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Exploring provider perspectives of the STEM club landscape: findings from one Australian state

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ABSTRACT

STEM clubs, often located in extracurricular settings, are designed to promote engagement and enjoyment of STEM-related topics and concepts. Given the current policy landscape, a closer examination of STEM clubs is warranted. This paper explores the opportunities and challenges presented by these programs by drawing on interviews with nine STEM club providers in Queensland, a state in north-eastern Australia. The study aims to elucidate the key elements perceived to contribute to the effectiveness and success of STEM clubs, whether school-based, library-based, or run by private businesses for profit. Through inductive thematic analysis, three prominent themes emerged: visioning, pedagogical design and intent, and facilitation. The analysis reveals that Queensland's STEM club context presents significant opportunities for authentic STEM learning and teaching, however, it also identifies challenges to be addressed, including recruiting facilitators who possess expertise in STEM knowledge and skills, possess the necessary confidence and ability to design and implement STEM activities, while also being able to engage and connect with student participants effectively. The findings have implications for STEM-related activities in other informal learning environments.

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Introduction

The integration of STEM education into the school curriculum opens up a range of exciting possibilities for engaging students in authentic learning experiences that encourage critical thinking, promote collaborative group work, and enable creative problem solving (Department of Education and Training, 2014). Although the affordances provided by such learning opportunities are well documented (English, 2017), initiating and implementing effective STEM education in classroom contexts is challenging (Allen & Peterman, 2019). These constraints include timetabling (Timms et al., 2018), teacher expertise (PwC, 2016), and lack of direct connection with curriculum requirements (Dare et al., 2018). Despite these limitations, STEM education is highly valued due to the important role it plays in preparing young people with the skills and knowledge to embark on STEM-related careers, a significant pressure point in the future jobs market (Department of

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Education and Training, 2014), as well as equipping them to be well-informed, civically minded citizens (Fitzgerald et al., 2020a).

In Australia, which is the context of this study, the long-term educational strategy at both federal and state level has focused on two overarching priorities. First, that all Australian students leave school with a strong foundation of STEM literacy, skills, and knowledge, and second, that students are inspired to take on more challenging STEM subjects at an advanced level (Education Council, 2015). All students participate in formal STEM learning within their school curriculum. Additionally, they may have the opportunity to engage in extra-curricular STEM learning, which can be either school-based or offered by external organizations such as businesses or libraries at locations other than school sites. In this research, a STEM club is defined as an extra-curricular learning environment allowing students to learn more about and engage with STEM concepts in a less formal setting than a structured classroom. It is a term commonly used in many countries, including Europe, the United Kingdom, Australia, Canada and New Zealand. We use STEM club as an overarching term that may include:

- Being organized within schools, for example, at lunchtime or after-school or having minimal or no relationship with schools (e.g. public libraries);
- Being run by private organizations either for-profit (businesses) or not-for-profit; and
- Operating on a regular basis (e.g. weekly) or during school vacation periods (e.g. STEM summer camps).

For this research study, STEM clubs are broadly experienced as computing or coding clubs, learning experiences focused on specific topics and interests, activity days in museums and libraries, and makerspaces.

STEM clubs can be interdisciplinary in nature, or they may focus more intently on one or more STEM subjects. They may include student-centered, hands-on activities as well as problem-solving activities to elicit critical and creative thought processes (Davis et al., 2023). They typically involve an array of STEM-focused learning opportunities that are tailored to the context and cohort (Holmlund et al., 2018). There is much variation in how STEM clubs operate, but all run outside of formal school lessons with the intention of facilitating STEM learning. In terms of pedagogical approach, STEM clubs often apply an inquiry-based learning strategy that is underpinned by student autonomy and exploration (Conradty & Bogner, 2019). Student involvement is intended to be voluntary although participation may be supported by teacher, parental, or peer encouragement. STEM clubs are generally organically facilitated rather than utilizing traditional instruction and whilst challenges may be set, specific learning outcomes are not made explicit as they would be in a structured curriculum.

