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Innovative Pathways in Mathematics Education: The Role of International Project Competitions in Student Growth

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This study examines the impact of international mathematics project competitions on middle and secondary school students, emphasising their role in fostering mathematical competence, critical thinking, motivation and a global STEM-oriented mindset. Drawing on an extensive review of international literature and historical developments, the research identifies four core benefits of such competitions: the identification and development of exceptional talent, extended learning opportunities beyond the classroom, encouragement of students to pursue scientific careers and the enhancement of educational institutions' reputations. The study further investigates the evolution and educational value of project-based competitions compared to traditional mathematical contests, stressing the importance of including real-life applications, algorithmic reasoning and teamwork. Particular emphasis is placed on the integration of underrepresented mathematics domains into project themes, arguing that these can inspire deeper student engagement and innovative thinking. The discussion also highlights the role of educators, competition design and interdisciplinary collaboration in supporting student growth through these platforms. Recommendations are presented for enhancing competition effectiveness and accessibility, including tailoring activities to twenty-first-century skills, encouraging female participation and expanding curriculum links. The paper concludes with a call for increased institutional support and broader recognition of the formative potential of mathematics project competitions in nurturing future researchers and creative problem-solvers.

Keywords: academic performance, critical thinking, international project competitions, mathematics education

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Inovativni pristopi v matematičnem izobraževanju: vloga mednarodnih projektnih tekmovanj pri razvoju učencev

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Ta študija preučuje vpliv mednarodnih projektnih tekmovanj iz matematike na učence srednjih šol in zadnjega triletja osnovne šole, s poudarkom na njihovi vlogi pri spodbujanju matematičnih kompetenc, kritičnega mišljenja, motivacije in globalnega razmišljanja, usmerjenega v STEM. Na podlagi obsežnega pregleda mednarodne literature in zgodovinskega razvoja raziskava opredeljuje štiri ključne prednosti tovrstnih tekmovanj: prepoznavanje in razvoj izjemnih talentov, povečane možnosti učenja zunaj učilnice, spodbujanje učencev k usmeritvi v kariere z znanstvenih področij in izboljšanje ugleda izobraževalnih ustanov. Študija nadalje preučuje razvoj in izobraževalno vrednost projektnih tekmovanj v primerjavi s tradicionalnimi tekmovanji iz matematike, pri čemer poudarja pomen vključevanja uporabnosti v praksi, algoritmičnega razmišljanja in timskega dela. Poseben poudarek smo dali na vključevanje premalo zastopanih matematičnih področij v teme projektov, saj ta po našem mnenju spodbujajo globlje vključevanje učencev in inovativno mišljenje. V razpravi poudarjamo tudi vlogo izobraževalcev, zasnovo tekmovanj in interdisciplinarno sodelovanje pri podpiranju razvoja učencev prek teh platform. Predstavljena so priporočila za izboljšanje učinkovitosti in dostopnosti tekmovanj, vključno s prilagajanjem dejavnosti veščinam 21. stoletja, spodbujanjem sodelovanja deklet in s širitvijo povezav med učnimi načrti. Prispevek sklenemo s pozivom k večji institucionalni podpori in širšemu priznanju formativnega potenciala projektnih tekmovanj iz matematike pri vzgoji prihodnjih raziskovalcev in ustvarjalnih reševalcev problemov.

Ključne besede: akademski uspeh, kritično mišljenje, mednarodna projektna tekmovanja, matematično izobraževanje

Introduction

In recent years, there has been growing interest in the participation of middle and secondary school students in international mathematics-focused project competitions, as also reflected in the annual reports published by the Regeneron International Science and Engineering Fair (Regeneron ISEF), one of the world's most prestigious project competitions (Society for Science, 2025a). This trend reflects a broader shift in educational paradigms, wherein problem-solving skills, global engagement and interdisciplinary collaboration are prioritised alongside traditional academic instruction (Sujatha & Vinayakan, 2023). Such competitions are increasingly acknowledged as valuable educational practices, offering students a platform to extend their learning beyond the confines of the classroom, cultivate higher-order thinking skills and foster intrinsic motivation (Traşcă et al., 2019).

