EngineeringUK

RAPID EVIDENCE REVIEW

STEM clubs and their ability to increase students' aspirations for engineering and technology careers

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This review brings together the available evidence on STEM (science, technology, engineering and mathematics) clubs and their ability to increase students' aspirations for engineering and technology careers. By summarising the existing studies, we draw out learnings on STEM clubs that can be used by STEM outreach providers to increase aspirations around engineering and technology careers.

Context

STEM engagement has the potential to provide young people with invaluable opportunities to learn about, consider or pursue educational and professional pathways towards engineering and technology careers. Therefore, it's becoming increasingly more essential to understand the effective aspects of these initiatives to demonstrate the value of STEM engagement.

In the UK, many STEM education providers offer diverse activities, each tailored to a specific set of objectives. For example, some STEM activities are designed to inspire participants about STEM careers, while others focus on building their technical skills related to STEM. One such avenue for delivering these STEM experiences for young people is through extra-curricular STEM clubs.

Given the limited presence of engineering and technology in existing school curricula, high-quality STEM clubs can play a key role in complementing or broadening the STEM curriculum, thereby having the potential to nurture and expand young people's aspirations for engineering and technology careers.

However, fewer STEM engagement activities focus specifically on engineering and technology, and there is limited evidence on the effectiveness of these interventions. While various models of these interventions exist, in this report, we'll focus on STEM clubs. We're particularly interested in understanding the role these clubs play in enhancing career aspirations among young people, especially in the context of engineering and technology careers.

About this review

This rapid evidence review aims to identify the modes of delivery of engineering and technology-related STEM clubs that have been evaluated. It seeks to explore the evidence of what aspects of these activities work to increase students' aspirations for pursuing careers in these sectors. Additionally, the review aims to identify any current gaps in the evidence, which can inform the design and evaluation of future engineering and technology interventions within STEM clubs.

While the review aims to provide insights and learnings from the evaluation of STEM club activities, it's important to acknowledge certain limitations. We've drawn on the relatively limited evidence available, so advise caution when looking at applying these findings more broadly. We provide links to the full papers so you can access all the details of the methods used and the findings. However, due to the scarcity of studies in this area, it's crucial to recognise that our ability to make generalisations or definitive conclusions is limited.

The reflections highlighted in this report, which are drawn from the papers directly and from the reviewer's perspective looking across the published studies, are intended to help those looking to explore similar approaches to benefit from the experience of others.

Research questions

This evidence review focuses on 3 key research questions:

1. Does STEM engagement delivered through STEM clubs increase students' aspirations for careers in engineering and technology?
2. What methods have been used to measure the effectiveness of these interventions?
3. Which studies show the best modes of delivery for informing the design of future engineering and technology interventions?

Database search

We searched 3 databases for relevant papers (ERIC, IEEE Explore, Science Direct). We conducted additional searches using Google Scholar and by following the references and citations of the studies included.

Inclusion criteria

To meet the inclusion criteria, papers must:

- clearly state the aims, participants, and context of the intervention
- evaluate the effectiveness of the intervention using quantitative, qualitative, or mixed methods
- have a specific focus on engineering and technology outcomes, rather than science or STEM more broadly
- involve an intervention that is delivered as part of a school-based STEM club

For the purposes of this evidence review, we defined a STEM club as extra-curricular sessions delivered in schools during lunch breaks or after-school hours aimed at enriching or broadening the STEM curriculum. This includes, for example, science clubs, robotics clubs, or coding clubs.

The papers reviewed used a range of names for the interventions they referred to, such as programme or workshop. This review will refer to the interventions as clubs or club activities for ease.

Research focused on STEM related holiday clubs or camps was not included in this review as attendance is more dependent on students' personal circumstances.

See Annex A to view the full methodology.

Outcomes of interest

For this review, we focused on programmes that addressed an increase in young peoples' aspirations to a career in engineering and technology (including computing) or pursuing options that keep them on a career path including subject choice and next steps after leaving school.

Screening strategy

We identified a total of 228 papers through the search and initial screening of titles and abstracts (see Appendix A for the full screening strategy). We eliminated irrelevant or duplicate papers through this initial process, leading to us identifying 52 articles for review.

We read these remaining papers in their entirety. We excluded studies that failed to meet the inclusion criteria or were of poor quality, unless they provided club content that is useful for learnings (see 'other relevant studies' section on pages 9 and 10). We discovered additional relevant studies by searching the references and citations of the selected papers, leading to a final review of 8 papers.

Synthesis of key findings

We studied the final papers to extract useful information about the delivery, evaluation, and key findings from each club. We summarised this data into a table to facilitate comparison of the club and outcomes.

