



Exploring primary children's STEM attitudes and career aspirations following a 14-week iSTEM intervention

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ABSTRACT

This study addresses a critical and underexplored area in STEM education literature by exploring the influence of a teacher-led, integrated STEM (iSTEM) programme within a formal school setting. Over a 14-week period, a cohort of 16 upper-primary classrooms in Ireland participated in an iSTEM programme incorporating educational robotics, the SUPERPOWERED programme. Utilising a pre- and post-test design, the study explored the influence of the programme on children's STEM attitudes and career aspirations. The findings indicate no statistically significant change in either STEM attitudes or career aspirations. This outcome, however, is considered positive, as the children maintained pre-existing positive attitudes throughout the programme's duration. This research provides empirical evidence from a formal context, highlighting the challenges of measuring short-term attitudinal change. The results hold significant implications for future iSTEM curriculum design, emphasising the need for clarity in curriculum goals and a comprehensive understanding of the factors that shape children's long-term engagement with STEM.

1. Introduction

The global landscape increasingly relies on innovation and competitiveness driven by advancements in STEM (comprising the disciplines of Science, Technology, Engineering, and Mathematics). Consequently, fostering and retaining talent across STEM disciplines is paramount for every nation's economic and societal progress (Bahr et al., 2025). Despite the high demand for STEM talent (Turner et al., 2019), educators and policymakers worldwide are confronted with a pressing issue: an insufficient and decreasing number of students pursuing STEM subjects and careers (Kitchen et al., 2018). This critical international challenge underscores the need to identify and understand the factors that cultivate the STEM attitudes and career interests of children (Turner et al., 2019; Xu & Lastrapes, 2022), not only to nurture STEM talent, but to foster a "STEM literate society" (Vasquez et al., 2013, p 9).

STEM Education has seen widespread adoption in educational policy across the globe, with Hurley et al. (2024), highlighting the increased focus on designing STEM learning experiences for primary and second-level students over the past two decades. There is broad agreement in the literature that high quality integrated STEM learning experiences (hereafter referred to as iSTEM) can enhance children's understanding of mathematics, science, technology and engineering,

while also connecting STEM with children's experiences of local and global issues (Murphy et al., 2023). The Irish STEM Education Policy Statement emphasises the importance of providing all children with a high- quality STEM education experience that creates a positive disposition towards STEM and enables them to participate, influence and succeed in a changing world (Department of Education 2017). Quality iSTEM also has the potential to develop problem-solving skills, digital competence, communication, creativity, connectedness and empathy (Murphy et al., 2023). On the contrary, poor iSTEM teaching has been found to have a negative impact on disciplinary learning and the development of transversal skills (Murphy et al., 2023). Given the importance and potential positive impact of high-quality STEM education on societal and economic issues, greater research is needed on the influence of iSTEM education programmes upon children's attitudes towards STEM disciplines and, upon STEM as a whole. Moreover, understanding children's STEM attitudes and career interests could inform curriculum developments and professional learning needs of teachers.

Despite growing interest in iSTEM education, existing research reveals significant gaps in the evaluation of iSTEM interventions, particularly within primary school contexts (Broderick et al., 2025; Gossen & Ivey, 2023; Xia et al., 2025). Firstly, the majority of published studies are conducted in informal out-of-school settings, with a notable lack of

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research evaluating iSTEM interventions delivered by classroom teachers. This represents a particularly significant omission, given empirical evidence suggesting that children's early life and school experience of STEM can influence development of their future career interests and choices (Broderick et al., 2025; Maltese et al., 2014). Secondly, evaluations of STEM interventions are often criticised for focusing on discrete STEM disciplines, predominantly science and/or mathematics, while frequently neglecting the disciplines of technology and engineering (Burke & Lehane, 2023; Xia et al., 2025). Consequently, a paucity of research exists on the effects of STEM as an integrated discipline on children's attitudes and experiences (Xia et al., 2025). Finally, concerns have been raised regarding the methodological rigor of some iSTEM studies. Xia et al. (2025) highlight that numerous studies fail to provide sufficient detail on data collection methods or rely solely on post-intervention data, hindering a comprehensive assessment of intervention impact (e.g., English, 2022). The need for research examining both pre- and post-iSTEM intervention data is further echoed by Graffin et al. (2022). Addressing these critical and underexplored areas, the present study evaluates the influence of a 14-week formal iSTEM programme incorporating educational robotics taught by class teachers in 16 upper-primary school classrooms in Ireland. This paper provides an overview of the iSTEM programme (hereafter referred to as SUPER-POWERED) and investigates its influence on upper-primary school children's attitudes toward STEM, and their STEM career aspirations.

2. Literature review

2.1. STEM education

Over the past decade, STEM education has undergone significant changes which continues to influence how science, technology, engineering, and mathematics are taught around the world. At its core, STEM education transcends the traditional siloed teaching of these individual disciplines. It promotes the integration of content and practices across science, technology, engineering, and mathematics. By engaging children in real-world, relevant learning experiences, STEM education supports the development of transversal skills such as problem-solving, analytical reasoning, technological literacy, creativity, and collaboration (Murphy et al., 2023; Vasquez et al., 2013). There are disparities when it comes to disciplines that are integrated, or indeed not integrated, when it comes to STEM. In a recent systematic literature review, Burke and Lehane (2023) reported a dominance of studies which integrated mathematics or science with another subject-area/discipline. 'Dyad' models of integration, whereby the connection between two of the STEM disciplines, were the second most prevalent. Science and mathematics were frequently paired as dyad models of iSTEM in the literature. Indeed, STEM pedagogical frameworks also highlight incongruences when it comes to iSTEM with, for example, Moore et al. (2014) not explicitly mentioning technology. Other studies have also highlighted the omission of technology from STEM education research studies (Xia et al., 2025). Defining STEM education poses a challenge as the "discipline grouping, and the term itself, are not used uniformly in international educational policy or practice" (Freeman et al., 2014, p. 3). The terms *Integrated STEM*, *iSTEM*, and *STEM integration* are often used interchangeably in both policy and research; however, they carry nuanced distinctions in scholarly literature and educational practice. In this paper, *iSTEM* will be used and refers to instructional approaches that purposefully connect concepts and practices across two or more STEM disciplines, with the goal of deepening children's understanding and promoting transdisciplinary thinking. In this paper, science, technology, engineering and mathematics will be purposefully integrated to tackle a real-world problem.