As part of a 2018 funded pilot research project, researchers at the University of Southern Queensland, Australia worked in partnership with Inspiring Australia, Queensland (IAQ, a Queensland State Government organization) and Queensland STEM clubs to explore provider perceptions of effective and successful STEM clubs. IAQ is part of a national strategy aiming to bring together and foster communication between scientists, business, educational organizations, and students. Aspects of this research project have been previously published, including a comprehensive literature review (Davis et al., 2023), a 'current state' report for the Queensland government (Fitzgerald et al., 2019), an online toolkit for STEM club providers, and as case studies (Fitzgerald et al., 2020b). With support from IAQ funding, these outputs have enabled providers to share insights into the unique educational opportunities provided by STEM clubs, including club development, operational considerations, and learning impacts. Based on interviews undertaken during the project, the intention of this paper is to explore, from a provider perspective, the perceived features of an effective STEM club across the State of Queensland as articulated through engagement with educators, business owners, and volunteers operating STEM clubs in a range of contexts and capacities.

The overarching research question informing the study reported in this paper is: What do the providers of STEM clubs perceive to be the determinants of effective and successful STEM clubs? In the following sections, the nature of STEM clubs is explored, and the research approach is described.

STEM clubs: an informal educational approach to STEM learning

Formal school settings tend to be characterized by a unique set of goals, teaching approaches, and learning outcomes (Stewart & Jordan, 2017). Learning tends to be center around a structured curriculum and often standardized assessment protocols and routines. In contrast, informal learning contexts, such as STEM clubs, tend to embrace more serendipitous learning, which lends itself to more open-ended learning outcomes (Sefton-Green, 2013). By way of example, Kotys-Schwartz et al. (2011) grouped informal learning into three key areas:

i everyday experiences;
ii designed settings (e.g. zoos, museums, environmental centers); and
iii programed settings (e.g. programs situation in schools, community- based, science organizations).

In the context of this study, STEM clubs are understood as operating in all three of these settings as well as sometimes in a combination of more than one area.

STEM clubs: benefits to students

Extant literature suggests many benefits for learners from informal STEM learning approaches. A recent meta-analysis undertaken by Nelson et al. (2024), involving 83 studies, identified that mathematics interventions in informal learning environments involving caregivers and others, yielded significant improvements in children's mathematics achievement. Other demonstrated benefits include improved problem-solving skills (e.g. Nygren et al., 2019), development of STEM capabilities and knowledge (e.g. Denson et al., 2015), increased student interest in STEM (e.g. Allen & Peterman, 2019), and further consideration of possible STEM careers (e.g. Çolakoğlu et al., 2023).

The informal nature of STEM club settings is positively viewed by students, as these environments provide a more relaxed and engaging approach to learning than sometimes experienced at school. Roberts et al. (2018) reported on student participation in STEM summer camps (an example of a STEM club environment drawing on an informal learning approach). They indicated that most of the students had positive perceptions of STEM learning and that their participation positively influenced their attitudes towards STEM subjects.

Zucker et al. (2022) also considered how informal STEM learning opportunities outside of school can increase student motivation. Their research highlighted the importance of involving parents and carers within the learning process, illuminating the importance of considering the social context in which STEM informal learning occurs.

STEM clubs: role of provider facilitation and expertise

Research suggests that utilizing STEM experts as facilitators benefits the quality of STEM clubs by enabling students to learn directly from experienced scientists and STEM practitioners. By incorporating this expertise into STEM clubs, students are afforded opportunities to engage in authentic, real-world tasks through a tactic and practiced approach. Consequently, the utilization of expertise transforms STEM from a theoretical concept into a tangible discipline-led experience. Research supports the correlation between the expertise of practicing scientists and individual proficiency in open-ended problem solving and authentic inquiry (Hume & Coll, 2010). However, engaging expert practitioners in informal STEM club contexts, to work alongside facilitators – who are typically teachers or facilitators without teaching qualifications, also referred to as STEM club educators – poses challenges due to constraints on their time and availability (Zeichner et al., 2015). Alternatively, in instances where experts are not available, facilitators could instead undergo training in STEM specific skills that are authentic and relevant (Burrows et al., 2018).

Yuen et al. (2013) advocated for providing STEM club facilitators with training tailored to the specific needs of learners in their respective contexts. Further, STEM club objectives should include the acquisition of mentors, such as STEM experts, to 'guide and motivate' (p. 26) by fostering an interest in STEM and developing intrinsic motivation towards learning tasks. Fitzgerald et al. (2020b) delineated various facilitation approaches employed by STEM club facilitators in diverse contexts, such as leveraging STEM professionals' expertise. Often acting as conduits between the STEM community and educators, STEM professionals bring a passion for their research areas into the learning environment, providing rich, authentic learning opportunities often drawing on real-world scenarios.