Reporting findings

Given the small number of papers included in the final review, we presented studies that met all the inclusion criteria first in this report. Papers that didn't meet the inclusion criteria, but provided club content ideas that could still be relevant, are included in a follow-up section (pages 9 to 11) . While still relevant, these papers didn't meet all inclusion criteria as they didn't provide enough information about the intervention evaluated.

Overall, we distilled key learnings from the evidence to help those planning and delivering similar approaches (pages 8 and 11). Some of these insights are drawn directly from the conclusions of the reviewed papers, while others reflect learning from across the studies as a whole.

Since clubs are rarely replicated in precisely the same way, we've distilled the learning to inform new clubs, rather than to recommend a specific club approach. Readers who are interested in more detail about any of the papers mentioned in this report should follow the references to read the papers in full.

Four out of the 8 studies identified from the screening process met all the inclusion criteria.

OVERVIEW OF FINDINGS

Out of the 4 studies that met all the inclusion criteria, 3 had positive short-term effects related to young peoples' engineering or technology career aspirations. These 3 studies are summarised below.

Positive findings

Educational computer games (Stewart-Gardine and others, 2013) is a voluntary after-school club consisting of one session per week for 5 weeks. As part of this intervention, 35 students aged 11 to 14 were encouraged to play a range of computer games. These included activities for students to learn how to modify and enhance the games, fostering creativity.

Findings: After taking part in the club, 31% of students said they could see themselves one day creating computer games, and 60% said they could see themselves studying computer science in university. The authors concluded the computer games influenced the students to view themselves as being capable of designing computer programmes in the future.

Beyond Blackboards (Blanchard and others, 2015) is a voluntary after-school robotics and engineering club. As part of this initiative, 58 middle schoolers[1] met twice a week between the autumn and spring terms. Teachers were provided with professional development to coach the clubs. The overall goal was to support teams to enter in a FIRST LEGO® League competition.

Findings: After participating in the club, students showed a greater interest in engineering. Focus group findings also suggest students improved their understanding of the connection between engineering and innovation. Additionally, they maintained positive attitudes toward teamwork involved in engineering careers, while a group of non-participants displayed a shift towards more negative attitudes. A more comprehensive overview of this study is presented in the next section (page 7) of this report.

Communication, Science, Technology, Engineering and Mathematics (CSTEM) Programme (Christensen, Knezek and Tyler-Wood, 2015) engaged 80 middle school students and 64 high school[2] students in a voluntary after-school club that ran across the entire academic year. The club engaged students to collaborate on project-based learning activities to solve 6 challenges, designed by industry professionals. The club promoted active engagement of 'doing science', rather than studying. These challenges involved competitions based on creating and developing projects focused on a number of topics, including remote-controlled robots, geoscience, creative writing, sculpture, film and photography. The students completed a survey during the end of year event.

Findings: The high school students who took part in CSTEM had a positive dispositions toward engineering and technology compared to students who took part in a 2-year maths and science residential programme (not significantly different). CSTEM middle school students had significantly more positive perceptions of engineering (significantly different), and in some cases of technology (not significantly different) compared to middle school students who didn't participate in CSTEM, but instead in an energy and climate change project. The authors concluded the findings imply that hands on, active learning, and engaging programmes related to making things relevant to the real world may be effective in promoting or retaining positive interest in STEM content and careers.

They suggested that students may become disinterested in science due to the way it's taught in schools, as it's disconnected from real world applications of the content. The authors highlighted the importance of tailoring content for specific age groups as the programme may not be as effective across middle school and high school students. It was also concluded that future studies should focus on pre and post surveys to measure changes in interventional programmes.

[1] Young people who attend middle schools in the USA are typically between the ages of 11 and 13.
[2] Young people who attend high schools in the USA are typically between the ages of 14 and 18.

OVERVIEW OF FINDINGS

Out of the 4 studies that met all the inclusion criteria, one had mixed findings related to young peoples' engineering or technology career aspirations. This study is summarised below.

Mixed findings

Wearables project (Hebert and Jenson, 2020) consisted of 12 sessions facilitated during two different voluntary after-school clubs that each met for two-hour long sessions on a weekly basis. One club per week was for those students who identified as female, and the other for those who identified as male. In total, 18 students aged 11 to 14 were tasked with creating wearable hats using LilyPad Arduino (a circuit board created for textiles) in the after-school clubs. The authors also analysed and compared findings from an in-school version of these club activities delivered during classroom time with a different group of 18 students. **Findings:** Before attending the after-school club, 94% of students who participated in the wearables project said coding should be taught in schools. However, after the wearables project, 80% of students thought this (14-percentage point decrease). On the other hand, among those who took part in the in-school version, 55% of students agreed coding should be taught in schools before the activities, and 70% agreed with this statement after completing the wearables project (15-percentage point increase). The authors suggested students who took part in the in-school version of club activities, so were likely not as interested in coding from the outset, recorded higher levels of interest after taking part in the class.