Given the inconsistencies with the definition of STEM, it is perhaps unsurprising that similar to other countries worldwide, Ireland is grappling with STEM education policy. STEM related curricular reform has been underway since 2017. The most recent curriculum development

sees STEM education as a curricular area in primary school. In September 2025, a new Science, Technology and Engineering (STE) curriculum specification was introduced which sits alongside the mathematics curriculum specifications to form a STEM curriculum. Teachers will begin to teach this STEM curriculum from September 2026. This movement aligns with post-primary reform at Junior Cycle (lower post-primary) and Senior Cycle level (upper post-primary), both of which emphasise the importance of iSTEM aimed at developing children's understanding of the natural world while developing active citizenship, problem-solving skills, critical thinking and creativity. Looking specifically at the primary school context, this is the first time that teachers will approach science, technology, engineering and mathematics in an integrated way. It should also be noted that primary school teachers' prior experience of STEM is the teaching of science and mathematics as discrete subjects. As neither engineering nor technology were discrete subjects in the previous curriculum, these will be relatively new to many teachers. Therefore, primary schools will require support with iSTEM and require both content knowledge and pedagogical knowledge to integrate traditionally siloed subjects, in a meaningful way.

Despite a wave of STEM educational policy documents and curricular movement towards STEM (Department of Education, 2017; Evagorou et al., 2024; NCCA, 2023; Portillio-Blanco et al., 2024), it is well established that there is a decline in students pursuing STEM subjects beyond the compulsory years (Küçükaydin & Ulum, 2025; Smith & White, 2025; Smith et al., 2024). In particular, the underrepresentation of females in STEM remains a notable concern (EU STEM Coalition, 2020; European Institute for Gender Equality, 2017; UNESCO, 2020). Evidence strongly suggests that interest in STEM careers is sparked during primary school, with early engagement in STEM subjects serving as a significant predictor of future career choices (Blotnick et al., 2018). Retrospective studies with adult participants corroborate this, indicating that STEM career aspirations often begin at a young age (Dabney et al., 2013; Maltese & Tai, 2010; Venville et al., 2013). This early development of interest, coupled with self-efficacy in STEM subjects, increases the likelihood of students pursuing STEM fields in higher education and beyond (Blotnick et al., 2018; Caspi et al., 2023). Declining interest in STEM subjects has a consequential impact on both the STEM literacy of our future society, and the number of students pursuing STEM careers, resulting in a STEM graduate shortage. Lack of interest towards STEM subjects in school has been widely cited as a key factor impacting children's interest and attitudes in STEM (Hafizan et al., 2017; Riskowski et al., 2009; Subotnik et al., 2009). With specific reference to females, Goos et al. (2023) reported that female students generally report lower interest, enjoyment, and self-efficacy in mathematics when compared to their male counterparts. Similarly, a recent Irish study (Broderick et al., 2025) reported that upper-primary female students have statistically significant lower self-efficacy in technology, engineering and mathematics compared to participating males students.

A number of targeted STEM interventions have been developed in an effort to address these concerns (Bahr et al., 2025). However, these have mostly been situated in a post-primary context. This is despite evidence that children's attitudes towards subjects and careers form from ages 10 - 14 (Archer et al., 2014; Archer Ker et al., 2013; Blotnick et al., 2018; Maltese et al., 2014). Therefore, it is imperative that iSTEM interventions are both developed and evaluated in a primary school context, so that the characteristics of effective interventions are identified, and the outcomes associated with iSTEM interventions are reported.

2.2. STEM interventions

A STEM intervention is a purposeful, evidence-informed educational strategy or programme implemented to improve learning outcomes, increase engagement, and foster long-term interest in STEM disciplines among students. These interventions often incorporate inquiry-based

and experiential learning (Bybee, 2013), technology integration (both digital and design) (Margot & Kettler, 2019), teacher professional learning (Darling-Hammond et al., 2017), and collaborative partnerships (Kelley & Knowles, 2016). Research indicates a limited number of studies examining iSTEM interventions in primary school settings. A recent meta-analysis by Xia and colleagues (2025) identified only two primary-level studies out of nineteen. This scarcity of primary-level iSTEM research likely stems from the ongoing inconsistencies in defining STEM education. For instance, in Ireland the term STEM was ambiguous and undefined in Irish educational policy (Usher, 2019). This policy interpretation of STEM has changed with the STEM Education Policy 2017 stating that “there is no definitive list of STEM subjects” (Department of Education, 2017, p6), compared to the recently published STEM Education curriculum specifications for primary schools (NCCA, 2025) which are explicitly focused on the subject areas of science, technology, engineering and mathematics. This ambiguity around defining STEM education is common internationally also (English, 2016; Vasquez et al., 2013). Among the few primary-level studies adopting an iSTEM approach, Çalışkan and Şenler (2024) explored the impact of a seven-week STEM programme on 34 primary school children’s 21st-century skills, STEM attitudes, and career interests. Their findings showed statistically significant improvements in attitudes towards each STEM discipline and more positive views on STEM careers. Similarly, Tran (2018) developed a computer science-based iSTEM programme, demonstrating that early exposure to STEM activities can foster positive perceptions and attitudes towards STEM. However, there are limitations in the reliability of these studies. For instance, while Çalışkan & Şenler do provide some details of the STEM intervention, there is no access to the measurement scale utilised nor is any detail provided as to how it was adapted for this study. Similarly Tran’s STEM intervention study (2018) provided links to an online platform that was used to deliver the STEM intervention, but this was adapted, and explicit detail is needed on what, how, and why it was adapted in order to better inform research on how STEM interventions can positively impact practice. The measurement scale used by Tran was also adapted, but limited details are provided on how the original scale from Archer et al. (2020) was utilised.

