a facilitator. Using a health check as a basis for continual reflection and refinement has provided Jay with process for linking the school priorities to the STEM clubs, so that these informal learning opportunities have become an integral part of the school's identity. Moving forward, Jay sees the growing potential to expand the opportunities for students to create and is mindful that this needs to be balanced with the provision of targeted resources, time and space to collaboratively develop the skills and confidence with parent helpers and school staff. As Jay's says there are no limits to what a STEM club can offer. Schools can start a STEM club with no money, it just requires one person who is interested and focused on ensuring that whatever is offered has a positive impact on students.

CASE STUDY 3
Library-based STEM club: *#STEAMsquad*

Western Downs Libraries is a nine-branch public library service operated by the Western Downs Regional Council. The region is situated west of Toowoomba in Queensland, and has a population of approximately 33,000. The area is classified regional with its major industry being agriculture.

Western Downs Libraries operates a program called *#STEAMsquad*, a weekly program for school-aged children that runs for six weeks in each school term. Limiting each round to six weeks provides time for program planning and activity development, and allows facilitators to balance *#STEAMsquad* with other programming responsibilities, including school holiday programs. The program is run at two of the service's branches, two days a week at each location, for a total of four cohorts each round. They accept 12 learners per cohort, who each attend one session per week for the six week program. This allows the service to accept 48 children each round. The program is exceptionally popular – when bookings open for each round, they typically book out within 10 minutes. The program currently accepts children from the age of seven. There is no age limit, but facilitators report that children 'lose interest' at around age twelve. While there is some repeat attendance from round to round (and, in fact, some children have been attending consistently for the two years the program has been operating), the aim is not to retain participants from round to round, but rather to provide a discrete experience in each round.

The program has a STEAM (Science, Technology, Engineering, Art and Mathematics) focus, rather than a STEM focus, because the facilitators believe that incorporating creativity is critical. They see creativity as a critical lens for the future workforce. The program of activities is carefully planned to incorporate a balance of all five STEAM elements.

The program facilitators design structured activity kits using templates that enable facilitators with limited experience to pick up the kit and deliver the program. This allows a range of library staff to play a role in running the program, but also means the kits can be made available for schools to loan. The service invests a significant amount of time into kit development and review. The kits are produced cheaply, and materials used are typically craft and easily accessible supermarket supplies. Library staff are often surprised at how simple activities and materials – like an activity that uses bicarbonate of soda and vinegar to replicate a volcano erupting – engage and excite participants.

The program arose out of an identified need in the community. There was a perception that the local schools may not have the expertise to offer STEAM experiences outside the classroom, nor the funding to support this kind of extra-curricular informal learning program. Library staff wanted to give children opportunities to engage with STEAM outside of school in an informal learning environment. There was also a desire to run a regular programming activity that wasn't the typical library book club. Finally, there was an identified opportunity to provide meaningful interaction for children who regularly attended the library after school, and a sense that engaging them in a STEAM program might assist.

#STEAMsquad provides opportunities for learners with interests that are outside traditional pursuits like sport, music or other group-based extracurricular activities to gain experience working in a team and to have a sense of belonging. It also provides opportunities for girls to get involved in STEM. In this sense, the club plays an inclusion role, providing opportunities for marginalised groups to get involved in a group activity and to develop an interest in STEM.

When designing activities, there is a focus on fun and excitement. 'It's giving the kids a chance to have fun with science outside of the school. We don't want to replicate anything that's done in the curriculum, we just want kids to experience fun science, just have fun with it.'

The program is operated by a small, committed group of staff who develop program resources around their other responsibilities. This is a common practice in libraries – staff with program delivery responsibilities often fit the development work in around the other operational aspects of their jobs. Some of the constraints the program is limited by include staff capacity, volunteer support, access to activity resources or kits, and funding – both one off and ongoing. Related to this, there is also a sense that they need more volunteer support to help the program be sustainable and to grow. This might involve assistance with preparing activities and kits, or with facilitation. Access to kits or activities designed and tested by other clubs would aid sustainability, because there is a considerable amount of time involved in kit development, with each activity being thoroughly tested before inclusion in a kit. Finally, funding is an issue, as it is for many STEM clubs. While they are able to assemble kits cheaply, having technology resources to take out to schools and use in *#STEAMsquad* is highly valued. Grant funding has supported purchase of these types of materials in the past.