Additionally, 15 students from the in-school version were interviewed and asked whether they would be interested in constructing a wearable or participating in a similar type of project at home as evidence of engagement in the project and of extending learning beyond the classroom. 60% indicated they would not engage in something similar at home. The main reason for this (67% of responses) was due to students not enjoying it, and other reasons included time concerns, competency and access to resources. The authors concluded that these findings show students may not be interested in, have time or resources to engage in making a wearable at home, and therefore may not be able to develop these skills if not provided an opportunity to do so in school. This highlights the importance of delivery in settings where young people are as they may not have the resources and/or competency to access them outside of school settings.

EXAMPLE OF A STEM CLUB THAT INCREASED STUDENTS' INTEREST IN ENGINEERING

Beyond blackboards: Engaging underserved middle school students in engineering (Blanchard and others, 2015)

Purpose

The primary purpose of this study was to investigate the impact of the Beyond Blackboards programme on students' interest and understanding of engineering, as well as their ability to align their educational and career pathways.

Participants

74 students from 3 middle schools in the USA participated in the Beyond Blackboards programme. Over three quarters (76%) of these students were from economically disadvantaged backgrounds. For context, young people who attend middle schools in the USA are typically between the ages of 11 and 13.

Delivery model

During the autumn term, students participated in 'innovation clubs' at their middle schools. These after-school robotics and engineering clubs presented students with engineering-design challenges using LEGO® MINDSTORMS NXT robotics kits and the NXT-G programming environment. Each school hosted the clubs twice a week, with varying meeting lengths, but they accumulated a total of 48 programme hours throughout the school term. These clubs were overseen by two teachers at each school, all of whom had undergone a professional development training in design-based learning to guide and support the clubs to compete in a FIRST LEGO League (FLL) competition. Additionally, each club benefitted from the assistance of undergraduate college students who acted as technical mentors, as well as engineers from local companies who acted as industry mentors.

Evaluation

Researchers conducted surveys both before the programme started and after its completion. These surveys asked questions about students' interest in and understanding of engineering. At the end of the school year, researchers carried out one-hour long focus groups in each school. During these sessions, students were given the opportunity to share insights into their motivations for taking part, their level of engagement with the club, their perceptions of how their peers see the club, and how their participation shaped their views of school, engineering, and problem solving. Out of the 74 students involved, 58 young people completed both surveys, and 19 participated in the focus group discussions.

Findings

Students who took part in the clubs were more interested in careers in engineering compared to a sample of non-participants.

Focus group findings also suggest students' interest in engineering and their understanding of the link between engineering and innovation increased, following participation in the programme.

Additionally, the authors found that throughout the programme, participants continued to share positive attitudes towards teamwork and its importance in engineering careers, whereas non-participants adopted more negative attitudes towards teamwork. This suggests the programme may play a role in protecting students from the usual decline in interest and attitudes, and that the programme may have enhanced students' interest in becoming engineers.

Discussion

The findings of this study provide suggestive insights into the potential causes behind the observed changes resulting from the programme, rather than conclusive explanations. Further research is needed to comprehensively understand whether Beyond Blackboards impacts students, along with determining the factors contributing to changes in their attitudes, interests, and expectations.

Additionally, as students voluntarily chose to participate in the clubs, their motivation and individual circumstances, which allow their attendance in after-school clubs, could have influenced their positive views towards engineering. While a robustness check was carried out on this aspect, additional research in this area would be beneficial.

The authors found that students responded favourably to the teamwork, creativity, and challenges involved in competing against other teams. Additionally, they found that being involved in and winning competitions may have influenced a school wide shift in attitudes around engineering and technology, so they concluded that taking part in competitions may have a wider benefit to the whole school.

Conclusion

Beyond Blackboards participants tended to be already more interested in engineering careers than their schoolmates. However, through the programme they reported gaining even greater interest in these careers over the academic year.

LEARNINGS

This section provides learnings drawn from the 4 studies that met all inclusion criteria for this review.

Consider who attends clubs. Research suggests voluntary participation to STEM clubs appeals more to those students who are already interested in engineering and technology or in careers in these sectors. This highlights the importance of targeting STEM engagement activities based on the objectives of the intervention. For example, it may be more appropriate to run compulsory in-school sessions if the aim is to widen participation and interest in engineering and technology. Whereas, if the aim is to support students who are already interested in engineering and technology to further engage them, voluntary clubs may be more appropriate.

Tailor club activities to specific age groups. Learning needs, interests, and cognitive development levels of students can vary significantly across different age groups. Club activities should be tailored to the age of participants to ensure that content is engaging and relevant for them.