Competitions in mathematics, particularly those organised at the international level, serve not only as tools for academic enrichment but also as mechanisms for talent identification and professional orientation. Research suggests that participation in these events contributes significantly to students' cognitive development and affects their long-term educational trajectories (Omerović et al., 2020; Campbell et al., 2010). Furthermore, these competitions offer schools and educators opportunities to innovate pedagogically, support differentiated instruction and integrate contemporary themes such as STEM and twenty-first-century skills into the curriculum (Adera, 2025; Gunes & Saralar-Aras, 2023).

Among the best-known mathematics competitions, the International Mathematical Olympiad (IMO) stands out for its historical significance and prestige (Andreescu & Enescu, 2011), often being regarded as the pinnacle of mathematical competitions. It provides a unique opportunity to identify the most outstanding and imaginative secondary school students from around the world, students who have devoted themselves to mastering mathematics for a variety of personal reasons. The roots of the IMO can be traced back to the late nineteenth century, when the first mathematical competitions were held in Eastern Europe. Romania hosted the first official IMO in 1959, marking the beginning of a tradition that continues to this day. With seven countries sending a total of 52 students, the initial event laid the foundation for what would become a prestigious global competition (Andreescu & Enescu, 2011).

Even in a future dominated by artificial intelligence, the story of the IMO is likely to endure. This reflects a broader truth in life: despite countless AI-driven transformations, some classics have the resilience to persist, although it would be exciting to see such traditions enriched and reimagined. Project-based competitions provide an alternative format that prioritises creativity, real-world application and collaborative inquiry (Issa et al., 2014; Harper, 2015). Currently, mathematical project competitions offer promising opportunities in this regard. The widespread presence of mathematics contests at national, continental and international levels, along with the sustained emphasis of global educational organisations on mathematics education, highlights a shared commitment to cultivating the next generation of mathematical talent essential for the future development of human society. The present paper explores the role and impact of such competitions in developing mathematical competence and scientific curiosity. It also emphasises the underutilised potential of underrepresented mathematics domains (e.g., non-Euclidean geometries and advanced trigonometry) in broadening students' conceptual horizons and enriching mathematics education.

Key Prior Studies

According to the National Council of Teachers of Mathematics (NCTM, 1998), "Mathematics can be thought of as a language that must be meaningful if students are to communicate mathematically and apply mathematics productively". Fostering mathematical discourse is therefore essential for promoting deep understanding and meaningful application (Alro & Snovsmose, 2004; Wakefield, 2000). Teachers are encouraged to incorporate opportunities for mathematical discourse, enabling students to engage with and appreciate the value of mathematical language. In line with this objective, international mathematics project competitions offer a unique context in which students from diverse backgrounds can interact with shared mathematical ideas (Smit et al., 2023; Webb et al., 2019). By bringing together learners who operate in different educational and cultural settings, these competitions promote a common mathematical language and create an integrative environment for global collaboration (NCTM, 1998; Wakefield, 2000).

The Historical Trajectory of Mathematics Project Competitions

The historical trajectory of mathematics project competitions is closely intertwined with the broader evolution of competitive educational practices. Competition and education have long been integral components of human societies, serving not only as mechanisms for assessing knowledge but also as tools for fostering motivation, excellence and progress (Bajnok, 2024; Verhoeff, 1997). In this context, educational competition has evolved from rudimentary performance comparisons to formalised events with pedagogical and scientific value.

Historical analyses trace the evolution of mathematics competitions from traditional problem-solving formats to project-based approaches. Earlier, Hawkins (1990) and Nemetz and Ersoy (1995) criticised the lack of extracurricular mathematical activities and pioneered early project-based competitions, particularly in applied statistics. Kenderov (2022) describes how such efforts eventually developed into a dynamic global ecosystem of competitions involving educators, mentors, parents and institutions.

One of the earliest forms of academic competition in schools was grading, which served as a benchmark for student achievement (Brookhart et al., 2016). Over time, however, the limitations of such evaluations led to the emergence of more structured competitions – particularly in mathematics – driven by the exponential growth of mathematical knowledge in the eighteenth and nineteenth centuries (Bajnok, 2024). The increasing recognition of mathematics as a foundational discipline in science and public policy led to the establishment of mathematical societies and academic associations around the world (Savage, 2010). These organisations played a pivotal role in the institutionalisation of mathematics education and subsequently in the promotion of mathematics competitions (Ramskov, 2000).