Community partnerships have been discussed as powerful connectors with schools (Tytler et al., 2018). While teachers possess specialized training, they may not possess the same depth of understanding as practicing or trained STEM professionals (Tytler et al., 2018). Although the importance of expert facilitators in STEM clubs is recognized, there is limited research detailing the methods and practices that contribute to its success.

STEM clubs: belonging to a collaborative learning community

STEM clubs independently run by community-based organizations serve to bring together meaningful partnerships between schools and local learners and their families (Warren, 2005). This approach supports the notion proposed by Wiseman et al. (2020) that teachers and learners are engaged in 'interesting problems and questions connected to place and community' (p. 265). Students are therefore encouraged to draw on their prior knowledge in addition to interpreting the current content and then communicating their findings. This engagement underscores the crucial role of STEM club providers in designing experiences to capture the interest of learners. As discussed by Tytler et al. (2018), a strong connection can exist between the curriculum and the work of STEM clubs. Even in informal learning settings, these clubs can align their activities with classroom context and the overarching STEM discipline-related curriculum, ensuring a seamless connection between out-of-school experiences and in-school learning. Thus, the aspects of curriculum intertwined with authentic tasks are addressed in relation to the 'student experience' (Tytler et al., 2018, p. 254) with an emphasis on the purpose of the STEM experience.

Successful collaborations have emerged between various educational contexts and STEM experts, offering valuable insights into effective STEM learning and teaching. LópezLeiva et al. (2016) discussed a collaborative model where university faculties and teaching staff co-teach STEM content, fostering new educational approaches (p. 180). Similarly, Shahali et al. (2017) illustrated a 'top down' approach where professional bodies sponsored STEM clubs in schools to tackle real world challenges. Collaborative STEM club communities involving industry, universities, teachers, and students working together to demonstrate positive outcomes. An Australian Industry Group report (AIG, 2017) described different collaborative models (e.g. single school-single company, multiple schools-multiple companies, multiple organizations) of STEM clubs across Australia, suggesting many benefits both in terms of student interest and enjoyment of STEM as well as teacher professional development. These models are indicative of the additional advantage of practising STEM professionals being included in school-based educative processes (Woolnough, 2001).

In summary, the current literature indicates a range of benefits from STEM clubs for learners, but it also reveals a gap around how STEM club providers perceive how their clubs should be managed and sustained to achieve successful outcomes. Next, we describe an exploratory interpretivist approach to identify themes around provider understandings of effectiveness and success within the STEM club landscape.

Method

Thanh and Thanh (2015) identified that interpretivist paradigms are predominantly utilized within qualitative research methodologies because they are concerned with understanding the meaning and interpretation of social phenomena from the participants' perspective. This approach was appropriate for this study because it encourages the sharing of meaning-making practices, while making space for methodologies that generate thematic outcomes. In context, the development of a more informed and holistic understanding of the STEM club landscape in Queensland was possible due to the ability to probe ideas and question decisions through provider interviews. In this section, participant selection is described before detailing the data collection and analysis processes.

Provider selection

This study adopted a purposeful sampling approach, a technique commonly used in qualitative research to select participants from the population of interest (Suri, 2011). As part of the wider project, STEM club providers were offered the opportunity to apply for a small grant to support innovation and resourcing. Grants were awarded to 50 recipients (from around 100 applications) with the condition that they would be invited to participate in this research study. Successful providers representing the range of STEM club contexts (12 providers in total) were invited, via email, to participate in a semi-structured interview with Authors 1, 2 and 3. From this invitation, nine providers from school, library, and private sector STEM club contexts opted to continue in this research. Their educational contexts, STEM club focus and the provider role are outlined in Table 1.

Data collection

Prior to data collection, human ethics permission was received from the University of Southern Queensland Human Research Ethics Committee (Approval Number: H19REA281F1). Data was collected through semi-structured interviews, aimed at gathering information about STEM clubs that are hard to directly observe, such as participants' thoughts and beliefs about STEM clubs as

Table 1. STEM Club context, focus, and representative.