Engage students through practical activities. This would consist of students 'doing engineering and technology', rather than passively studying from a textbook. A club may be more impactful if the delivery includes practical, hands-on activities that explicitly demonstrate the connection between engineering or technology concepts and their real-world applications. This may be particularly helpful for continued student engagement.

Factor in the duration and timing of club activities. Sufficient time for activities is essential, particularly when these involve design and building components. Students need the time not only to engage directly with the content of the activities, but also to set up their workstations, tidy up and make progress on their projects. Sessions shorter than 40 to 50 minutes may not be enough for hands-on learning.

Additionally, ongoing student participation in extra-curricular clubs may be hindered by school holidays or periods with exams or school trips. Considering the timing and duration of club sessions may help in creating more engaging and accessible learning environments for students.

Provide comprehensive training to teachers responsible for delivering club content. Effective facilitators need to have the relevant skills to lead club activities and provide valuable support for students. Professional development courses could be a viable approach to ensure that teachers are well prepared to deliver club activities.

Engage experts in the design of club content. Experts from engineering, technology or education, including educational specialists, industry professionals and graduate students can provide valuable insight for designing club activities. Their involvement could ensure that activities are not only educationally enriching, but also closely aligned with current industry practices and trends. A collaborative effort could enhance the overall quality and relevance of the club.

Involve role models in club activities.[3] Role models could be industry professionals, academics, university students, alumni or 'near-peer' mentors. Their involvement can expose students to educational or professional STEM pathways. However, the effectiveness of their engagement with young people will likely depend on role models' backgrounds, approachability, age-appropriate communication and their willingness to share both successes and challenges from their experiences.

Providing training and support for role models may be needed to enhance their effectiveness. Additionally, allowing sufficient time for young people and role models to build relationships has the potential for more meaningful long-term impacts on students' career aspirations.

Consider including competitive elements in clubs. Introducing competitive elements into clubs has the potential to enhance engagement and foster a sense of enthusiasm among students. Competitions can offer an added layer of excitement and motivation, particularly for students with existing interest in STEM. These competitions could take various forms, such as internal contests among club participants or competitions between clubs at the same school. Another option is for club teams to work towards enrolling in and participating in national engineering or technology related competitions. The experience of working together, showcasing creativity, and tackling challenges as a team could be highly rewarding for students.

Additionally, the benefits of these competitions may extend beyond individual club members. Being involved and even winning competitions may influence broader shifts in attitudes toward engineering and technology within the school.

[3] EngineeringUK's 'Rapid Evidence Review: Interventions to increase girls' aspirations for engineering and technology careers' shares more learning from interventions that used various approaches for engaging girls, including by involving with role models. For more information on this and to download the full report, please visit our website: https://www.engineeringuk.com/research-policy/provision-outreach/rapid-evidence-reviews/

The remaining 4 studies identified by the review process didn't meet all our inclusion criteria but offer learning that could be considered by STEM engagement providers when designing activities for STEM clubs.

OVERVIEW OF FINDINGS

The 4 studies on the next 2 pages used content and approaches that may be relevant for STEM engagement providers. We've included a summary of the intervention and the findings. We also highlight the reasons for their exclusion from the core papers of this review.

The Pedal Power programme (Wang and Billington, 2016) provided a learning experience that combined physics, mechanical engineering, and maths with youth development components. Fifth grade girls (age 10 to 11) attended the programme once a week for 6 weeks, with each session lasting 4 hours. Three girls participated in interviews both before and after taking part in the programme. They also completed a Draw a Scientist Test. **Findings:** Two girls changed their perceptions of who could become an engineer from before the programme to after the programme, and they started to perceive that gender was not an issue and that girls could become scientists or engineers. One of these girls felt that after the programme she might be able to become an engineer as she knew how to fix a bike. The authors concluded that girls need more opportunities that expose them to various science and engineering experiences, particularly in out-of-school environments to broaden their understanding of science and engineering. This again highlights the need for STEM clubs.

Reasons inclusion criteria was not met: The authors didn't clearly define whether the programme was a club nor the total number of participants. The intervention may have been delivered during school holidays.

E-textiles module (Kafai and others, 2014) engaged 15 students between the ages of 16 to 18 in a 10 week-long e-textile module. Students participated in the programme twice per week in computer science lessons, each lasting 65 minutes. A total of 12 students took part in interviews both before and after participating in this module. All students had chosen to be a part of a science and technology school. **Findings:** The e-textile activities engaged students in computing concepts and broadened their perceptions of computing. Authors concluded students expanded their thinking about the relevance of computing to their personal lives, their self-concept as computer scientists, and their understanding of computing as a field.

Reason inclusion criteria was not met: The intervention took place during a computer science class.