Although in-school, primary-level iSTEM programmes are scarce, extensive research has examined the influence of STEM programmes upon primary school-aged children’s attitudes towards STEM and/or STEM career aspirations in after-school or outreach settings (George et al., 2020). An outreach setting is an informal educational environment outside the classroom, delivered by an external facilitator rather than the class teacher. Examples include after-school STEM programmes, summer camps, science centres, zoos, and parks (Tillinghast et al., 2020). While distinct from formal school environments, findings from these studies can illuminate the potential of STEM interventions for primary school-aged children

Studies of STEM outreach activities consistently show that children often already hold positive attitudes towards STEM before programme participation (Ching et al., 2019; Conrad et al., 2018; George et al., 2020; Johnson et al., 2025). This is particularly salient given the self-selected nature of the participants of many outreach programmes, suggesting pre-existing interest may influence initial attitude measures. For instance, George and colleagues’ (2020) study reported a significant baseline difference in STEM attitudes between intervention and control groups. Following interventions, many studies found no significant pre-to post-intervention change in attitudes which were potentially already high (Conrad et al., 2018; George et al., 2020; Katz et al., 2024).

Nevertheless, exceptions exist: Ching et al. (2019) observed significantly more positive attitudes towards mathematics following an after-school robotics programme. Conversely, Johnson et al. (2025) reported significantly less positive attitudes towards science among girls in two Irish primary schools after a STEM intervention. Notably, neither study reported significant changes for other STEM disciplines (Ching et al., 2019; Johnson et al., 2025). Given the consistently high baseline attitudes, this lack of change is often interpreted as a positive outcome in

much of the existing research. However, this stability in attitudes, as measured by instruments like the S-STEM scale (used in the present study and further discussed in Methods), has been attributed to several methodological and contextual factors. These include the short-term nature of many interventions (e.g., one week), which may be insufficient to produce measurable attitude shifts (Conrad et al., 2018), and the pedagogical approaches (such as hands-on investigations, collaborative group work and inquiry) employed by teachers (Johnson et al., 2025). Indeed, studies in other curricular areas such as geography have also found direct connections between pedagogical approaches (including collaborative group work, inquiry and fieldwork) and children’s positive attitudes, both in the Irish context (Usher, 2023) and further afield in Germany, UK and Czechia (Kubiak et al., 2012; Schubert, 2021).

Problem-based learning (PBL) has been identified as a key pedagogical approach for effective STEM education (Smith et al., 2022; Wang, 2021 and Corrigan, 2020). Authentic problems set in a real-world context encourage subject integration as different kinds of knowledge, skills and abilities are needed to address them (Smith et al., 2022). Furthermore, PBL is child-led with the teacher as facilitator whereby children are more motivated to take ownership of their learning (Suciana et al., 2023). The engineering design process has also been identified as a key pedagogical approach to STEM education. Marulcu and Barnett (2016) highlight that the engineering design process encourages children to think and talk through how to solve problems and noted the use of engineering design process together with problem-based learning as a way of positioning children as scientists or engineers themselves in how they approach, understand and address a real-world problems in a systematic manner.

Regarding attitudes towards STEM, Conrad et al. (2018) found no gender differences in pre- or post-intervention attitudes or career aspirations, though this was a very small-scale study ($n = 18$). In contrast, a larger study by Wiebe et al. (2018) concluded that gender significantly impacted male and female interest in STEM careers. Several studies focused exclusively on one gender (e.g., females; George et al., 2020; Johnson et al., 2025), precluding comparisons between boys and girls. When children’s STEM career aspirations were explored, the impact of interventions often appeared minimal. Conrad et al. (2018) observed similar career aspirations both before and after a summer camp, with consistent high interest in fields like engineering, computer science, and applied science (e.g. energy), and lower interest in areas like environmental or veterinary work. Wiebe et al. (2018) reported gender differences in STEM career aspirations, with males showing more interest in core STEM (e.g., physics, mathematics, engineering, computer science) and females in biology and medicine. They concluded that STEM attitudes and career aspirations begin forming at the elementary school level. Most studies discussed above are relatively small-scale quantitative studies, with the exception of Wiebe et al. (2018). While Wiebe et al. (2018) included a substantial sample of 6254 primary school children, this data was part of a larger sample and reported holistically, rather than disaggregated by school level (e.g., elementary, middle, and high school student responses were combined). Although inferences can be drawn from the reported regression models, a deeper interrogation of the elementary school data by the authors would have provided more pertinent findings for this current study.

A growing body of research highlights the potential of educational robotics to enhance STEM interventions by fostering student engagement and promoting key skill development. Anwar et al. (2019)’s systematic literature review reported that integrating robotics into education can enhance STEM interventions by increasing children’s interest and participation in STEM fields (Kim et al., 2015; Mohr-Schroeder et al., 2014), supporting the development of critical thinking and problem-solving abilities (Okita, 2014), developing computational thinking (Grover & Pea, 2013; Menekse, 2015), and improving domain-specific knowledge in mathematics (Alfieri et al., 2015; George et al., 2020; Martinez Ortiz, 2011), physics (Williams et al., 2007), and scientific literacy (George et al., 2020; Sullivan, 2008). A recent

meta-analysis of STEM interventions utilizing educational robotics ($n = 28$) further highlights the significant positive effect of educational robotics on student knowledge, applied skills, and learning attitude in STEM compared with non-robotic-supported STEM education (Bai & Tian, 2025). Moreover, robotics-based activities cultivate essential engineering skills. Verner and Ahlgren (2004) showed students developed systems thinking, collaborative problem-solving, and teamwork through designing, constructing, and operating robots. Petre and Price (2004) observed similar findings, noting that robotics competitions supported students in learning engineering design processes, such as identifying and communicating solutions. Nevertheless, the novelty effect cannot be entirely ruled out, as following their meta-analysis, Bai and Tian highlight the short-term nature (i.e., less than one month) of most studies examined (2025).