While they have been operating a very well attended STEM program for over two years, library staff have not had an opportunity to take a step back and take a holistic look at their practice. While they intuitively knew why they were offering the program – to give learners opportunities for fun, exciting, informal STEAM learning that they weren't getting in schools – they had never taken the opportunity to articulate a vision or direction for the club. Participating in the pilot of the evaluation framework gave staff an opportunity to take a critical look at their practice and to articulate the vision they were instinctively working towards.

In terms of evaluation, the focus has largely been on collecting attendance statistics because this is a requirement for reporting to their parent organisation. They are not required to undertake program evaluation, but there is a growing focus on reporting on impact through telling stories and the team are collecting stories to support this. Twice a year, the team of staff involved in delivering the program get together to discuss what is and isn't working. This is largely informed by informal observation of what happens during the sessions. For the *#STEAMsquad* facilitators, success can be defined as 'being booked out within 10 minutes'. Success also looks like participants who are 'happy, laughing, they'd just be – just there you know, in the moment feeling it, having fun doing it'.

Conditions informing learning and teaching in STEM clubs

At a glance, these cases seem to tell three very different stories about the ways in which STEM clubs are used to engage school-aged learners in developing STEM knowledge and skills. On the surface it might seem like the informal nature of the learning environment is the common thread pulling these partnerships together but a closer examination reveals that it runs much deeper than this. These three cases illustrate that while there is no single way in which STEM clubs support meaningful STEM learning

and teaching, there are a number of components that can foster the right educational conditions. From these cases, the following four conditions emerged:

1. Meeting a community need;
2. Inclusive of diverse learners and learning needs;
3. Creating space for passionate learning; and
4. Responsive to the context.

Each condition is explored in more depth below.

Meeting a community need

By their very nature, clubs reflect the needs of the community in which they are positioned. Research into the value of sporting clubs clearly documents this trend (see report from the Centre for Sport and Social Impact (2015)). These findings have applicability to other club contexts as they capture the interests and aspirations of the cohorts they represent. As STEM capabilities become both more prevalent and valued (Siekmann & Korbel, 2016), communities are recognising the need to create spaces that support the exploration of STEM ideas (Lowrie, Downs, & Leonard, 2018). The three cases reveal that their STEM clubs were formed to meet an identified need in their community. Thematically, these needs can be characterised around three constructs: purpose, belonging, and opportunity.

Both the school- and library-based cases foregrounded issues with managing behaviour as a key stimulus for introducing a STEM club and providing participants with a sense of purpose. Fostering a sense of purpose within a learning environment matters as it provides direction and focus which may otherwise be missing or challenging to achieve in other contexts (Tirri, Moran, & Mariano, 2016). Equally it is about facilitating learning at the point of need for the learner (Tirri et al, 2016). As an informal learning context, STEM clubs have an enhanced capacity to target what they do to recognise the needs of their specific cohorts and to provide activities that engage their interests (Martin, 2004). In this sense, STEM clubs have the capacity to be a bridge between personal capabilities and skill development.

Finding authentic ways to cater for the diverse participant needs was another factor driving STEM club formation for both the school-based and private provider. Regardless of the cohort, the intent of the STEM clubs, in these instances, was to bring like-minded individuals together through a shared interest. Fostering a sense of belonging reassures learners of the safety of the learning environment in terms of understanding and meeting their needs as well as challenging and extending their knowledge and skills (Sahin, Ayar, & Adiguzel, 2014). For learners with ASD, a place to belong is particularly important as shared understandings reduce potential conflict and confusion (Tobias, 2009). This sentiment applies to other cohorts, including girls (Dasgupta & Stout, 2014) and teenagers (Haugen, Morris, & Wester, 2019).

Engaging in club-based activities is an important developmental component of a young person's life (Roth & Brooks-Young, 2016). Anecdotally, the club landscape in Australia remains focused on extra-curricula activities in the areas of sport (e.g. team sports, gymnastics) and the Arts (e.g. music, theatre). As interests change, however, club offerings need to as well (Krishnamurthi, Ballard, & Noam, 2014). In this context, both the library and private provider instigated their STEM clubs as a way to address a need. The provision of a diversity of informal learning opportunities opens up avenues to participants' that are new, didn't seem possible or hadn't been previously considered (de Carteret, 2008).