OVERVIEW OF FINDINGS CONTINUED

Pioneers for promoting motivation to teach programming (Efecan, Sendag and Gedik, 2020). This study involved randomly assigning 54 students aged 14 to 15 to a treatment or control group[4]. For 6 weeks, all students attended a basic programming course. The treatment group watched 15-minute-long motivational presentations from real life pioneers in the field of IT and programming before taking part in the activities. The control group didn't watch any motivational presentations as part of their participation. **Findings:** From interview data, students in the treatment group said they felt motivated by the pioneer stories. Themes that emerged from the authors' analysis suggested that due to the motivational presentations, there was an increased interest in the course and motivation for programming. Additionally, students from the treatment group reported having gained an understanding of what to do to become a good programmer. The authors concluded that this intervention method can be suggested for teachers to improve motivation of students for programming.

Reasons inclusion criteria was not met: Authors didn't clarify when sessions took place (this may have been in class time).

Robotics and game design (Newton and others, 2019). This study involved 82 students between the ages of 8 to 12 who participated in a robotics and game design after-school club. Participants took part in 2-hour long sessions, delivered twice per week, for a total of 10 weeks (total of 40 hours). Beyond the club participants, 31 students from another school volunteered to take part in a STEM summer camp that covered the same robotics and game design tasks for 5 hours a day for a total of 40 hours. The evaluation consisted of conducting two surveys, one before and a second one after students participated in the intervention. The aim of the survey was to measure self-efficacy in technology and attitudes towards technology. **Findings:** Data was analysed from a total of 93 students who took part in either the club or summer camp. After participating in the 40 hours of activities, students' self-efficacy score on computer gaming increased significantly. There were no significant changes on overall attitudes toward engineering and technology. This may be due to the fact that attitudes toward engineering and technology were already positive in the survey conducted before the activities started, highlighting that volunteer participation attracted young people who likely were already interested in these fields. The authors concluded that students were able to reflect on how gaming and robotics task were relevant to careers in computer science and engineering, which suggests that these activities may be used to broaden underrepresented students' participation in these areas.

Reason inclusion criteria was not met: The authors didn't distinguish their analysis or presentation of findings by whether students had attended the after-school club or the summer camp. Therefore, findings cannot be attributed solely to participation in clubs.

[4] In programme evaluations that use randomised control trials, a 'treatment group' participates in a specific programme, while a 'control group' does not, helping researchers compare the effect of a programme.

LEARNINGS

This section offers insights from the 4 studies that didn't meet all inclusion criteria for this review, as well as from other studies screened during the review process. While these studies may not fully meet the inclusion criteria, they provide practical learning for designing engineering and technology engagement in clubs.

Consider the gender of students attending clubs. While in many cases mixed-gender groups can be effective, some research suggests that for certain age groups and activities it may be beneficial to have a targeted approach. For example, avoiding mixed gender groups may benefit the engagement of primary school-aged girls in STEM. Additionally, activities that appeal to a broader range of interests, such as e-textiles, may encourage participation from girls or students who may not otherwise be interested in computing activities. By being mindful of gender dynamics and offering diverse activities, STEM engagement has the potential to widen participation in STEM.

Consider what students may or may not know when designing club content. Linked to tailoring content to specific age groups, club activities or programmes should be designed with the awareness that participants may have different levels of knowledge or prior experience with certain skills or topics. If a club aims to teach new skills, ensure there is dedicated time and support for skill-building at the start or throughout the intervention. Tailoring content to students' existing capabilities, while also offering opportunities to develop skills, could contribute towards meeting the diverse needs of club participants.

Prioritise technical aspects in clubs. Research suggests that emphasizing technical skills, like programming, can be an important pathway to students' future success in technology-related fields. Encouraging students, particularly girls, to engage with these technical aspects can contribute towards building a strong foundation for participants' STEM education.

Clubs should involve activities that encourage problem solving and creativity. Including these kinds of activities could influence students' interest in engineering and technology. Activities such as science fairs, environmental clubs or math clubs that involve problem solving and design have been associated with greater interest in these areas. This has the potential to nurture students' own interest and capabilities.

Ensure club content does not require participants to attend all sessions. Club attendance can be erratic with not all students able to attend all sessions. This could be accommodated for by creating smaller projects that can also be completed by students per session or allowing for catch up time during sessions.

Support teachers in being prepared for their clubs. Teachers who are well prepared and enthusiastic about the subject matter can influence students' perceptions and attitudes towards engineering and technology.

Who role models are could make a difference. The extent to which students find role models relatable and relevant could influence how effective they are. Students may relate more to role models from similar backgrounds or the same local area. Additionally, encouraging role models to also share challenges and failures they faced in their experience could influence students' motivation.

Multiple or longer-term engagement in STEM activities is likely to be more effective than one-off engagements. Short-term interventions may not be enough to shift interests and aspirations in engineering and technology careers. Some students may have pre-existing perceptions of scientists and engineers that require more exposure and time to shift. It's not realistic to expect every student to be positively influenced by a club that runs for a short period of time.