Echoing the broader trend in STEM intervention research, most robotics studies are situated in outreach contexts. Only one identified study focused on primary school-aged children within school-based contexts. Alfieri and colleagues (2015) examined a robot-mathematics intervention with 112 upper-primary school children, reporting positive impacts on children's interest in robotics, valuing of mathematics, and proportional reasoning skills. A recent study of primary school-aged children ($n = 37$) who participated in an extra-curricular STEM club involving educational robotics reported that the intervention significantly enhanced students' interest and abilities in STEM, while also increasing their willingness to pursue STEM careers (Zhang et al., 2025). While in an informal STEM context, Conrad et al. (2018) found that a short-term robotics camp increased children's interest and engagement in STEM, with many participants expressing heightened motivation for STEM careers. Both studies underscore the value of immersive, hands-on learning experiences and mentorship in shaping positive STEM identities. However, they also reveal disciplinary asymmetries in impact. This suggests that while informal and extracurricular STEM programmes can boost children's engagement and confidence, their effects may be uneven across domains and thus require a design with greater disciplinary balance. Building on this, Bai and Tian's findings suggest that while educational robotics have been associated with an overall positive impact in STEM interventions, context is critical with results varying depending on educational setting and implementation factors. These findings indicate a need for more rigorous and nuanced investigations to understand under what conditions, and for which learners, educational robotics is most effective. This is echoed by Chiu and Li (2023) who have called for extensive research to examine the potential of robotics to advance STEM education successfully.

In summary, there is limited published research examining school-led, long-term STEM support programmes and the associated impact on attitudes toward STEM and the STEM career interests of primary school children. This scant representation of primary-level studies underscores a notable gap in the research landscape. Bahr et al. (2025) also reported that school-integrated programmes are considered to have more potential to increase children's interest in STEM due to short-term effects on constructs such as interest. This emphasises the necessity for further investigation to elucidate the influence of formal STEM experiences on primary-level children.

2.3. Research question

In light of the discussed importance of iSTEM education, this study addresses a critical and underexplored area in the research literature by examining a primary-level iSTEM programme (i.e., SUPERPOWERED) facilitated by classroom teachers during normal instruction time. This long-term programme (14 weeks) specifically integrated science, technology, engineering, and mathematics through the use of educational robotics, and collected data pre- and post-SUPERPOWERED. The aim of this study was to examine the influence of participating in SUPERPOWERED upon upper-primary school children's attitudes towards STEM, and upon their STEM career aspirations. The study addressed the

following research questions:

1. Does participation in the iSTEM programme influence children's attitudes towards Science, Technology, Engineering, and Mathematics (STEM) disciplines?
2. Does the iSTEM programme's influence on children's attitudes towards STEM differ significantly by gender?
3. Does participation in the iSTEM programme influence children's interest in STEM career pathways?

3. Current study

3.1. FIRST LEGO league SUPERPOWERED

The FIRST LEGO League (FLL) is a global iSTEM programme aiming to foster critical thinking, coding, design skills, and teamwork (FIRST, 2025). Each FLL season focuses on a real-world problem (e.g., sustainable and renewable energy), encouraging participants to use technology to solve complex authentic challenges. FLL comprises divisions for three different age ranges; Explore, the middle division, targets upper-primary children and is the specific focus of this study. Explore introduces engineering fundamentals as children investigate real-world problems, learn to design, and code robotic prototypes using LEGO Education sets (e.g., WeDo 2.0 or SPIKE Essential). Internationally, Explore is typically run as an extracurricular programme in after-school clubs and communities (Graffin et al., 2022; Melchior et al., 2018). In Ireland, a guide was prepared to support teachers in adopting FLL Explore as a classroom project. The *Teacher Guide for Ireland* integrated the FLL Explore programme with the Irish Primary School Curriculum, and STEM education in particular (see Butler et al., 2022, 2023, 2024). Developed by an interdisciplinary team of academics, with input from primary school teachers and STEM coordinators, the Teacher Guide aimed to assist teachers to engage children in learning and connect science, technology, engineering and mathematics through real-life authentic contexts. This study focuses upon the FLL SUPERPOWERED season supported by the Teacher Guide for Ireland.

SUPERPOWERED immersed children in the real-world problem of Energy, guiding them to investigate how energy is generated, stored, and used. Structured into 14 one-hour sessions, the programme was designed to progressively build the conceptual understanding necessary for project participation. The first four sessions developed children's understanding of different sources of energy and how energy is transported and used in their everyday lives. Children conducted science investigations as part of these lessons: children conducted research on different types of renewable and non-renewable energy sources; they investigated the best place on school grounds to locate a wind turbine; children conducted an energy audit to investigate how much they use daily and identified how they could reduce energy consumption. Children then transitioned into the programmable robotics phase. Here, children constructed and coded LEGO robots thematically linked to energy. For instance, children built and programmed a wind turbine to demonstrate the journey of energy, thereby applying the conceptual understanding and skills developed in Sessions 1–4 to their robotic creations. This phase also fostered computational thinking skills, including the use of if/then statements with sensors. LEGO Education set software supported these builds, providing an intuitive interface and scaffolding their computational thinking. Table 1 provides an overview of SUPERPOWERED, and the full SUPERPOWERED Teacher Guide for Ireland is available online (Butler et al., 2022).

SUPERPOWERED is deeply rooted in two complementary pedagogical frameworks: Problem-Based Learning (PBL) and the Engineering Design Process. PBL, an instructional design, engages learners in small groups to collaboratively seek solutions to realistic, open-ended problems within specific domains. In this approach, children independently gather information and resources while teachers provide indirect guidance (Wang, 2021). The FLL Explore exemplifies a PBL activity by

Table 1
SUPERPOWERED overview.

Session	Session topics/activities
1	Energy Journeys Learners will consider energy in their everyday lives, including what energy is, where it comes from and how it travels.
2	Renewable and Non-renewable Energy Sources Learners will identify and explore the advantages and disadvantages of renewable and non-renewable sources of energy.
3	Investigating Wind and Wind Energy Learners will examine wind as a source of energy. They will develop an understanding of how wind is formed and consider the factors that impact the location of a wind farm.
4	Examining How Wind Turbines Work Learners will examine how wind turbines function. Learners will build the LEGO wind turbine and explore how it works.
5	Energy Storage Learners will explore how energy is stored and distributed.
6	Power On Learners will be introduced to the LEGO Education Set (SPIKE Essential or WeDo 2.0). Learners will be introduced to a simple block-based coding language. Learners will build and code a motorised LEGO robot.
7	Motorise Model (Safety and Sensors) Learners will be introduced to sensors and their associated coding blocks. Learners will build and code a LEGO robot which uses/ responds to a sensor. Learners will begin to consider how sensors could enhance the safety of their LEGO builds
8	Electric car (Energy Consumption) Learners will build and code a motorised LEGO vehicle and then adapt it into an 'Electric Car' in order to explore an example of energy consumption.
9 - 10	Team Model In teams, learners will create a Team Model that shows 'Better ways to source, store, and use energy'. Their Team Model can address a specific part of the energy journey, or all of it.
11 - 12	Team Poster In teams, learners will plan, design and create their Team Poster.
13	Let's Share In teams, learners will plan for how they will share their Team Model and Team Poster at the final event.
14	Let's Reflect Learners will reflect upon the SUPERPOWERED lessons, their Team Model and Poster, and their understanding of energy journeys.

