Research Trends on Teaching and Learning Mathematics within STE(A)M Education

Tendências de Investigação no Ensino e Aprendizagem da Matemática no Contexto da Educação STE(A)M

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In the contemporary debate on educational innovation, the STEAM (Science, Technology, Engineering, Arts, Mathematics) approach has emerged as a theoretical and operational paradigm of growing importance, capable of responding to the needs for complexity, interconnection and dynamism that characterise knowledge societies. The inclusion of the Arts within the traditional STEM framework constitutes an explicit epistemological stance that recognises creativity, imagination, aesthetics and expressiveness as integral dimensions of knowledge construction and learning processes (Bequette & Bequette, 2012; Yakman & Lee, 2012).

Within this framework, mathematics education occupies a distinctive position. Although mathematics has traditionally been associated with formalism, abstraction and logical rigour, research in mathematics education has consistently highlighted the fundamental role of intuitive, visual, physical and aesthetic processes in the development of mathematical concepts (Sinclair, 2004). The STEAM approach allows these dimensions to be recomposed, promoting a view of mathematics as a cultural practice that is historically

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and socially mediated. From this perspective, creativity is not opposed to logical reasoning but constitutes an essential complement to it, as evidenced by the historically creative and intuitive nature of mathematical activity (Hadamard, 1945). Accordingly, STEAM-oriented practices encourage imagination, critical thinking and exploratory learning paths, in which uncertainty and error play a productive role.

Several studies suggest that STEAM learning environments can have a positive impact on students' attitudes towards mathematics, cognitive engagement, and intrinsic motivation, particularly when traditional teaching is inaccessible or alienating (English, 2016; Henriksen, 2014). In mathematics education, STEAM facilitates the design of meaningful interdisciplinary pathways that integrate diverse forms of reasoning and multisensory experiences, supported in a balanced manner by the arts and STEM disciplines. Such approaches have been shown to foster deeper understanding, improved retention and enhanced transfer of mathematical knowledge when compared to conventional classroom practices.

STEAM education framework

From a theoretical perspective, the STEAM approach is consistent with constructivist, socio-cultural, and situational views of learning, in which mathematical knowledge is understood not as a set of static objects to be transmitted, but as the outcome of discursive, instrumental and social practices developed within learning communities (Hmelo-Silver et al., 2007). STEAM promotes dynamic learning environments that facilitate knowledge transfer across disciplinary boundaries while preserving the epistemic integrity of each discipline. Within such environments, convergent and divergent forms of thinking are articulated through student-centred inquiry, design and experimentation, supported by purposeful teacher guidance.

The integration of the arts further expands the semiotic resources through which students construct mathematical meaning. Research highlights the role of multimodal representations—visual, gestural, digital and narrative—in fostering deep conceptual understanding and cognitive flexibility (Sinclair & Freitas, 2014). From this perspective, the plurality of expressive modes characteristic of STEAM contributes to a more inclusive vision of mathematics education, reducing epistemic barriers and addressing phenomena such as math anxiety and cultural marginalisation (Perignat & Katz-Buonincontro, 2019).

The literature distinguishes between different levels of STEAM integration. English (2016) notes that many ostensibly interdisciplinary initiatives are limited to the juxtaposition of disciplinary contents, resulting in mathematics being reduced to a merely procedural role. In contrast, authentic integration positions mathematics as a cognitive infrastructure for modelling, abstraction and generalisation, essential for addressing complex and meaningful problems (Fitzallen, 2015). In this regard, Project-Based Learning

(PBL) offers a fertile context for STEAM integration by foregrounding problem posing and problem solving as central mathematical practices, thereby positioning mathematics as a structuring language within STEAM experiences (Ubben, 2019; Diego-Mantecón et al., 2019). Empirical research has already shown that well-designed STEAM programmes can promote the development of advanced problem-solving, critical thinking and collaboration skills (Capraro et al., 2013). Systematic review studies also show a positive impact on attitudes towards mathematics and professional aspirations in STEM fields, although the results are highly dependent on the context and implementation methods (Li et al., 2020).

Challenges and opportunities for developing STEAM approach

Despite growing empirical evidence, research on STEAM education continues to face several significant challenges. These include the need for a clearer operational definition of interdisciplinarity—distinguishing authentic integration of epistemic practices from mere content juxtaposition (Martinez, 2017); the development of assessment strategies capable of capturing complex and transversal learning outcomes beyond traditional testing formats; and the design of teacher education programmes that adequately prepare educators to orchestrate highly integrated STEAM activities, particularly in mathematics education.