Offering students many opportunities for active engagement in engineering activities over time may be more effective. This continued exposure has the potential to broaden participants' understanding and knowledge as well as interest in engineering and technology careers.

LIMITATIONS OF THE EVIDENCE

This section presents the limitations of the evidence in this review, especially for the studies that met all inclusion criteria, and how these limitations affect our ability to draw conclusions about the effectiveness of engineering and technology specific STEM clubs.

The quality of evaluation methods used to assess whether clubs were effective varied across studies. Limited robust evaluation methods makes it challenging to determine whether an intervention is meeting its goals. It can also make it harder to understand which factors, such as type of delivery or target audience, can influence the extent to which STEM clubs are effective.

Some studies didn't analyse how different aspects of club activities affected the outcomes. This limitation means that it was not always clear how club activities worked differently for certain students or situations. In turn, this makes it hard to understand what works best and for whom.

Some of the evaluations included very small numbers of participants. Having small sample sizes of students who take part in the studies makes the results less reliable and harder to apply to larger groups. It also increases the chances of making errors when interpreting findings.

Students could participate in clubs on a voluntary basis. It's very likely that those who decided to take part in club activities were already interested in or perform highly in STEM subjects. This limits the extent to which one can clearly conclude the impact resulting from the club rather than from pre-existing interest or other contextual factors.

Clear descriptions of the type and duration of club activities are limited. Additionally, there is a lack of consistency in terminology used to describe different types of clubs and club activities. This leads to ambiguity about what the intervention consists of, making it more challenging to compare across different studies and draw conclusions about the effectiveness of specific content or different modes of delivery.

Studies often collected data immediately after the club activity. There is limited exploration of long-term outcomes, with studies reviewed primarily focusing on short-term outcomes of STEM clubs. This means we've less insight into the long-term effects of club-based STEM engagement on students' educational pathways and career aspirations in engineering and technology. Understanding how participating in STEM clubs influences students over a more extended time period is crucial for assessing the lasting impact of these initiatives.

Most studies relied only on student's self-reported measures. Self-reported measures are subjective and may be influenced by various factors, such as social desirability bias, which is when participants respond in a way that makes them look favourable or how they think they should respond.

While some studies show promising findings on STEM clubs' ability to influence students' aspirations for engineering and technology careers, there are still significant gaps in evidence for this topic. This section highlights some of the gaps and provides ideas for future research and practice.

More studies that focus on engineering and technology outcomes rather than 'STEM'

Engineering and technology are distinct fields that pose unique challenges and require specific knowledge and skills. However, most papers screened and reviewed for this report used the term 'STEM' as a broad term. This makes it challenging to distinguish between the individual fields making up the acronym. Due to the lack of studies that focused on engineering and technology aspirations, many studies that didn't make a clear distinction or specific focus on our fields of interest were not included in this review.

Standardised terminology around 'clubs'

Beyond conducting more studies that specifically focus on engineering and technology, future research should also carefully consider the language and terminology used when referring to the evaluated interventions. Many of the existing studies use a range of terminology for clubs and STEM activities delivered in this context, such as programmes and workshops. STEM clubs need to be defined further and there should be consistent categories around types of STEM engagement activities that are used across the sector. More detail is needed on the duration, frequency, attendance, and what time of year the club are delivered. This attention to language is key to ensure clarity and consistency across our work, enhancing the quality and comparability of research in this field and enabling us to better understand the characteristics that make an effective STEM club.

Longitudinal studies tracking long-term outcomes of STEM clubs

None of the studies reviewed tracked students who participate in STEM clubs over a longer period of time, throughout their educational pathways and later careers. Longitudinal studies are important for understanding the long-term impact of clubs and identifying what makes a successful club for students' continued participation in engineering and technology education and pursuit of careers in these fields.

Publication of evaluations from the UK

More evaluations of STEM clubs focusing on engineering and technology outcomes from the UK should be published. None of the final studies reviewed were based in the UK, meaning we're limited in our ability to generalise the findings to the UK education system. It's likely there are specific factors related to how clubs operate in this context. Understanding barriers that schools or students may be facing in accessing or participating in clubs in the UK could inform practice to make these spaces more inclusive. Additionally, publishing these evaluations in peer reviewed journals can help to build a quality evidence base and ultimately ensure that more interventions are tailored to the needs of students in the UK education system.

Further, publishing evaluations not only helps to share best practice and lessons learned with other practitioners and researchers, but also provides evidence for policymakers and funders to support the development and scaling of effective interventions.

DATABASE SEARCH

We searched three databases of scientific research for relevant papers (ERIC, IEEE Explore, Science Direct). We conducted additional searches using Google Scholar and through the references and citations of the studies included in the review.