Although national contexts varied, the goals of these early competitions were strikingly similar: to stimulate interest in mathematics, identify talented individuals, and nurture future scientists and innovators (see Iraq's National Math Project Olympiad, Türkiye's TÜBİTAK National Math Olympiad, USA's Siemens Competition in Math, Science, and Technology and STEM Expo). Competitions were seen as a remedy for systemic educational gaps, providing enrichment for high-achieving students whose needs were not adequately met by the standard curricula (Almarashdi et al., 2023; Khmelevsky & Chidlow, 2021; Razpotnik et al., 2024). Over time, they evolved into integral components of formal education systems, offering legitimacy and structure to out-of-school learning experiences and project-based inquiry. As such, the origins of mathematics project competitions highlight not only a response to historical educational demands but also a continued effort to cultivate academic excellence through meaningful and challenging learning opportunities.

The Role and Benefits of International Project Competitions Focused on Mathematics

Existing literature highlights a notable increase in international project competitions focused on mathematics, offering students a platform to demonstrate both analytical and creative abilities (see Thrasher, 2008). These competitions have been shown to enhance not only mathematical knowledge but also critical thinking, teamwork, communication and motivation among students (Akpinar et al., 2015; Balta et al., 2023). Several studies also emphasise their potential to increase students' confidence and interest in STEM fields, often serving as gateways to scientific careers (Biber & Saralar-Aras, 2024; Miller et al., 2018).

Participation in these competitions has pedagogical implications for both students and teachers. For example, More (2018) emphasises the importance of integrating mathematical thinking with real-world applications, while Kushnarev and Libertini (2021) advocate for modelling and interdisciplinary approaches as central themes of competition tasks. Riley and Karnes (1998) further suggest that competitions provide a foundation for understanding student motivation, learning strategies and reflections on mathematical problem-solving. Furthermore, gender-related disparities have been examined. Li (2019) and Balta et al. (2023) report that male students often dominate participation in technical and mathematical domains, while also highlighting the importance of inclusive policies to encourage female engagement.

Research has also explored how competition formats influence educational outcomes. In particular, studies highlight four key dimensions relevant to our research: the identification and development of exceptional talent, extended learning opportunities before and after competitions, guidance towards STEM careers, and the broader institutional and social impact of competitions. De Losada and Taylor (2022) frame mathematics competitions as a form of design science, exploring their theoretical underpinnings and implications for curriculum alignment. Geretschläger and Donner (2022) analyse the alignment and divergence between competition content and classroom topics, while Baker et al. (2022) investigate participation trends in underrepresented regions, such as African countries. In addition to these empirical and theoretical contributions, the literature underlines the socio-educational role of competitions. Soares et al. (2022) discuss the potential of international contests to foster social skills and collaborative learning environments. By focusing on these dimensions, the literature review directly informs the research question and subsequent analysis of competition effects.

Finally, the literature acknowledges the importance of adapting competitions to twenty-first-century educational goals (Biber & Saralar-Aras, 2024; Szabo et al., 2020). This includes fostering algorithmic thinking, integrating technology and open-source tools, promoting project-based inquiry and incorporating advanced mathematical domains (Kurudirek & Berdieva, 2024). The current study builds upon these foundations to examine not only the cognitive and motivational outcomes of participation but also the curricular and institutional opportunities these competitions present.

Research Problem and Research Questions

While existing research on international mathematics project competitions provides valuable insights, the literature remains fragmented and limited in scope, particularly with respect to the broader and long-term educational impact of such competitions. Although several studies highlight specific outcomes or describe particular competitions, a comprehensive understanding of how these events influence students' cognitive, motivational and career-related development is still emerging. This gap underscores the need for an integrative synthesis. Drawing on an interpretive review of literature published between 1980 and 2025, the present study aims to synthesise current knowledge on the educational role of mathematics project competitions. Accordingly, the central research question guiding this inquiry is:

- Do international mathematics project competitions influence middle and secondary school students' mathematical competence, motivation and orientation towards scientific careers, and what educational conditions enhance the impact of these competitions?