In summary, STEM clubs are often enacted to meet a particular community need. Through meeting this need, STEM club participants are provided with a sense of purpose, an avenue through which to belong and opportunities to extend their learning in meaningful ways.

Inclusive of diverse learners and learning needs

An Inclusive learning environment typically welcomes and provides equitably opportunities for all learners regardless of their gender, physical, intellectual, social, emotional or linguistic backgrounds (Harris, Miske & Attig, 2004). With decreasing STEM participation rates along with disproportionate gender and ethnic representation reported in formal settings (Prinsley & Johnston, 2015), it is interesting to note that each STEM club within this study attributed their success to promoting an inclusive learning environment. While each STEM club took a different approach to inclusion, they each utilised social structures to purposefully promote learning through, for example, fostering positive participation and respectful interactions between facilitators, participants and peers (O'Keefe, 2013).

In an informal environment, the facilitators provide a particularly critical role in promoting positive interactions between participants and engaging them in the learning process (Gilles, 2006). For the school- and private providers, the facilitator's role was flexible. They were often positioned as a 'supporter on the side' moving between individuals and groups to provide affirmative feedback and specific support. At other times, they were 'co-learners' in the process by actively modelling verbal and non-verbal learning behaviours. This pedagogical approach differs from simply planning group activities as it requires STEM club facilitators to consciously interact with participants to foster open and positive communication by modelling how to question and clarify. The pedagogies adopted by the STEM clubs highlight how inclusive practices are fostered when inter- and intra-personal skill development is valued.

Catering for a diverse range of learning needs requires considered and careful planning so that each participant can access and engage in the provided learning opportunities (Carter & Abawi, 2018). In this instance, each STEM club catered for a range of participant ages and programs were essentially multi-age in nature. To support these diverse learning needs, a range of interactive, indirect (problem and inquiry) and experiential (real-world applications) pedagogical methods were used (Saskatchewan, 1991). The school and private providers utilised parallel or sequenced activities that catered for different interests, abilities and learning styles. Whereas, the approach of library provider was to develop and implement pre-planned kits that led the students through an inquiry question or series of steps to explore a topic in a fun and engaging way. By explicitly designing their learning spaces and purposefully incorporating specific pedagogical methods, the STEM clubs enabled participants to learn within a social structure where their individual strengths were utilised and individual needs catered for.

While each STEM club's planning approach was different, a common thread of reflective practice was evidenced. The clubs were informed by the participants' interest and engagement to determine the effectiveness of the provided learning opportunities as well as to make decisions about where to next. Through these reflective cycles deliberate pedagogical choices were made to maximise learning. The result was the provision of an educational space where students felt safe, comfortable and included.

Creating space for passionate learning

As informal learning environments, STEM clubs naturally afford autonomous learning opportunities for students at relative low stakes when compared to formal settings. Autonomy, along with good quality relationships and opportunities to increase competence, is important in facilitating intrinsic motivation, where the participant engages with an activity because they find it interesting and enjoyable. This interest and enjoyability is because of the inherent qualities rather than there being some other outcome such as a good test result or performing better than somebody else. There is significant evidence to suggest that when learners are intrinsically motivated, they learn with greater depth and conceptual understanding and with positive attitudes and emotions (see Leon, Núñez, & Liew, 2015; Su & Reeve, 2010).

Effective STEM clubs act as an incubator for positive and joyful learning experiences. They are a learning environment where STEM-focused discovery is psychologically rewarding. As showcased by the three cases, well-crafted STEM club learning activities provide opportunities for students to discover natural phenomena or be challenged to solve problems either on their own or with their peers and facilitator. Through their actions, an engaged learner wholeheartedly endorses what they are doing, feels choice about what they are learning, grows in competence and mastery, and develop relationships with others. Further, their personal wellbeing may be positively supported not just through engaging with interesting activities, but through the development of relationships with their STEM club peers and facilitators.