featuring (a) ill-structured problems, (b) a learner-centred method, (c) teachers as facilitators, and (d) authentic tasks (Suciana et al., 2023). Complementing PBL, the Engineering Design Process provides a structured approach for problem-solving that aligns with the programme's emphasis on cultivating design thinking—a critical skill for all learners (Li et al., 2019). Through the Engineering Design Process, children are encouraged to adopt an engineering mindset, applying scientific, technological, and mathematical skills to investigate real-world problems and propose creative solutions. The Engineering Design Process typically involves four key stages: 1) exploring a problem and developing potential solutions; 2) testing these solutions; 3) refining and retesting solutions based on findings; and 4) sharing learned insights with others. While Fig. 1 illustrates this as a cyclical process, children often navigate through these stages iteratively, revisiting them multiple times throughout the programme as they refine their work.

3.2. Procedures

SUPERPOWERED was taught by class teachers in 14 classrooms over a 14-week period during the 2023 academic school year. Although participating teachers volunteered, they did not necessarily have specialised training or interest in STEM beyond the pedagogical science and mathematics modules completed as part of their primary teaching degree. To prepare for the programme, teachers engaged with a 2 h, out-of-



Fig. 1. Engineer design process (from Butler et al., 2022, p.9).

school professional learning (PL) session immediately prior to their engagement with the project. This PL was designed to develop their self-efficacy and pedagogical understanding of engineering and technology. Specifically, the session allowed teachers to participate in the learning activities from the SUPERPOWERED teacher guide, thereby experiencing the problem-based and inquiry pedagogical approach underpinning the curriculum while simultaneously developing the necessary conceptual understanding to teach the programme effectively. Furthermore, the teacher guide provided explicit detail in terms of teacher background knowledge, step-by-step programming instructions, key questions to promote discussion, explicit learning outcomes, and all resources required to teach the programme.

4. Methods

To investigate the influence of SUPERPOWERED on primary school children, this study employed a pre- and post-test design. A survey instrument was administered to participating children by their class teacher before and after their engagement with SUPERPOWERED. This methodology allowed for the assessment of changes in children's attitudes towards STEM and their STEM career aspirations, directly addressing the study's research questions.

4.1. Participants

An initial total of 404 upper-primary-level children from 14 Irish primary-level classrooms participated in this research. Classes were identified through convenience sampling, where the schools were known to the researchers. Ethical approval was sought and received in advance of the study. Class teachers facilitated data collection by explaining and distributing the survey instrument at the beginning and end of the intervention. Children's participation in the study was voluntary and anonymous. While the questionnaires did have a code to identify which school the data set was from, the children were not given a unique identifier, and the questionnaire was not tracked pre- and post-intervention. After the removal of incomplete surveys, a final sample of 251 children participated, representing a 62 % completion rate. These children were distributed across 4th class (ages 9–10, $n = 66$), 5th class (ages 10–11, $n = 126$), and 6th class (ages 11–12, $n = 59$). The sample

consisted of $n = 126$ male (50.2 %) and $n = 121$ female (48.2 %) participants. A further $n = 4$ participants (1.6 %) chose not to disclose their gender. The small sample size of this group made meaningful statistical analysis and comparison with the larger male and female groups unfeasible and were therefore excluded from gender-related analyses

4.2. Data collection

Data on children's attitudes towards STEM (conceptualised as self-efficacy and confidence) and their STEM career aspirations were collected using the Student Attitudes towards STEM (S-STEM) survey instrument, administered before and after SUPERPOWERED. The S-STEM instrument, developed and validated by the [Friday Institute for Educational Innovation \(2014\)](#), is a robust measure. It has consistently demonstrated high reliability (Cronbach's alpha 0.89–.92) across various studies ([Broderick et al., 2025](#); [Conrad et al., 2018](#); [George et al., 2020](#); [Unfried et al., 2015](#); [Unfried, Faber et al., 2014](#); [Wiebe et al., 2018](#)). The survey comprises three subscales measuring children's confidence and self-efficacy in specific STEM disciplines: mathematics (8 items), science (9 items), and engineering and technology (9 items). These items utilise a five-point Likert-type scale, ranging from 'strongly disagree' to 'strongly agree'. Each subscale included both positively and negatively worded items to mitigate response bias and encourage more thoughtful engagement from participants. A fourth subscale assesses children's interest in future STEM-related careers, employing a four-point Likert-type scale from 'Not at all Interested' to 'Somewhat Interested', to 'Interested' to 'Very Interested.' Example items from each subscale are presented in [Table 2](#).

4.3. Data analysis

All pre- and post-test data were coded, cleaned, and prepared for analysis using SPSS Version 29. This preparation included re-coding negatively worded items. A composite variable, 'overall attitude toward STEM', was then computed for both pre- and post-test by averaging the three disciplinary subscales. The internal consistency of the S-STEM instrument was assessed using Cronbach's alpha coefficients (see [Table 3](#)), which confirmed strong internal consistency pre- and post-test. Descriptive statistics were first calculated to provide a comprehensive overview of the sample's characteristics and key variables. Subsequently, inferential statistics were employed to examine differences between pre- and post-test data. Tests for normality revealed that the data were not normally distributed. Consequently, Wilcoxon signed-rank tests were utilised to determine significant differences between pre- and post-test scores within each S-STEM subscale. Additionally, gender-based differences were explored using Mann-Whitney U tests.