Provider context	STEM club focus	Provider role
School 1	A lunchtime primary school (5–11 years) club with a focus on delivering thematically organized activities (e.g. flight).	STEM Club coordinator and registered teacher
	A lunchtime primary school club (9–11 years) focused on developing skills associated with robotics in addition to problem-solving skills.	STEM Club coordinator and registered teacher
School 3	A lunchtime secondary school club (12–15 years) centered on activities in the areas of electronics, coding, and engineering.	STEM Club coordinator and registered teacher
School 4	A lunchtime middle school club (12–14 years) developing participant skills in programming.	STEM Club coordinator and registered teacher
Library 1	A program focused on children under five years of age embedded in the traditional 'story time' programming.	Education programmer and STEM club educator.
Library 2	An outreach program for children and adolescents (7–12 years) running after school and during school holidays focused on the development of STEM skills and strategies.	STEM Outreach coordinator and STEM club educator
Business 1	A touring STEM Show (6–11 years), which visits schools and works with home schooling families.	Sole owner and facilitator and STEM club educator
Business 2	A school holiday program (Ages: 13–15 years) focusing on developing digital technology skills particularly related to aerospace.	Co-facilitator and STEM club educator
Business 3	A series of after-school and weekend programs (Ages: 6–14 years) that introduce children and young adults to different modern technologies (e.g. coding, game design, video production, etc.).	Co-owner and co-facilitator and STEM club educator

Note: STEM club educator is a term used to describe the person responsible for providing the learning opportunities within the Business and Library STEM clubs. They are not registered teachers.

well as operational elements. While the open-ended, conversational style of a semi-structured interview provides a sense of familiarity and comfort for the interviewee (Guest et al., 2013), Creswell (2013) argues that qualitative research cannot be completely devoid of value or bias. To ensure impartial data collection, we followed Kallio et al.'s (2016) framework to design a credible semi-structured interview protocol aligning with our research objectives and context.

The interview questions were formulated to investigate the gap identified within the literature. The literature emphasized that while STEM clubs offer various benefits, such as informal, open-ended learning opportunities resulting in enhanced problem-solving skills, STEM knowledge and increased interest in STEM subjects and careers, there is a need to address how providers perceived and sustained these clubs. Further exploration was required to understand the effectiveness and success factors within the STEM club landscape. The research team reviewed the questions to determine if the main ideas derived from the literature were adequately represented and that the sequence and language was appropriate for participants. The process for follow-up questions in the form of paraphrasing, to minimize the insertion of researcher notions, was discussed and agreed upon. As a result, the following key questions shaped the interviews:

1. What is the purpose of your STEM club?
2. What is your vision for the STEM club?
3. How do you facilitate your STEM club?
4. What kind of support would make your STEM club more effective?
5. What are the benefits of running your STEM club?
6. What are the barriers to running your STEM club?

Once the interview process and questions were developed, a research team member, designated as an interviewer (Authors 1, 2 and 3), was allocated to each STEM club provider. The allocation process ensured every interviewer had sufficient familiarity with the STEM club environment, while also ensuring they did not interview individuals from the STEM club with whom they had a pre-existing relationship (Creswell & Poth, 2016). Representatives from each STEM club provider were interviewed either on the phone or via online video conferencing at a mutually convenient time. The interviews ranged in length from 30 min to an hour and were audio-recorded before being transcribed.

Data analysis

The process for analyzing the data was inductive, endeavoring to capture the contextual components and practices associated with STEM club implementation, both within and across clubs. Braun and Clarke's (2023) approach to inductive thematic analysis was employed to ensure the findings were grounded in the data and to identify explicit elements and underpinning assumptions. The process was iterative. Initially, Authors 3 and 6 independently read the transcripts to immerse themselves within the data and establish a foundational understanding of the data. They then independently coded the data, then compared the codes to ensure consistency, applying inter-rater reliability methods (Creswell, 2013). Discrepancies were discussed until a consensus was reached. The authors then identified themes by examining the codes and patterns in the data (Braun & Clarke, 2023). Finally, the themes were reviewed against the initial codes to ensure that each theme related to the research objectives and to reduce overlap. This step was crucial before reaching final agreement on the themes.

Findings

This section reports the findings in relation to the research question: *What do the providers of STEM clubs perceive to be the determinants of effective and successful STEM clubs?* The data analysis identified three themes: vision, pedagogical design and intent, and implementation challenges and successes. Each theme is discussed using illustrative quotations from the providers and concludes with a synthesizing statement.

STEM club vision

This theme explores the ways in which the STEM club providers articulated their vision through the decisions they made about purpose and approach. From the outset, School 1 articulated a vision that resonated with many of the interviewees:

> the purpose is to develop kid's interest and capability in STEM as well as other teachers because I always try to get other teachers to assist to build their capabilities. At the end of the day we want kids doing STEM and keen on STEM.