Method

This study adopts a qualitative literature review methodology to explore the pedagogical, cognitive and structural dimensions of mathematics project competitions within educational contexts. The review draws on a wide range of academic sources, including peer-reviewed journal articles, books, policy reports and competition archives, with a specific focus on mathematics education. The literature search covered publications accessible between 1980 and 2025 and was conducted using academic databases: ERIC, Scopus, JSTOR and Google Scholar. Keywords included "mathematics competitions", "project-based learning", "gifted education", "STEM contests", "educational impact of competitions", and "mathematics talent development". Boolean operators (e.g., AND, OR) and filters (e.g., peer-reviewed, English or Turkish language) were used to refine the search results.

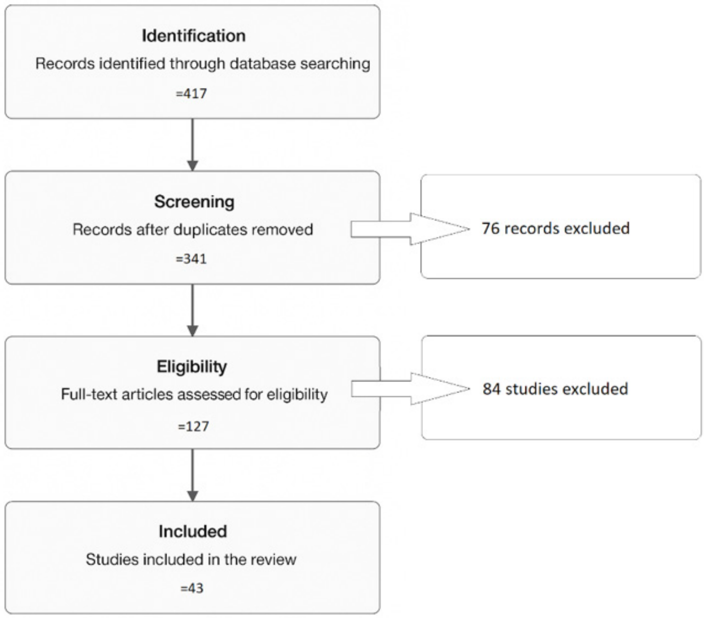
The exact search process involved multiple phases: identification, screening, eligibility and inclusion. Initial searches yielded 417 records across all data bases (identification). After removing 76 duplicates, 341 records remained for screening. Of these, 214 records were excluded based on titles and abstracts for lacking relevance to mathematics competitions or educational outcomes (screening). The remaining 127 full-text articles were assessed for eligibility. After applying the predefined inclusion and exclusion criteria, 84 studies were excluded due to insufficient educational focus, lack of theoretical relevance or absence of project-based competition components (eligibility), resulting in 43 sources being included in the final review (inclusion).

The inclusion criteria enabled the identification of studies that:

- focused explicitly on mathematics-related competitions at national or international levels;
- addressed educational, cognitive or institutional outcomes;
- provided empirical findings or theoretical insights relevant to the role of competitions in learning environments.