5. Findings

The aim of this study was to examine the influence of participating in SUPERPOWERED upon upper-primary school children's attitudes towards STEM, and upon their STEM career aspirations. Addressing RQ1, a series of Wilcoxon Signed-Rank tests were conducted on pre- and post-test responses to investigate the influence of SUPERPOWERED on children's attitudes toward STEM. As presented in [Table 4](#), children's

Table 2
Example items of S-STEM instrument.

Scale	Example Item
Mathematics	I can get good results or scores in maths tests.
Science	I feel good about myself when I do Science
Engineering and Technology	I am interested in what makes machines work.
Interest in future STEM-related careers	Computer Science: People write instructions to design computer games and other programmes. They also fix and improve computers for other people.

Table 3
Cronbach's alphas for S-STEM subscales.

Scale	Cronbach's α	No. of items
<i>Pre-test</i>		
Mathematics	0.900	8
Science	0.867	9
Engineering and Technology	0.833	9
Overall	0.896	26
<i>Post-test</i>		
Mathematics	0.906	8
Science	0.881	9
Engineering and Technology	0.865	9
Overall	0.913	26

Table 4
Results of Wilcoxon signed-rank tests.

Scale	Pre-test Median	post-test Median	Wilcoxon signed-rank test		
			z	p	r Effect size
Overall STEM	3.52	3.45	−1.19	.233	0.0835
Mathematics	3.75	3.75	−1.17	.242	0.0768
Science	3.22	3.11	−0.80	.422	0.0515
Engineering and Technology	3.56	3.56	−1.17	.243	0.0770

attitudes toward STEM (overall and by discipline) did not change significantly between the two testing periods. The median scores for overall STEM attitude remained stable at 3.52 pre-test and 3.45 post-test, indicating that children held consistently positive attitudes throughout SUPERPOWERED. This same pattern of stability was observed across the disciplinary subscales of Mathematics, Science, and Engineering and Technology. It is worth noting that, while it was not statistically significant, science was the only disciplinary subscale where children self-reported a lower median following the intervention.

Pertaining to RQ2, Mann-Whitney U tests were conducted to explore potential differences in overall and disciplinary STEM attitudes between males ($n = 126$) and females ($n = 121$) pre- and post-test. No significant gender-based differences were found for attitudes toward Mathematics, Science, or overall STEM attitude. However, attitudes towards engineering and technology pre-test were statistically significantly higher for males (Mdn = 3.67) than females (Mdn = 3.44), $U = 6047.5$, $z = -2.048$, $p = .041$. This statistically significant difference remained post-test, with males (Mdn = 3.67) reporting more positive attitudes toward engineering and technology than females (Mdn = 3.44), $U = 5656.5$, $z = -2.378$, $p = .017$. The post-test results show a greater statistically significant difference because its p-value is lower.

Next, a series of Wilcoxon Signed-Rank Tests were conducted to investigate pre- to post-test changes in overall and disciplinary STEM attitudes, analysed by gender. See [Table 5](#). No statistically significant changes were observed in attitudes towards overall STEM, Mathematics,

Table 5
Results of Wilcoxon signed-rank tests for male ($n = 126$) and female ($n = 121$).

Scale	Gender	Pre-test Median	Post-test Median	Wilcoxon signed-rank test (post-pre)		
				z	p	r Effect size
Overall STEM	M	3.55	3.49	−1.01	.314	−0.10
	F	3.44	3.37	−0.81	.418	−0.08
Mathematics	M	3.75	3.75	−1.17	.242	−0.11
	F	3.75	3.75	−0.92	.358	−0.09
Science	M	3.22	3.11	−1.55	.122	−0.14
	F	3.11	3.22	.70	.698	0.07
Engineering and Technology	M	3.67	3.67	−0.39	.698	−0.04
	F	3.44	3.44	−1.44	.149	−0.14

Science, or Engineering and Technology for either boys or girls between the two testing periods. Examination of the descriptive statistics in Table 5 revealed that Mathematics was the only subscale where boys and girls self-reported identical median attitudes; with girls otherwise generally reporting lower median attitudes toward STEM subscales compared to males. Furthermore, while not statistically significant, it was observed that female attitudes towards Science showed the only positive median change following SUPERPOWERED. Whereas male attitudes towards Science showed a negative median change.

Addressing RQ3, the influence of participation in SUPERPOWERED on children's interest in STEM career pathways was initially examined using descriptive analysis. Most career interests remained stable, with a median score of 2 ("somewhat interested") both pre- and post-test (See Table 6). Notably, gender differences were observed in several career interests. Females reported higher median interest in Biology (Mdn = 3 vs. 2 for males) and Veterinary (Mdn = 2.5 post-test), while males reported higher median interest in Computer Science and Engineering (both Mdn = 3 vs. 2 for females). While median analysis indicated overall stability, examination of mean scores revealed that Engineering was the only career that showed an overall mean increase in interest post-test, a trend observed for both male and female pupils. A small mean increase in interest in Biology was also noted for females following the intervention.

Drawing from the descriptive analysis, which highlighted notable shifts in central tendency for specific careers, Veterinary, Energy/Electricity, and Engineering were selected for further examination using Wilcoxon signed-rank tests. The increase in female ($n = 118$) interest in Veterinary was not found to be statistically significant (before Mdn = 2, after Mdn = 2.5, $z = 0.405$, $p = .685$, $r = 0.037$). The decrease in male ($n = 116$) interest in Energy/Electricity was also not found to be

statistically significant (before Mdn = 3, after Mdn = 2.5, $z = -1.424$, $p = .154$, $r = -0.132$). Finally, for Engineering, despite the observed mean increase in interest, there was no statistically significant change in median Engineering interest (before Mdn = 3, after Mdn = 3, $z = -0.889$, $p = .374$, $r = -0.058$).