The school-based STEM clubs were at various stages of articulating a purpose, with School 4 mentioning that 'maybe one of our things we need to develop is to have an actual plan first then a vision'. School 4 discussed the general purpose of their STEM club as being to engage and build interest around STEM as well as 'to prepare kids for future life and employment'. For School 4, this combined hands-on, inquiry-based experiences with developing employability skills. School 2 drew upon national and international competitions, such as The *Lego League,* to ensure their students became 'keen on STEM'. Fun, enhancement (e.g. extending classroom-based learning and teaching) and engagement were recurring motifs when the providers discussed their STEM club purpose and approach.

The notion of 'fun' centered around developing the students' interest in STEM. Across the interviews, an overarching purpose for STEM clubs from most providers was not to replicate what was already being taught in the classroom but to create unique and enjoyable experiences that allowed students to explore and engage with STEM concepts in a different way. The emphasis on fun experiences was ultimately to foster a positive attitude towards STEM and inspire a love for STEM, by introducing fun elements such as 'building cup gliders or engaging in challenges with time limits using items like Oreos and marshmallows' (School 2). This included creating opportunities for students to have 'fun outside of STEM and school' (Library 2), as well as incorporating 'competitive elements and offering prizes for certain activities' (Library 1). As outlined by School 2, 'when students are having fun, they tend to feel proud of their accomplishments, and it enhances their engagement and motivation'. The providers reported that a sense of accomplishment and enjoyment became a driving factor for students to participate actively in STEM activities.

Multiple coding references referred to ideas of enhancement with School 2 and School 4 stating that their purpose included 'try[ing] to get other teachers to assist [in STEM club activities] to build their capacities' (School 4), which often resulted in a 'steep learning curve' (School 2) for those involved. School 3 stated that they believed that the teaching of STEM was impacted by 'the confidence of the teachers' as the 'workforce does not have the capability or are trained how to run a STEM club'. This perceived barrier contributed to many STEM clubs supporting teachers to develop their capabilities through participation and the creation of support mechanisms, such as 'a small subscription for teachers where we can, you know, offer all of this content that we've sort of put together' (Business 1). Library 1 held similar beliefs where their content was considered complementary in supporting their educators' formation of 'additional skills'.

At the core of what drove each of the Business providers was a purpose linked to engagement that focused on working with children and young people to 'enrich' their STEM learning. For example, Business 3 expressed that '… we're just trying to think of different ways to empower kids, you know, to own the technology rather than be driven by the technology'. Business 1 also had a clear and well-defined vision or, in the owner's own words, an 'overriding sense of purpose'. In this case, the focus driving this STEM club was 'making the world a better place' by enabling young learners to 'experience and enjoy' STEM and become 'more critical and creative thinkers' as a result. Engagement of learners in STEM also drove Business 2, but the purpose was more geared to enticing young people to pursue further studies in STEM by focusing on future industry needs in STEM-related fields. As the owner of Business 2 articulated, they:

> want to see … as many young Australians as possible educated and engaged in areas like high-tech aerospace and engineering to help feed those 20,000 jobs expected to be in the Australian space industry within the next ten years.

Business 3 articulated a STEM club vision from an industry perspective with a drive to support children and young people to be technology creators, not just consumers. However, Business 3 acknowledged that the cohorts interested in STEM clubs often find it challenging to fit into other contexts. Therefore, they have worked at creating 'a place for students to come that might not sort of fit into the traditional kind of activities' and to foster a sense of belonging amongst their participants.

In summary, the key learnings connected with this theme are:

- STEM clubs strived to provide participants with learning experiences outside of the classroom that engender fun and promote positive attitudes towards STEM;
- The enactment of STEM clubs had the added layer of enhancing educator capabilities and competencies around STEM education as aligned with the club vision, and
- STEM clubs were created to engage participants with diverse needs and interests in thinking about the possible pathway opportunities inherent in STEM.

Pedagogical design and intent

This theme on pedagogical design and intent includes building teaching capacity in facilitators and meaningfully engaging students in STEM learning, signaling some overlap with the STEM club vision statements. In terms of engagement, Library 1 discussed how the pedagogical intent of their offering was to 'expose people to resources that they just might not ever see here, particularly because we're in a regional community'. In the context of Library 1, this inclusive approach was celebrated through the hands-on pedagogical focus of *Story Time*. Library 2 referred to STEM-related concepts mentioning 'the children make three different types of cars, say you know, wind power'. However, their approach to planning was less structured around content and curriculum and more around student interest, referring to their planning as being 'most of the time incidental'. In this sense, the notion of engagement was about promoting interest and investment in STEM concepts and thinking. This differs from engagement as identified as part of STEM visioning, which was more focused on participation over cognitive connections.