The passion for STEM of the facilitators should not be underestimated in contributing to the success of a STEM club. This was certainly evident in the STEM clubs described in the above cases. Passion can be described as a set of powerful emotions in relation to a particular subject or activity. Vallerand (2015) describes a dualistic model of passion where passion can be *obsessive* or *harmonious*. Obsessive passion involves engaging in an activity at the expense of other aspects of life. In contrast, harmonious passion involves being fully engaged in a personally important activity through choice and in proportion to other important things in their life. A *harmoniously passionate* STEM club facilitator will be passionate about STEM, but also see relationships as important and want participants to be happy. An *obsessively passionate* STEM club leader may become fixated that activities are done absolutely correctly or that students win a STEM competition rather than participate for the experience. Effective STEM clubs involve harmoniously passionate facilitators that are able to convey their love and excitement for STEM to the students who in turn are engaged and excited as well.

To conclude, a STEM club will typically consist of engaged students who are intrinsically motivated to learn about a specific area of STEM, feel they have some choice about their learning, and may nurture a passion that is mirrored by the passion expressed by the STEM club facilitator. In many ways, some of the structural aspects that are necessary in the formal classroom are cast aside in a STEM club environment, which contributes to the joy of STEM discovery and thereby its success.

Responsive to the context

In this chapter, STEM clubs are represented as operating in three different organisational contexts: a private enterprise; a school; and a library service. These examples demonstrate that context is a multifaceted concept. STEM club contexts include the local communities they operate within, as well as the broader organisations in which they are situated. Context can also refer to the physical environment in which the STEM club operates. Regardless, the STEM clubs described in the case studies illustrate the importance of responding to context to support effective STEM learning.

One finding that emerged was that clubs positioned within a broader organisation – in this instance, a school or library service - experience similar factors impacting on STEM club operation. For example, support from the organisation's leadership is critical to STEM club success. Time is also a common issue with both teachers and library staff taking STEM club responsibilities on in addition to their usual workload, or juggling STEM club work around other commitments. Staff interest and expertise create issues in terms of staffing STEM club activities on an ongoing basis, which impact succession planning. Finally, funding constraints are also common to STEM clubs operating within a broader organisation. Effectively managing organisational considerations and their impacts on STEM club operation is critical to creating a positive STEM learning and teaching environment.

A potential challenge for STEM clubs operating within schools is to manage the tension between the formal classroom learning environment and the informal environment of a STEM club. Ideally, the role of STEM club facilitator is to mentor (Dolenc et al., 2016) and to 'step back from being "in control"' (Blanchard et al., 2017. p. 91). For teachers, it may be challenging to shift between their role as 'teacher' to 'facilitator'. STEM clubs run by libraries and private STEM club providers, on the other hand, run outside the school and classroom environment and are staffed by people who are not teachers. They do not have the same ties to formal curriculum that might be present, even subconsciously, in school-based clubs. While it is certainly possible to create an effective informal learning environment in a school setting, it might be easier to achieve this when a STEM club sits outside a formal context.

Responding to context is so essential to effective STEM club practice that is inextricably linked to the other three conditions drawn out in this chapter. In meeting community needs, STEM clubs are effectively responding to their context. A focus on inclusion of diverse learners and their learning needs is another example of STEM clubs responding to their context. In creating space for passionate learning, STEM clubs are again responding to their broader context by carving out space for students to pursue interests, deeply engage with STEM, and participate in informal learning, even when the broader organisational context is one built around formal learning (as in school-based STEM clubs).

Regardless of the context in which they operate, to provide effective informal learning experiences that nurture a passion for STEM, clubs must respond to the context in which they are positioned. This means responding to the community in which the club is situated as well as the broader organisational context. It also means carefully considering the impact of the organisational context on the creation of an environment that facilitates informal STEM learning.

What does this mean for STEM learning and teaching?

STEM clubs by their very nature offer an alternative way to engage with STEM education that does not rely on complying with the requirements and structures that inform more formalised classroom-based practices. The three cases shared in this chapter respond to the key question underpinning this project - *how do STEM clubs support STEM learning and teaching?* – as they showcase the value that this more informal learning approach can have on the STEM knowledge and skill development for both participants and facilitators. Emerging from these cases are four conditions that can be drawn upon to make sense of STEM club effectiveness. Quality STEM club programming:

1. Meets the needs of the communities they are positioned within;
2. Caters for diverse learners and learning needs;
3. Promotes learning for the joy it; and
4. Has the flexibility to work with contextualised factors.