Inclusion criteria

To be included in the review, papers must:

- clearly state the aims, participants, and context of the intervention
- evaluate the effectiveness of the intervention using quantitative, qualitative, or mixed methods
- have a specific focus on engineering and technology outcomes, rather than science or STEM more broadly
- participants must be students aged five to 18 in education, teachers or parents
- involve an intervention that has the aim of increasing young people's interest in and aspiration for a career in engineering or technology
- be peer reviewed journal articles or reports published between 2013 and 2023 in English from OECD countries

Scoping criteria

Search results were narrowed down based on the following scoping criteria.

Scope	
Location	OECD countries
Language	English
Date	2013 onwards
Setting	School based STEM clubs, i.e. extra-curricular activities enhancing the STEM curriculum. These can include clubs delivered through different models: • Targeted / offered to students already interested in STEM • Aimed at widening participation in STEM
Outcomes measured	An increase in young people: • Aspiring to a career in engineering and technology (including computing) • Pursuing options that keep them on a career path towards engineering and computing, including subject choice at GCSE, A-level and next step after leaving compulsory education
Population	Young people in compulsory education School age (5-18)

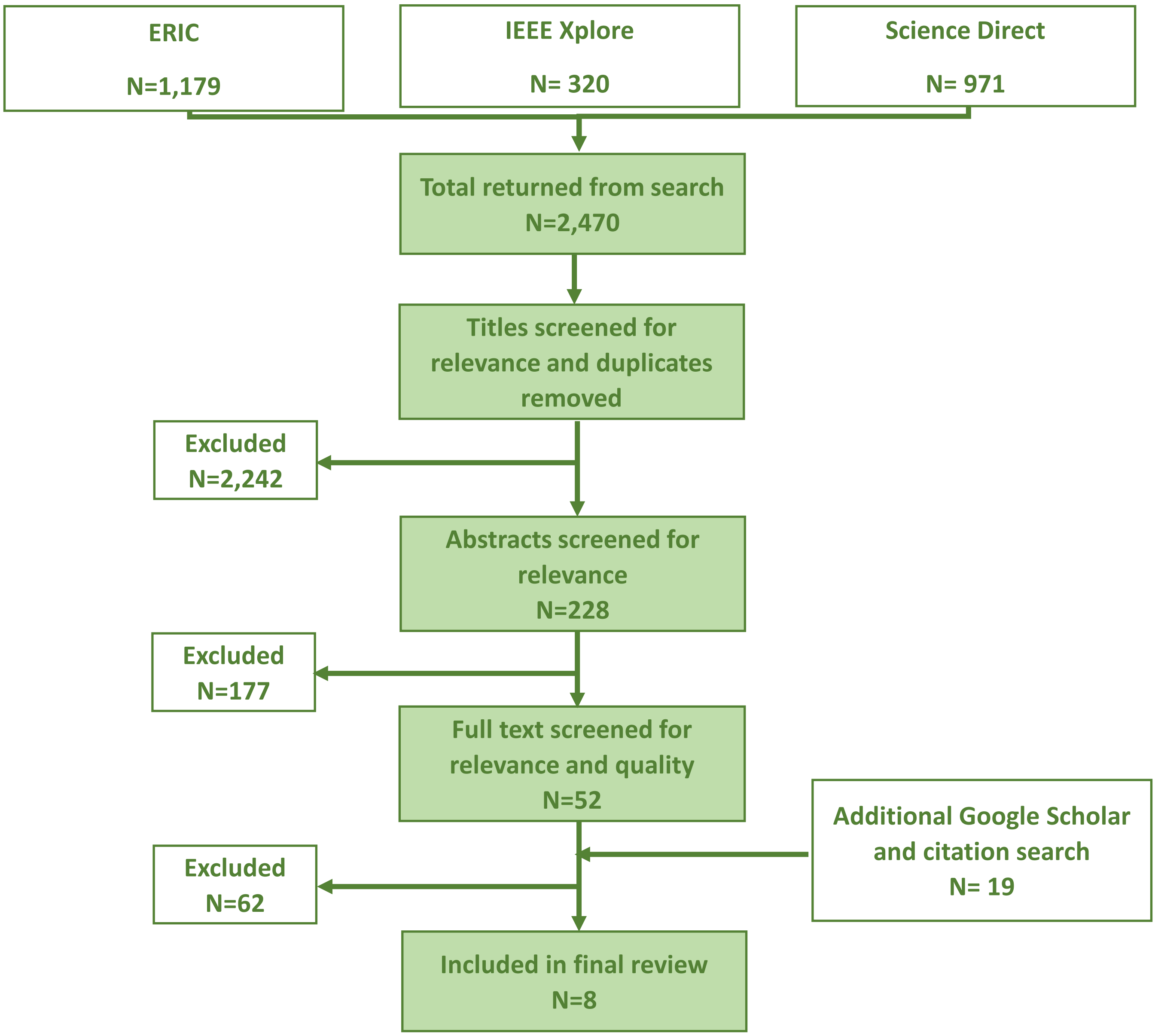
Search terms

The databases were searched using the following search terms.