While STEM club purpose was also interested in capacity development, this was more through the lens of STEM club enactment in line with the intended vision. From a pedagogical stance, this theme captures the interest in developing the knowledge and skills of STEM club participants, both educators and students. For School 2, increasing the capacity of their facilitators took the form of learning on the job, which was articulated as noticing that through their planning and delivery of the content, they now 'have a lot of those skills'. This aligned directly with the pedagogical direction of School 2 to increase 'the capability of everyone involved' with the intention that this would have an impact beyond the STEM club and into the classroom. This further quote from School 2 speaks to the flow on effects from learning and teaching in a STEM club, 'now I can go and use that in my teaching, so I think I just like the learning myself and I just like teaching the kids, they just have such a ball that it makes me happy'.

Challenges in pedagogical intent did, however, arise when discussing the planning and development of content for the school-based STEM clubs, as exemplified through this quote from School 3, 'there is not a curriculum that I have to follow'. A more informal approach to planning was expressed by School 4, in relation to taking mental or written notes and using reflection around the following questions to inform pedagogical decision making, 'a level of did that go well and what did kids learn and was it worth doing and what will we do next time?'. This kind of thinking seemed to replace the discussion around curriculum links and unit planners, which might usually be related to a school-based pedagogical focus.

The owners of Business 1 and 3 articulated the pedagogical intent informing their STEM club development and implementation in similar ways to school-based providers. Pedagogical intent was reflected by both business providers using terms such as 'engagement', 'enjoyment', and 'STEM related skills development'. The three library-based providers used similar terminology to describe elements that informed their pedagogical decision making with 'fun with purpose' (Library 2) a resonating construct. For Business 3, their specific STEM club focus was 'having that environment where we can build team skills and give [participants] the experience of working collaboratively with a number of other students'. A key element referred to by the Business 1 provider was the autonomy demonstrated by his STEM club participants, largely home-schooling families, which manifests as an ability to self-manage themselves rather needing to rely on others. For example, 'you can trust them to keep themselves safe' and 'if you don't want them to do something, you point it out and they're generally very respectful'. Business 1's pedagogical approach to their STEM club has been primarily focused on adjusting strategies to meet the learning needs of the home-schooling families they serve. These children are accustomed to more informal learning environments, which differ significantly from the formal structure of learning within schools.

In contrast to the home-schooled participants working with Business 1, students frequently engaged in the Business 3 STEM club tended to demonstrate less autonomy indicating a perception of limited influence over their attendance. This tendency is exemplified by the following quote: 'We've had kids that have come in who have literally, their parents have had to drag them in [the] door and they've almost been shaking when they get in there'. Consequently, students involved in the Business 3 STEM club often required significant support from the STEM club facilitator to build their confidence and encourage their participation in activities.

In summary, the key learnings connected with this theme are:

- STEM clubs played a key role in developing the capacity of educators in planning and implementing STEM education in meaningful and relevant ways; and
- The pedagogical decision making associated with STEM clubs was informed by a desire to genuinely engage learners with diverse needs and interest in STEM-oriented learning.

Implementation challenges and successes

The final theme draws out the providers' examinations of the implementation challenges and successes they faced when developing and/or implementing a STEM club. A key focus was on 'building facilitator confidence and capacity' (School 3) in the delivery of their programs. School 1 engaged with teachers who were enthusiastic to deliver the program, which was reflected upon as a success due to the passion and interest they had in their STEM club. Similarly, this drive and willingness to learn was evident in the reflection from School 2. Although they would often need to undertake additional research before they included a new topic or focus, the facilitator and the participants 'would learn together' (School 2) to build capacity.

Many school-based STEM clubs were run by the initial creator and facilitator of the STEM club, who subsequently sought to gain further support from colleagues. In the context of School 1, this included a STEM coordinator as well as a 'young teacher who's really keen'. The notion of 'keenness' appeared as both a positive feature and potential challenge as school-based providers often had a surplus of keen, interested, and willing teachers, however, they lacked the confidence necessary to run the STEM club autonomously.

School 1 also reflected upon the additional challenges of time and planning in their facilitation of the STEM club, coupled with feeling pressure around their additional duties and 'everyone being busy'. Broadly, school-based providers spoke about resolving this issue through the acquisition of STEM 'experts' as facilitators. As a result of acquiring a STEM mentor, School 2 noted that students began to see STEM as a more achievable and feasible career pathway due to the positive impact the mentor had on participating students alongside ‘a great mind to promote STEM thinking’. Experts were particularly valuable when implementing programs, as articulated by School 2, ‘I really didn’t have a lot of knowledge around 3-D printing and Lego robotics … I would do enough research that I could get it all started and then we would learn together’.