6. Discussion

This study examined the influence of participating in the SUPERPOWERED iSTEM programme upon upper-primary school children's attitudes towards STEM, and upon their STEM career aspirations. A primary finding was that participation in the programme had no significant effect on children's attitudes toward the STEM disciplines, or STEM as a whole. This result aligns with findings from previous STEM intervention studies (Conrad et al., 2018; George et al., 2020; Katz et al., 2024). It is important to note that all of these studies were conducted in outreach settings, whereas this study was conducted in a formal school context. Median scores above 3 (out of 5) were reported across all STEM disciplines, and for overall attitude toward STEM, both before and after SUPERPOWERED. This is slightly lower than the pre-intervention median score of 4 for overall attitude toward STEM reported by Johnson et al. (2025), who used the same survey instrument with Irish primary school children. Yet, Johnson et al. reported a decrease in overall attitudes (median = 3.50) following their outreach intervention; although this decrease was also not statistically significant. It is possible that this difference in post-test attitudes could be explained by differences in programme design (duration; the current study was conducted in formal school settings whereas Johnson et al.'s was an outreach intervention).

Following SUPERPOWERED, Science was the only discipline that saw a decrease in attitudes, yet this was not statistically significant. Previous studies utilising the same scale reported similar results (Broderick et al., 2025; Johnson et al., 2025). A notable difference is the statistically significant decrease in female attitudes towards science post-intervention reported by Johnson et al. (2025). The more varied sample of this study facilitated further analysis, and reported gender-based differences in attitudes towards Science. Females reported a positive median increase in attitude toward Science following SUPERPOWERED, whereas males reported a negative median decrease in attitude towards Science.

Denner et al., 2025 recently published report on Irish 4th-class children's (aged 8–9) attitudes towards science and mathematics using TIMSS data from 2015, 2019, and 2023 (Denner et al., 2025) enables a comparison of findings between national data and the present study. Their report highlights a steady decline in children's liking of science/mathematics and confidence in science/mathematics from 2015 to 2018 and then 2023. Acknowledging that this decline is reported every four years and the current study was carried out over an academic school term, a stable pre- and post-score could still be considered a positive outcome given that SUPERPOWERED maintained the children's positive attitudes. This positive outcome is further emphasised by the fact that the participants in this study are in the age 10–14 zone of declining attitudes towards STEM (Archer et al., 2020). Taken together, these findings suggest iSTEM programmes like SUPERPOWERED could maintain, or improve, the attitudes of children in an age zone that is prone to declining attitudes towards STEM. Additional research is warranted to further determine whether similar iSTEM programmes for primary-level contexts could contribute to addressing the concerns relating to declining interest in STEM disciplines, and the STEM graduate shortage.

Attitudes towards the majority of STEM careers remained stable following SUPERPOWERED, with the median score of 2 (out of 4) indicating that the children were somewhat interested in STEM careers before and after SUPERPOWERED. Two exceptions were the careers of computer science and engineering which both returned overall median scores of 3 pre- and post-SUPERPOWERED. There were also some gender differences reported, with females indicating a higher level of

Table 6
Children's interest in future STEM-related careers before and after intervention.

Career	Gender	Pre-test		Post-test	
		Mean	Median	Mean	Median
Physics		2.40	2.0	2.29	2.0
	M	2.42	2.0	2.28	2.0
	F	2.34	2.0	2.26	2.0
Environmental work		2.39	2.0	2.32	2.0
	M	2.38	2.0	2.25	2.0
	F	2.36	2.0	2.35	2.0
Biology		2.58	2.0	2.47	2.0
	M	2.53	2.0	2.31	2.0
	F	2.61	3.0	2.62	3.0
Veterinary		2.50	2.0	2.38	2.0
	M	2.48	2.0	2.25	2.0
	F	2.50	2.0	2.50	2.5
Mathematics		2.34	2.0	2.29	2.0
	M	2.36	2.0	2.36	2.0
	F	2.29	2.0	2.19	2.0
Medicine		2.39	2.0	2.29	2.0
	M	2.40	2.0	2.22	2.0
	F	2.38	2.0	2.35	2.0
Earth science		2.39	2.0	2.29	2.0
	M	2.49	2.0	2.22	2.0
	F	2.34	2.0	2.32	2.0
Computer science		2.65	3.0	2.57	3.0
	M	2.78	3.0	2.72	3.0
	F	2.53	2.0	2.38	2.0
Medical science		2.29	2.0	2.17	2.0
	M	2.28	2.0	2.12	2.0
	F	2.31	2.0	2.20	2.0
Chemistry		2.39	2.0	2.35	2.0
	M	2.38	2.0	2.29	2.0
	F	2.39	2.0	2.39	2.0
Energy/Electricity		2.41	2.0	2.35	2.0
	M	2.56	3.0	2.43	2.5
	F	2.24	2.0	2.24	2.0
Engineering		2.77	3.0	2.83	3.0
	M	2.91	3.0	2.96	3.0
	F	2.62	3.0	2.67	3.0

interest in biology (median = 3) compared to males (median = 2), and males indicating a higher level of interest in computer science (median = 3) compared to females (median = 2). These median scores were consistent pre- and post-SUPERPOWERED and are therefore indicative of an overall trend in interest in careers rather than as a result of SUPERPOWERED. Other non-statistically significant changes were reported pre- and post-SUPERPOWERED; for instance, female interest in veterinary increased while male interest in electricity/energy decreased from a median of 2.5 pre-intervention to a median of 2 post-SUPERPOWERED. Males reported greater interest in core STEM careers (energy, computer science), while females were more interested in biology, these findings are broadly consistent with the gender differences reported by Weib et al. (2018). It is difficult to explain how SUPERPOWERED could have influenced these gender differences as there were no explicit or implicit connections made to veterinary work. Moreover, given the focus of SUPERPOWERED on an investigation of how energy is sourced, distributed, and used, a decline in interest in an energy/electricity related career is striking. Perhaps, the content explored in SUPERPOWERED provided the children with a more realistic understanding of Energy/Electricity, which caused this decline.