Among these challenges, assessment emerges as a particularly critical issue. The competencies fostered through STEAM approaches—such as problem solving, creativity and collaboration—are difficult to capture through standardised, outcome-oriented evaluation tools (Pellegrino & Hilton, 2012). This limitation often reinforces disciplinary "silos" and binary notions of achievement, raising epistemological and methodological questions about the validity and reliability of assessment practices in integrated learning contexts. Addressing these issues requires expanding assessment frameworks beyond the assignment of grades, drawing on perspectives such as multiple intelligences and hierarchical models of cognitive processes to better reflect the diversity of students' learning trajectories (Capozucca, 2022).

Within this context, the contributions gathered in this special issue offer relevant insights into mathematics teaching and teacher education within STEAM frameworks across educational levels.

Alsina and Salgado (2025) analyse the potential of a well-designed STEAM task sequence in early childhood education to foster integrated learning and the development of STEAM competence. Their study highlights that meaningful STEAM education requires intentional integration of science, mathematics, engineering, technology and the arts, with artistic creation and design-based activities playing a key role in supporting mathematical meaning-making, communication, and functional thinking. The authors also emphasise the importance of sustained teacher scaffolding to ensure conceptual consolidation in mathematics and science, offering a research-informed model for STEAM-based task design in early mathematics education.

Focusing on early childhood mathematics, Brasili (2025) explores preschool children's recognition of rotational and reflectional symmetries through hands-on and visually rich activities. The findings underline the developmental progression from rotational to reflectional symmetry and highlight the role of spatial thinking and invariance as foundational cognitive resources. From a STEAM perspective, the study illustrates how visual, manipulative and aesthetic experiences can support embodied mathematical learning and interdisciplinary integration from an early age.

Sousa et al. (2025) examine the role of creativity in the design of mathematical tasks by in-service and pre-service teachers within a formative framework combining the STEAM approach, Didactic Suitability Criteria and the Task Design Study Cycle. Their results show that structured professional learning environments support the development of mathematically robust, creative and context-sensitive tasks, while also revealing persistent constraints related to time, resources and institutional conditions. The study highlights the potential of STEAM-oriented task design to reposition teachers as authors of innovative mathematical experiences rather than mere curriculum implementers.

García-Velázquez and Beltz González (2025) present the design and evaluation of an educational game aimed at addressing gender inequalities in STEM through the integration of mathematical optimisation and social reflection. By foregrounding women's scientific contributions, the game promotes inclusive mathematical engagement while supporting the development of arithmetic reasoning and divergent thinking. The findings demonstrate how game-based STEAM approaches can simultaneously foster rigorous mathematical learning and critical awareness of social equity issues.

Mota and Martinho (2025) analyse a teacher training programme in primary education designed to promote integrated STEM projects in which mathematics plays a structurally visible role. Their study shows that collaborative, project-based professional development can strengthen teachers' didactic intentionality and enhance students' engagement, while also revealing systemic barriers related to curriculum fragmentation and planning constraints. The authors argue that effective STEM integration in primary education requires deliberate planning of mathematics as a central modelling tool.

Last but not least, Alonso and Villarreal (2025) provide a systematic review of STEM/STEAM research in Latin America, identifying publication trends, dominant research themes and conceptual uses of the STEM/STEAM framework. Their analysis reveals that mathematics is frequently positioned in an instrumental role, but gains greater epistemic centrality when approached through mathematical modelling. The review identifies critical gaps in curriculum design, assessment and teacher education, offering valuable directions for future research in the region.

Conclusions

The STEAM approach represents a promising theoretical and methodological framework for rethinking mathematics education in an integrated, inclusive and culturally meaningful way. Far from compromising disciplinary rigour, integration with the arts helps to highlight the creative, aesthetic and social dimensions of mathematics, restoring its character as a complex human practice. This thematic issue aims to contribute critically to this debate by promoting an informed dialogue between research, educational design and educational practice.

The journey of STEAM in mathematics education is not a passing trend, but a comprehensive response to the complexity of the contemporary world and the need for teaching that is meaningful, motivating and formative. By integrating rigour, creativity, practice and reflection, STEAM offers us the opportunity to think of mathematics not as a disciplinary monolith, but as a bridge between thinking and creating, between knowing and transforming. That is why the contributions in this special issue can be another piece in an ongoing dialogue — an invitation to explore, experiment and reinvent mathematics education through the stimulating lens of STEAM.

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