Echoing school-based providers, library providers also indicated similar types of challenges. Library 2 reflected upon constraints of time in relation to implementation. They worked from predeveloped robotics kits that were distributed and used by the students. Library 2 indicated that using these kits and running the STEM club this way allowed for ‘anybody to actually do it’. The structure of following a model or set template was also elaborated upon by Library 1. They embedded the ‘First Five Forever’ literacy approach (Webb, 2016), which focuses on adults (e.g. parents or carers) playing, singing, and talking with young children to create opportunities for learning. Library 2 trained their facilitators to use this technique and applied it in the ‘procedure and principle in the planning of their sessions’. A challenge of having a structured programming approach such as *First Five Forever* was the turnover of staff for facilitation. This impacted the ability of Library 2 to communicate the design and delivery of the STEM club once the main facilitators had moved on.

Business providers highlighted ‘expertise’ (Business 1) and ‘strong industry links’ (Business 3) in their responses around facilitation. For example, Business 3 expressed, ‘we rotate through some of our lead engineers from aerospace, when they have moments available, so that they can show young students what it looks like to follow their university ambitions and go into the industry’. Business 3 was operated by a team with strong STEM skills and attributes with one of the owners having a background as ‘electronics engineer who worked as a software engineer for close to 20 years’. They also employed young people with STEM experience and interest as education assistants as they were more likely to easily connect with the participants and act as role models. Likewise, Business 2 built sustainability into the facilitation of their education programs with ‘teachers and trainers upskilled by [the] team who have been working with them’ and importantly ‘[they are] going to keep checking in with them and hopefully see them continue to run these courses over the next year, term- on-term, or however they run their programs’. Businesses 2 and 3 both articulated the skills and attributes they seek in their STEM club facilitators. This area was not so relevant to Business 1 as the owner was the sole facilitator. Business 2 had an education team made up of tutors, who were both experienced and relatable. The owner articulated that a focus of hiring is on ‘younger tutors because they are relatable, obviously, to students’ as well as those who have ‘either studied engineering at university or have recently finished’.

In summary, the key learnings connected with this theme are:

- Seeking STEM club facilitators who have both the confidence and capacity to plan and implement STEM club activities; and
- Adopting STEM club facilitators, who are expert in STEM knowledges and skills while being relatable and accessible to participants.

Understanding STEM clubs through the theoretical lens of self-determination theory

To better comprehend the perspectives of STEM club providers, we propose self-determination theory (SDT; Ryan & Deci, 2017) as a guiding framework. SDT posits those environments fostering autonomy (feelings of choice and self-endorsement), competence (growing in one’s capabilities), and relatedness (a sense of belonging) lead to better motivational outcomes. STEM clubs inherently align with the principles of SDT (Fitzgerald et al., 2020b). The inquiry-based and exploratory nature of STEM club activities, if effectively designed, holds the potential to nurture competence, stimulate autonomy, and foster relatedness (Martin et al., 2018).

The articulation of STEM club visions, emphasizing ‘fun’ experiences and unique learning opportunities, serves as a critical entry point for this analysis. The focus on ‘fun’ can be interpreted through the lens of SDT as an avenue to support autonomy, allowing students to engage in enjoyable activities of their choice without the constraints of formal assessments (Evans & Boucher, 2015). This aligns with the SDT proposition that environments facilitating personal choice and self-endorsement contribute to higher quality motivation. Moreover, the commitment to enhancing educator capabilities, as evidenced by schools and businesses, introduces a dimension of relatedness. The collaborative approach, wherein providers are encouraged to build their capacities collectively, fosters a sense of belonging and authentic relationships (Ryan & Deci, 2017). However, care must be taken to ensure that the external experts impart their knowledge and wisdom in ways that the facilitators benefit by learning and becoming autonomous, rather than becoming reliant on those experts.

The theme of pedagogical design and intent within STEM clubs reveals a delicate balance between fostering competence and autonomy. The commitment to developing the knowledge and skills of both educators and students aligns with SDT's emphasis on competence. The on-the-job learning experiences, as described by School 2, signify a pathway for educators to grow in their capabilities, directly contributing to the enhancement of competence (Ryan & Deci, 2017). However, challenges arise in the informal planning approaches mentioned by some schools, such as School 3's absence of a specific curriculum. Although SDT acknowledges the importance of autonomy in learning environments, the balance with structure must be carefully struck to avoid sacrificing substantive learning for the sake of autonomy (Cheon et al., 2020).