The limited interest reported in this study for most STEM careers is consistent with both national (Broderick et al., 2025) and international literature (Archer et al., 2020). Despite research indicating that between 10 and 14 years is a crucial period in which children make up their minds about interest in STEM and STEM careers (Archer et al., 2020; Bennett & Hogarth 2009; Griethuijsen et al. 2015; Osborne et al. 2003), research also indicates that interest in STEM post-compulsory schooling and concurrently in STEM careers is slow to change despite investment of time and resources towards STEM (Archer et al., 2020). Developing positive attitudes towards STEM disciplines and STEM as a whole does not correlate directly with increased interest in STEM careers (Archer et al., 2013, 2020). Archer et al. (2020) concluded that efforts to broaden children's interest in STEM careers need to begin at primary school. SUPERPOWERED did not explicitly focus on the development of children's understanding of STEM careers, nor did it explicitly link SUPERPOWERED to the relevant careers, for example, Energy/Electricity. If anything, the findings from this study highlight the need for more explicit connections to STEM careers throughout STEM interventions, to accurately assess the influence, if any, of iSTEM interventions on children's interest in STEM careers. McMaster et al.'s (2025) Australian study is an example of this. They explicitly included a connection to STEM careers in their STEM intervention, MindSET-do, and results indicated that the primary children's interest in STEM-related careers increased significantly following the intervention. This study implies that engagement in an iSTEM programme may not be enough to influence children's interest in, or awareness of, STEM careers.

While the S-STEM scale has been validated through its use in other studies in primary-level contexts, it is not without its limitations and findings must be interpreted with this in mind. Most significantly, STEM was integrated throughout SUPERPOWERED, whereas the S-STEM scale measured attitudes toward discrete STEM disciplines. This iSTEM approach may have confounded the results because teachers didn't explicitly label learning activities by subject discipline (e.g., "science" or "mathematics"). It is possible that children didn't recognise which content belonged to which discipline. The composite variable "overall attitude toward STEM" was created in an attempt to overcome this challenge, but as it was derived from an average of the disciplinary subscales, it did not fully account for the integration of STEM conceptually. This made it difficult to accurately assess attitudinal changes at the disciplinary level. The scale also problematically combines Technology and Engineering into a single construct, which may reinforce the research priority given to science and mathematics. In terms of technology, the S-STEM survey does not differentiate between digital technology or design technology. In fact, the questions in the sub-scale do not really address either design or digital technology, with a stronger

focus on engineering-based questions. Additionally, the scale may not have been sensitive enough to detect attitudinal changes over a 14-week period, a finding consistent with other research using the same scale in shorter interventions (Conrad et al., 2018; Johnson et al., 2025). Future studies should consider a mixed-methods approach to overcome this limitation. When a qualitative element was incorporated in similar studies, findings indicated that interventions positively influenced children's STEM self-efficacy (George et al., 2020), STEM content learning, and their development of perseverance, problem-solving, and teamwork skills (Ching et al., 2019; George et al., 2020). Mixed methods, including qualitative interviews with the class teachers, would also provide insight into how they themselves approached SUPERPOWERED in their teaching, in that these teachers volunteered to teach the programme and so they may have cultivated a positive attitude within their classroom from the outset. Finally, the career aspirations component of the scale was limited by its brief descriptions and the fact that many careers did not align with the content of SUPERPOWERED. For future research, it would be beneficial to select careers with an explicit connection to the iSTEM programme, using more detailed descriptions to improve their relevance and accuracy or potentially inviting relevant professionals into the classroom to speak to the children and enhance the authentic, real-world context of the learning. Indeed, Deehan et al. (2024) highlight the importance of external experts to both teachers and children in STEM education.

7. Concluding remarks

This study addressed several significant underexplored areas in the existing literature on iSTEM education. By evaluating a 14-week iSTEM programme delivered by classroom teachers in a formal upper-primary school setting in Ireland, our research provides a novel contribution, moving beyond the prevalent focus in the research literature on informal, out-of-school contexts. Furthermore, by focusing on iSTEM rather than as a collection of discrete subject disciplines, this study directly responds to calls for more holistic evaluations of STEM interventions, including whether or not conceptual development and improvement in STEM literacy were achieved. Finally, our use of both pre- and post-test data enhances the methodological rigor, offering a more comprehensive view of the SUPERPOWERED programme's influence. Our findings reveal that while SUPERPOWERED did not elicit a statistically significant change in children's attitudes toward STEM, this outcome should be interpreted with a nuanced perspective. The participating children began the programme with an already positive disposition toward STEM and were somewhat interested in STEM-related careers. This aligns with and reinforces prior research, such as that by Meschede et al. (2022), suggesting that positive early attitudes and interests are likely to be sustained. This finding is particularly salient given the formal, classroom-based nature of the intervention, distinguishing it from studies conducted in informal and outreach environments. While SUPERPOWERED ran for 14-weeks, a key consideration for future research is whether this duration was adequate to elicit a measurable shift in attitudes toward STEM. The finding of no significant change aligns with STEM outreach initiatives, including those that are considerably shorter (e.g., two weeks). Factors, other than duration, such as the programme's content, use of educational robotics, pedagogical approach, or the STEM leadership in schools (Geiger et al., 2023), may play a more significant role in shaping attitudes. Deehan et al. (2024) highlight the limitations of interventions and the need to appreciate the significance of school culture and teacher perceptions. Building a school culture that supports innovative child-led pedagogy is crucial to meaningful STEM education (Wilson 2021). Xu et al. (2023) outline the importance of teacher perspectives of STEM in that, even within the school, there can be different perspectives on how STEM can be made useful and applicable. Understanding these perspectives can be the first step towards the development of a shared vision required to facilitate school change and build a successful school culture.

Future research should therefore consider the wider school culture as well as individual teacher perspectives and attitudes. Longer-term iSTEM interventions should also be explored to determine the time required for measurable attitudinal change. The lack of significant change also highlights a broader challenge in measuring the influence of iSTEM education. This difficulty may not be unique to researchers; teachers may experience similar challenges in assessing the learning outcomes associated with iSTEM. Given the complexities of defining and assessing integrated learning, our findings underscore the need for greater clarity and shared understanding of what constitutes "iSTEM" among educators and policymakers. In light of this, future research should incorporate qualitative elements, such as interviews or drawing activities (e.g., "Draw an Engineer"), to gain deeper insights into children's understanding of each discipline within STEM. This approach could provide a richer, more comprehensive picture of how children conceptualise and engage with STEM disciplines.

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The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethical approval statement

The research has undergone institutional ethical approval and was conducted in accordance with the ethical guidelines.

Informed consent statement

Informed consent was obtained from all individual participants included in the study.

Consent for publication

All authors consent to publication

CRedit authorship contribution statement

Denis Moynihan: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Nicola Broderick:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Joe Usher:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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