Figure 1

PRISMA flow diagram of the study selection process

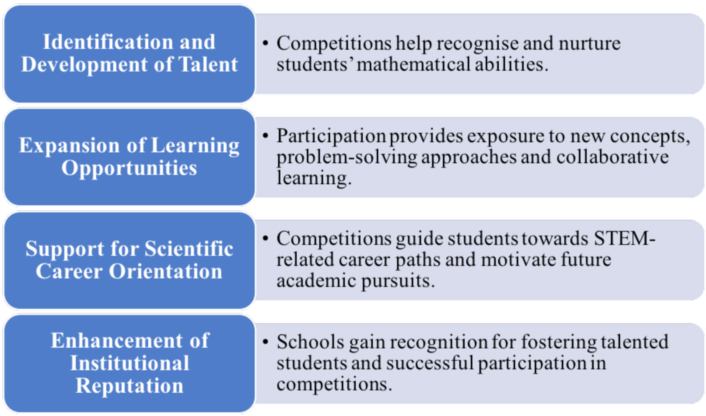


Sources unrelated to mathematics or lacking sufficient educational relevance were excluded. A PRISMA-style diagram (Figure 1) is provided to illustrate the review process, including the numbers at each stage. Figure 1 outlines the systematic progression from the initial identification of 417 records to the final inclusion of 43 studies. Each step – duplicate removal, screening, eligibility assessment and inclusion – reflects the application of predefined criteria related to the educational and mathematical relevance of competition-focused research. The research approach is interpretive, aiming to synthesise the pedagogical, cognitive and structural roles of mathematics competitions in educational ecosystems. The coding and analytical procedure followed an iterative thematic synthesis: repeated reading of texts, open coding, categorisation of themes and synthesis across different source types. The findings are presented in a thematic structure organised around historical emergence, participant outcomes and institutional implications. In order to ensure validity and credibility, triangulation across document types (e.g., research articles, policy texts and competition archives) was employed.

Results

The findings of the study are presented across four interrelated thematic areas, each capturing a distinct but interconnected benefit of mathematics project competitions in the context of middle and secondary education. These themes include the identification and development of talent, the expansion of learning opportunities, support for scientific career orientation and the enhancement of institutional reputation. Figure 2 provides short descriptions of each theme.

Figure 2
Benefits of mathematics project competitions



Theme 1. Identification and Development of Exceptional Talent

One of the primary contributions of mathematics project competitions lies in their ability to discover and nurture gifted students whose potential often remains untapped within conventional curricula (Ozdemir, 2022; Ozdemir & Isiksal Bostan, 2021; Schnell & Prediger, 2017; Singer et al., 2016; Slapničar et al., 2024; Yuret, 2024). The reviewed research provides valuable insights into talent identification and support mechanisms, and highlights the role of competitions in recognising mathematically gifted learners. For example, Leikin (2021) emphasises that high-potential students require challenging and enriching environments beyond standard curricula, whereas Subotnik and colleagues (2011) stress the integration of both nature and nurture in gifted education, advocating for structured opportunities such as project-based competitions. Siegle et al. (2016) further note that equitable access to enrichment programmes ensures that underrepresented students are identified and engaged. Empirical evidence also suggests that participation in competitions can reveal previously unnoticed talent: for example, Schnell and Prediger (2017) show that targeted enrichment activities uncover high-potential students in underprivileged contexts, and Yuret (2024) examines how participation in international mathematics competitions, such as the IMO, helps identify mathematically gifted students early on, highlighting the potential for targeted support and development of their talents.

Most education systems are designed to address the learning needs of the average student population, frequently overlooking those with high mathematical aptitude (Kalman, 2002; VanTassel-Baska, 2003). According to Riley and Karnes (1998), students with exceptional abilities are often left unchallenged and uninspired by the standard curriculum, which may lead to disengagement and underperformance. Mathematics competitions, by contrast, offer these students a platform to challenge themselves, develop their skills and gain recognition (Kafai, 2014; Riley & Karnes, 1998). Such environments foster perseverance and self-efficacy by rewarding original thinking, creativity and the ability to handle complex problem-solving tasks (Ozturk & Debelak, 2008; Thrasher, 2008). In this sense, competitions serve as powerful enrichment tools, offering targeted and meaningful learning experiences to high-potential students across different educational contexts.

Theme 2. Extended Learning Before and After Competitions

The educational impact of mathematics competitions is not limited to the event itself but extends significantly to both the preparatory and post-competition phases (Campbell & Walberg, 2010; Rebholz et al., 2022). As students prepare for competitions, they are exposed to topics and problem types that often go beyond the formal curriculum, encouraging independent learning, deeper inquiry and sustained engagement (Carpenter & Pease, 2013; Karnes & Riley, 2005). Bicknell and Riley (2012) note that the very act of preparing for a mathematics competition can lead to substantial academic growth, even for those who do not achieve top placements. Furthermore, the post-competition phase – characterised by reflection, discussion and peer feedback – amplifies the learning process. Soares et al. (2022) argue that interactions occurring after competitions, whether in school corridors or informal discussions, are instrumental in deepening mathematical understanding and in reinforcing conceptual retention. Instructors also benefit from these cycles by exploring advanced mathematical content, which in turn may enrich their instructional practices (de Losada, 2017). The cyclical nature of preparation and reflection creates a continuum of learning that transcends the boundaries of a single event.