The theme of implementation challenges and successes reflects the interplay between competence and autonomy. The emphasis on 'building facilitator confidence and capacity' within schools underscores the commitment to competence (Ryan & Deci, 2017). The success stories of teachers and participants learning together in a collaborative manner exemplify the growth in competence derived from STEM club experiences. However, the reliance on external experts, as seen in the case of STEM mentors and industry professionals, introduces complexities in the autonomy-competence dynamic. While external expertise can undoubtedly enhance competence, a critical perspective prompts us to question whether this reliance hinders educators' autonomy to develop and implement STEM activities independently.

The emphasis on 'fun' experiences as a driving force behind STEM club visions draws attention to SDT's focus of intrinsic motivation. Intrinsic motivation is posited in SDT as undertaking activities for their inherent satisfactions i.e. doing something because it is enjoyable. Further the theory suggests that when the learning environment is supportive of autonomy, competence, and relatedness needs, intrinsic motivation is enhanced. The notion that 'fun' is not merely a superficial approach, but a strategic pedagogical tool aligns with the SDT proposition that satisfying the needs of autonomy, competence, and relatedness contributes to intrinsic motivation (Ryan & Deci, 2017). However, this raises questions about the use of extrinsic motivators that are sometimes introduced into STEM clubs, such as competitive elements and prizes.

Overall, an examination of STEM clubs through the lens of self-determination theory offers valuable insights into the complex dynamics of facilitator enhancement and student engagement. The alignment of STEM clubs with the SDT principles of autonomy, competence, and relatedness underscores their potential as transformative spaces within the educational landscape. However, this exploration suggests that there may be risks, such as an overreliance on external expertise and the inappropriate introduction of extrinsic motivators. The future trajectory of STEM clubs requires a conscientious effort to strike a balance between autonomy and competence, ensuring that the principles of self-determination theory guide their evolution.

Limitations of this research

As exploratory research, there are some limitations associated with this study. First, and primarily, the research is situated in only one state in Australia, and that must limit the value of the findings in terms of generalizability. However, even in this one state, we found a variety of STEM clubs, differing in the nature of their providers, their content focus, their vision, and how they operated. Clearly, each STEM club varied according to its local context. Therefore, what is generalizable is the importance of context, in terms of provider and purpose, nature of operation and desired outcomes.

The promotion of STEM learning is seen as a priority in many parts of the world, and if new STEM clubs are to be developed then the local context, in terms of geography community and culture need to be considered. For example, we found evidence from our providers that enjoyment and informality are perceived to be important features of STEM clubs. However, this kind of focus may not be appropriate in certain cultures where strict hierarchies between adults and students are deemed important to successful learning.

This study has gained insight through the experiences of a purposeful sample of STEM club providers, but extending findings beyond its context requires caution. Future research in different countries will lead to improved understanding of STEM clubs and their role. Despite these limitations, the outcomes provide baseline data that would be useful to other organizations wishing to facilitate a STEM club. We point particularly to the importance of context, setting a supportive motivational climate, identifying challenges to sustainability, and drawing on the appropriate STEM expertise when considering the applicability of this study.

Conclusion

This exploration into the provider perspectives of the perceived features of effective and successful STEM clubs within an Australian state has provided valuable insights that contribute to the ongoing discourse around STEM education. It is evident from the findings that providers have diverse expectations and criteria when assessing STEM club success. Although academic achievement and skill development are universally recognized as indicators of success, the emphasis on collaborative and experiential STEM learning experiences is critical to their effectiveness. The role of STEM club facilitators emerged as a pivotal factor in shaping the success of STEM clubs. Providers highlighted the significance of knowledgeable and motivated educators who can inspire students and effectively facilitate hands-on learning experiences. Professional development opportunities for educators, with a focus on integrating innovative pedagogies and staying abreast of technological advancements, were identified as crucial.

It is noteworthy that the perceived features of effectiveness and success in STEM clubs are dynamic and responsive to the rapidly evolving STEM landscape. Technological advancements, emerging trends, and evolving educational paradigms necessitate a continuous re-evaluation of the criteria used to assess the effectiveness of STEM clubs. In conclusion, this study highlights the need for ongoing dialogue and collaboration among providers to collectively shape the trajectory of STEM education in Australia.

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