These four conditions are useful outcomes of this project as they have implications that can be applied in two key ways to inform and improve STEM education practices. Firstly, they can be considered as a framework of sorts from which to develop and implement a relevant and meaningful STEM club. This is particularly useful if the conditions are reframed as questions – for example, what are the specific needs of your community? – to lead discussion about the possibilities and challenges that might be faced. Secondly, these conditions can be reimagined as a set of considerations for teachers to modify and adapt to suit their own classrooms practices and environments. There is an opportunity to take-away the quality aspects of informal learning to enhance what is possible for STEM education in a formal educational context.

References

Blanchard, M. R., Hoyle, K. S., & Gutierrez, K. S. (2017). How to start a STEM club. *Science Scope, 41*(3), 88-94. Retrieved from https://sites.ced.ncsu.edu/stem-career-awareness/wp-content/uploads/sites/5/2018/04/1b.-Teachers-Toolkit-How-to-Start-a-STEM-Club.pdf

Carter, S., & Abawi, L. A. (2018). Leadership, inclusion, and quality education for all. *Australasian Journal of Special and Inclusive Education*, *42*(1), 49-64

Centre for Sport and Social Impact. (2015). *Value of a community football club.* Retrieved: https://www.aflvic.com.au/wp-content/uploads/2015/02/Latrobe-Value-of-a-Community-Football-Club-Final-PDF.pdf

Dasgupta, N., & Stout, J.G. (2014). Girls and women in Science, Technology, Engineering, and Mathematics: STEMing the tide and broadening participation in STEM careers. *Policy insights from the behavioural and brain sciences, 1*(1), 21-29.

de Carteret, P. (2008). Diverse pleasures: Informal learning in community. *Australian Journal of Adult Learning, 48*(3), 502-519.

Dolenc, N. R., Mitchell, C. E., & Tai, R. H. (2016). Hands Off: mentoring a student-led robotics team. *International Journal of Science Education, Part B, 6*, 188-212. https://doi.org/10.1080/21548455.2015.1039467

Gillies, R. M. (2006). Teachers' and students' verbal behaviours during cooperative and small-group learning. *British*

Harris, R., Miske, S., & Attig, G. (2004). Embracing Diversity: Toolkit for Creating Inclusive Learning-Friendly Environments. *UNESCO Bangkok*.

Haugen, J.S., Wachter, C., & Wester, K. (2019). The need to belong: An exploration of belonging among urban middle school students. *Journal of Child and Adolescent Counseling, 5*(1), 1-17.

Krishnamurthi, A., Ballard, M., & Noam, G.G. (2014). *Examining the impact of afterschool STEM programs.* A paper commissioned by the Noyce Foundation.

Lowrie, T., Downes, N., & Leonard, S. (2018). STEM Education for all young Australians. A Bright Spots STEM Learning Hub Foundation Paper for SVA, in partnership with Samsung. University of Canberra STEM Education Research Centre.

Martin, L. (2004). An emerging research framework for studying informal learning and schools. *Science Education, 88*(1), 71-82.

O'Keeffe, P. (2013). A sense of belonging: Improving student retention. *College Student Journal*, *47*(4), 605-613.

Prinsley, R., & Johnston, E. (2015). Transforming STEM teaching in Australian primary schools: everybody's business. *Canberra, Australia: Australian Government, Office of the Chief Scientist*.

Roth, J.L., & Brooks-Gunn, J. (2016). Evaluating youth development programs: Progress and promise. *Applied Developmental Science, 20*(3), 188-202.

Sahin, A., Ayar, M.C., Adiguzel, T. (2014). STEM related after-school program activities and associated outcomes on student learning. *Educational Sciences: Theory & Practice, 14*(1), 309-322.

Saskatchewan (1991). Instructional approaches: A framework for professional practice.

Siekmann, G., & Korbel, P. (2016). Defining 'STEM' skills: Review and synthesis of the literature. Adelaide, SA: NCVER.

Tirri, K., Moran, S., Mariano, J.M. (2016). Education for purposeful teaching around the world. *Journal of Education for Teaching: International research and pedagogy, 42*(5), 526-531.

Timms, M. J., Moyle, K., Weldon, P. R., & Mitchell, P. (2018). Challenges in STEM learning in Australian schools: Literature and policy review

Tobias, A. (2009). Supporting students with autistic spectrum disorder (ASD) at secondary school: A parent and student perspective. *Education psychology in practice: Theory, research and practice in educational psychology, 25*(2), 151-165.