Theme 3. Encouragement Towards Scientific Careers and Professional Growth

Participation in project-based competitions plays a formative role in guiding students towards STEM-oriented academic and career pathways (Sagge et al., 2022). According to Valsiner (1997), early positive academic experiences significantly influence individuals' future professional interests. Success in a competition may represent such a formative experience, prompting students to invest more effort in the field and develop stronger academic identities (Dyson, 2009; Sujatha & Vinayakan, 2023). Empirical evidence supports this impact: a substantial proportion of participants in international competitions, such as the IMO, continue to pursue STEM-related degrees and careers (Yuret, 2024). Similarly, the situation of former ISEF participants who have entered the alumni category provides further insight, demonstrating sustained engagement in STEM fields (Regeneron International Science and Engineering Fair, 2025; Society for Science, 2025a). For instance, the ISEF brings together approximately 1,600–1,800 young scientists annually from over 60 countries, and the Society for Science reports a global alumni network of over 70,000 former participants (Society for Science, 2025b; Regeneron ISEF, 2023), highlighting both the scale and long-term influence of these competitions. Competitions therefore function not only as academic events but also as career-exploration platforms. Many renowned scientists and mathematicians attribute their initial interest in research and discovery to early participation in such competitions. Additionally, competitions often include interdisciplinary dimensions – integrating science, engineering or computer science – which further broadens the participants' awareness of potential career trajectories. This early exposure is especially valuable in shaping the aspirations of students from underrepresented or underserved backgrounds.

Theme 4. Institutional Prestige and Educational Ecosystems

Beyond individual student outcomes, mathematics project competitions have a broader systemic impact on schools and educational institutions (Akveld et al., 2022; Smith et al., 2019). High-performing students who excel in competitions contribute to raising the academic profile and prestige of their schools. As Kenderov (2006) argues, the success of an institution is not solely contingent on the capabilities of its teachers but also on the aptitude and performance of its students. Schools that attract and support talented students through competitive programmes often experience a ripple effect: heightened expectations, more ambitious learning environments and a greater culture of academic excellence (Dai & Rinn, 2008; Subotnik & Rickoff, 2010). In response, many schools actively invest in organising competitions or offering incentives such as scholarships or admission privileges to participants. These efforts not only enhance institutional visibility but also build lasting affiliations with prospective students and their families (Sagge et al., 2022). Ultimately, the presence of mathematics project competitions contributes to a dynamic educational ecosystem in which excellence is both nurtured and recognised at multiple levels.

In addition to the four core contributions outlined above, the literature also emphasises a number of supplementary competencies fostered through participation in mathematics project competitions. These competencies, while not always formally assessed, have significant implications for students' academic and personal development. For instance, engagement in such competitions cultivates higher-order reasoning, encouraging learners to analyse, evaluate and synthesise mathematical concepts rather than merely apply procedures (Bicknell & Riley, 2012; Masriyah et al., 2024). Oral communication skills are also advanced through the presentation and defence of project ideas, often in front of juries or peers, which strengthens students' ability to articulate mathematical reasoning clearly and persuasively (Soares et al., 2022; Wakefield, 2000).

Furthermore, students develop vital self-management and leadership abilities, particularly when working independently or guiding group projects (Kurudirek & Berdieva, 2024; Lee et al., 2017). The interactive nature of competition-based learning supports meaningful relationships between students and educators, fostering mentorship and dialogic engagement (Akpinar et al., 2015). Responsibility and long-term retention are enhanced as students take ownership of their learning, often engaging with content at greater depth than in typical classroom settings (Dweck et al., 2014; Sunzhong et al., 2022). Finally, exposure to diverse perspectives and feedback-rich environments prepares students for real-world social and employment contexts, where collaboration, adaptability and reflective thinking are essential (Herrity, 2023). These dimensions further underscore the comprehensive educational value of mathematics project competitions beyond conventional academic measures.

Discussion

This section relates the study's findings to broader educational theories and implications, highlighting how the benefits of mathematics project competitions may align with twenty-first-century learning goals, educational equity and the development of interdisciplinary competencies. Firstly, the identification and development of exceptional talent through competitions supports the notion of differentiated instruction and enrichment for gifted learners. This aligns with Tomlinson's (2001) model of differentiated pedagogy, which emphasises the importance of tailoring educational experiences to students' readiness levels, interests and learning profiles. Competitions serve as high-challenge contexts that stimulate the cognitive engagement of high-potential learners, filling a crucial gap left by standard curricula.