Concept	Search terms
Engineering and technology	Search terms The databases were searched using the following search terms.
STEM club	(“STEM club” OR club OR science OR “after-school” OR “extra-curricular”) AND
Intervention	(Program* OR Interven* OR Workshop* OR Session* OR Club* OR Activit* OR Approach* OR Project) AND
Delivery model	(“wide* participation” OR target*) AND
Aspiration	(Aspir* OR Interest* OR Motivat* OR Choice* OR Choos* OR Selection OR Ambition) AND
Career	(Job OR Career OR Study) AND
Context	(School OR Student*)

SEARCH STRATEGY

We identified relevant papers for the evidence review using the search strategy outlined in the diagram below. After an initial screening of titles and abstracts, we excluded papers that didn't meet the inclusion criteria. Further scrutiny of the remaining papers was conducted to ensure they were relevant and of reasonable quality. Finally, we synthesised and analysed the papers that met both the inclusion and quality criteria. A summary of all the papers included in the final review can be found in Annex B.



Synthesis of final papers

The key features of the methodology and evaluation of the intervention in the final papers, as well as the key findings and discussion points, were extracted and summarised. This information was synthesised into a table, which allowed the different interventions and their outcomes to be compared. The key learnings from the discussion sections of the papers were summarised to provide insights into the practical implications of the evaluations. These insights are summarised in the 'Learnings' throughout the report.

Location

The majority of the reviewed papers on STEM clubs comes from the USA, with one study from Canada and another one from Turkey. We found no relevant UK evaluation papers published in academic journals.

Country	Number of papers
USA	6
Canada	1
Turkey	1

Type of clubs

Of the 4 studies that met the inclusion criteria, all of them were after-school clubs. Of the other 4 studies identified that didn't meet all the criteria, 2 were modules delivered during school time, one was a programme that didn't specify when it took place throughout the year, and one didn't distinguish in analysis or presentation of findings by whether students had attended the after-school club or the summer camp.

Context	Count
After-school club	4
Modules at school	2
Programme outside of school	1
After-school club and summer camp	1

Gender and age

Nearly all of the interventions were mixed gender (7), and one intervention was for girls only. The majority of the interventions were for students of secondary school age (5), with 2 aimed at primary aged students and one spanning both phases of education.

Disciplines

As shown in the table below, there was overlap between disciplines covered in the clubs/interventions.

Discipline	Count
Engineering	1
Engineering and science	1
Engineering and technology	1
STEM (broken down into engineering and technology)	1
Coding	1
Computer science	2
Computer programming	1

Authors	Country	Discipline	Simplified delivery model	Length of intervention	Gender	Phase of education	Evaluation Sample	Relevant outcomes measured	Overall findings
Blanchard and others (2015)	USA	Engineering	After-school robotics and engineering club	Autumn to Spring term	Mixed	Middle school	58	Interest in engineering	Positive - met inclusion criteria
Christensen and Tyler-Wood (2015)	USA	STEM (breaks down into engineering and technology)	After-school CSTEM club	One school year	Mixed	Middle school and high school	144	Disposition towards STEM (broken down into engineering and technology)	Positive - met inclusion criteria
Hebert and Jenson (2020)	Canada	Coding	After-school e-textiles club	12 after-school club sessions	Mixed	Secondary school	32	Interest in coding being added to the school curriculum	Mixed - met inclusion criteria
Kafai and others (2014)	USA	Computer science	E-textiles session during computer science classes	Two classes per week for 10-weeks	Mixed	Secondary school	15	Perception of computer science	Positive - didn't meet all inclusion criteria
Newton and others (2019)	USA	Engineering and technology	Robotics and game design after-school club and summer camp	After-school club: 2 hours per day for 2 days per week for 10 weeks STEM summer camp: 5 hours per day for a total of 40 contact hours	Mixed	Primary school	93	Engineering and technology	Negative - didn't meet all inclusion criteria
Stewart-Gardine and others (2013)	USA	Computer science	After-school computer games club	One session per week for five weeks	Mixed	Secondary school	35	Aspiration to study computer science	Positive - met inclusion criteria
Wang and Billington (2016)	USA	Engineering and science	Programme	One session per week for six weeks	Female	Primary school	3	Perception of engineering and influence for future careers	Positive - didn't meet all inclusion criteria
Efecan and others (2020)	Turkey	Computer programming	Programme	Six weeks	Mixed	Secondary school	54	Motivation in computer programming	Positive - didn't meet all inclusion criteria

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