Secondly, the extended learning processes that occur before and after competitions resemble the principles of experiential learning (Kolb, 1984), where students cycle through concrete experiences, reflection, conceptualisation and experimentation. Preparing for and reflecting on project competitions fosters metacognitive growth and deeper conceptual understanding, reinforcing mathematics as a process-oriented and exploratory discipline rather than a static set of procedures.

Thirdly, the role of competitions in career orientation resonates with theories of academic identity development (Gee, 2000) and vocational psychology. Participation offers students authentic experiences that shape their self-perception as capable mathematicians or scientists, thus influencing their long-term educational and professional aspirations. Moreover, early exposure to interdisciplinary STEM tasks within competition settings broadens students' career imagination, which is particularly impactful for students from underrepresented backgrounds.

Finally, the institutional implications of competitions extend beyond reputation-building; they contribute to school culture transformation. According to Senge (2006), learning organisations thrive when individuals at all levels engage in continuous growth. Schools that support competitive academic environments foster shared values of excellence, innovation and intellectual risk-taking. These environments not only benefit individual students but also promote collaborative professionalism among teachers, reflective practices and school-wide commitment to academic ambition.

Taken together, the discussion highlights how mathematics project competitions operate as catalysts for both individual and systemic advancement in education. Their multidimensional influence – pedagogical, cognitive, affective and institutional – positions them as valuable assets in modern education systems aiming to cultivate globally competent, inquiry-driven learners.

Conclusion

The present paper has explored the multifaceted contributions of mathematics project competitions within secondary education, highlighting their unique capacity to enrich student learning, foster critical skills and enhance education systems. Through a detailed analysis grounded in literature and theory, we have demonstrated that such competitions not only serve as platforms for identifying and supporting gifted students (Riley & Karnes, 1998) but also function as powerful vehicles for experiential learning (Kolb, 1984), academic identity formation (Gee, 2000) and school culture transformation (Senge, 2006).

Importantly, the incorporation of underrepresented mathematical domains into project-based tasks underscores the potential of competitions to inspire innovative thinking and conceptual expansion (Geretschläger & Donner, 2022). By providing students with authentic, interdisciplinary and real-world problem-solving experiences (Bicknell & Riley, 2012; Soares et al., 2022), these competitions bridge the gap between traditional curricula and the dynamic demands of twenty-first-century education.

In light of the findings and discussion, we advocate for a broader and more strategic integration of project-based mathematics competitions into formal education systems. Policymakers and school leaders should consider providing sustained institutional support, including teacher training, resource development and inclusive participation strategies (Dania et al., 2025; de Losada & Taylor, 2022; Balta et al., 2023). Moreover, competition organisers are encouraged to design challenges that are accessible, equitable and aligned with both curricular goals and emerging global competencies (Kenderov, 2022). Ultimately, mathematics project competitions hold significant promise as scalable, adaptable and impactful tools for cultivating the next generation of critical thinkers, problem solvers and lifelong learners in an increasingly complex world.

Limitations

This research has several limitations. First, as the study is based on a qualitative literature review, its findings rely primarily on an interpretive synthesis of existing sources rather than systematic empirical evidence or primary data collection. Second, the reviewed literature provides limited insight into how mathematics project competitions operate across diverse sociocultural and educational contexts, which constrains the generalisability of the synthesis. Third, the influence of demographic factors such as gender distribution, socioeconomic status, geographic disparities (e.g., rural-urban differences) and access to educational resources has not been sufficiently examined in existing studies. Moreover, variations in competition formats, assessment criteria and institutional support across countries are not consistently documented in the available literature, further limiting cross-contextual comparison. Taken together, these limitations highlight important directions for future research, including the need for more context-sensitive empirical studies, longitudinal analyses and comparative investigations across different competition ecosystems.

Future Directions

Firstly, in light of the evolving landscape of mathematics education, integrating underrepresented domains into project competitions offers promising opportunities for deepening students' conceptual understanding and creativity. While traditional school curricula often emphasise Euclidean geometry, alternative geometrical systems such as Galilean and taxicab geometries challenge students to reconsider foundational assumptions about space, distance and parallelism (Saralar-Aras & Kurudirek, 2025; Yaglom, 1979). These systems not only expand students' mathematical horizons but also foster higher-order thinking skills through unfamiliar conceptual frameworks (Kurudirek, 2023).

The inclusion of such content aligns with broader educational goals of nurturing innovation and inquiry. Students working on projects involving non-Euclidean geometries often encounter complex, open-ended problems that require original thinking, abstract reasoning and creative problem-solving (Nugroho et al., 2021; Shillor, 1997; Sukestiyarno et al., 2023). Moreover, these themes offer a rich interdisciplinary connection to physics, computer science and philosophy, thereby enriching the educational experience. Project-based engagement with these topics may help cultivate a lifelong interest in mathematics and related fields.

Secondly, the successful implementation of innovative mathematics competitions depends largely on the commitment and expertise of educators. Studies underscore the pivotal role of teachers in preparing students for competitions, especially when content goes beyond standard curricula (Ersoy & Nemetz, 1995; Goos & Bennison, 2019). These educators act not only as instructional guides but also as mentors who cultivate motivation, resilience and academic identity.

Professional development opportunities tailored to competition contexts can enhance teacher capacity to support high-level student engagement. Collaborative initiatives between mathematicians and mathematics educators – especially those grounded in interdisciplinary approaches – can also reshape instructional practices and extend the reach of competition-based learning. Drawing from Valsiner's (1997) zone theory, such collaborations may expand the professional agency of educators by encouraging exploration beyond the traditional scope of their roles.

Finally, mathematics project competitions provide a valuable platform for promoting equitable access to meaningful learning experiences. However, realising this potential requires deliberate attention to inclusive practices. Teachers and school leaders must ensure that competitions are accessible to all students, including those from underserved or underrepresented backgrounds (Niemi, 2021). Encouraging diverse participation can help combat stereotypes about mathematics ability and foster a more inclusive vision of who can succeed in STEM fields.

Support from parents and educational institutions also plays a critical role. Parents can act as facilitators of early interest in mathematics by nurturing curiosity and perseverance (Bubić et al., 2021). Meanwhile, institutions can strengthen their support systems by offering targeted programmes, revising curricular frameworks to integrate project-based learning and investing in educator training. These collective efforts can create a more holistic and engaging mathematics education ecosystem.

Recommendations

In order to maximise the benefits of mathematics project competitions, several strategic recommendations can be proposed:

- Policymakers and curriculum designers should consider embedding project-based and interdisciplinary tasks within national mathematics curricula, thereby legitimising and supporting competition-aligned learning in formal settings.

- Training programmes should equip teachers with the skills to guide students through complex project development, including algorithmic thinking, real-world modelling and the exploration of advanced mathematical domains.
- Organisers should aim to design competition tasks that are equitable, culturally responsive and accessible to a wide range of students. This includes providing differentiated entry points and scaffolding where needed.
- Partnerships between schools, universities and research centres can help build sustainable networks that support the development and dissemination of best practices in project-based mathematics education.
- Competitions should be viewed not merely as isolated events but as part of a continuum of learning that includes preparation, reflection and dissemination. Platforms that allow students to present and discuss their projects can deepen learning and foster academic communication skills.

Ethical Statement

This article is a literature review and therefore does not require ethical approval. All of the sources that were examined or consulted, or that inspired the development of the ideas presented in this paper, have been properly cited and referenced in accordance with academic and publication ethics. The authors affirm that due care has been taken to avoid plagiarism, and that all intellectual contributions from prior works have been appropriately acknowledged.

Data Availability Statement

Since the present study is a literature review, it does not involve the collection or analysis of primary empirical data.

Disclosure Statement

The authors have no competing interests to declare.

Following the completion of the initial draft, the authors used ChatGPT-4o (OpenAI) on 15 August 2025 with the following prompt: “Please assist with linguistic editing and improving grammatical clarity of this paper.” All outputs were reviewed and revised by the authors, who take full responsibility for the final content.

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