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BEYOND STEM: A NARRATIVE REVIEW OF STEAM EDUCATION'S IMPACT ON CREATIVITY AND INNOVATION (2020–2025)

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Abstract

STEM education, although essential for building technical competencies, has faced criticism for its limited capacity to develop the innovation and creativity needed for the 21st century. STEAM education has emerged as a paradigm shift by embracing the Arts for developing comprehensive problem-solving, divergent thinking, and adaptability alongside analytical proficiency. This narrative review of research from 2020 onwards examines the consolidated evidence of published studies from 2020 to 2025 on the shift from STEM to STEAM education's effects on the innovation-readiness of learners. Complying with PRISMA guidelines, the present review examined 40 peer-reviewed articles to map the international landscape of STEAM research that reveals a predominant contribution from the USA, Spain, and other nations from Asia. The majority of the findings demonstrate convincingly that STEAM's project-based, transdisciplinary, and technology-facilitated teaching approaches substantially enhance the creative thinking, problem-solving capacity, motivation, and collaborative skills of learners across varying age groups and learning levels. CPACK and Design Thinking as crucial theoretical pillars are important in its effective implementation. Despite the fact that the evidence demonstrates the positive impact of STEAM, there is an existing need for successful curricular changes, continuous professional development of teachers, and effective investments in the development of digital infrastructure. It was concluded in this review that STEAM education has a considerable potential as a catalyst for preparing learners to engage with a more complex and innovation-driven world, and offers insights for potential directions to inform policy development and practical implementation.

Keywords: STEAM Education, Creativity and Innovation, 21st-Century Skills, Interdisciplinary Learning, Educational Technology

Introduction

STEM education, encompassing Science, Technology, Engineering, and Mathematics, has long been recognized as a driving force for economic growth and technological advancement. Its interdisciplinary approach equips students with the analytical, problem-solving, and technical skills essential for success in the 21st-century workforce. Nevertheless, regardless of its advantages, STEM education has been criticized for having a few weaknesses in enhancing creativity and innovation. Conventional STEM programs tend to focus on standardized knowledge learning and technical skills, with certain cases sacrificing divergent thought, imagination, and capacity to create original solutions to complex problems. Research has indicated that although STEM can enhance the level of creative thinking to a certain degree, STEM students tend to be low to medium in terms of their level of creativity, with tests showing lower-than-expected performance on tests of creative thinking (Sirajudin et al., 2021; Monsang & Srikoon, 2021). It implies that although STEM has been demonstrated to be instrumental in developing entry-level competencies, it does not necessarily cover the entire spectrum of competencies an innovator should have, including flexibility, empathy, and the willingness to take risks (Lee et al., 2016; Conradty & Bogner, 2018).

To address these shortcomings, teachers and policymakers have called to incorporate the Arts into STEM to create STEAM (Science, Technology, Engineering, Arts, and Mathematics) education. STEAM is a paradigm shift and focuses on the importance of creativity, imagination and solving problems in a holistic manner in addition to technical skills. The arts, including visual and performing arts, design, and humanities, are most likely to enrich the educational experience and develop analytical and creative skills since STEAM is more holistic. Arts in STEAM are not superficial and are part of achieving the capacity to synthesize knowledge, think of multiple perspectives, and create an innovation that is both useful and significant (Cheng et al., 2022; Rolling, 2016). STEAM education promotes inquiry-based, project-based learning, during which students integrate practical tasks that combine scientific investigation with creative expression, thus improving their creative thinking and innovativeness (Ahmad et al., 2021; Suchikova & Kovachov, 2024).

The shift to from STEM to STEAM has become increasingly popular around the world, as it is reflective of the wider educational trends and policy changes to equip students for the rapidly evolving world. STEAM has been implemented by countries in Asia, Europe, and North America as a result of the increasing awareness that economic competitiveness and social well-being depend heavily on creativity and innovation (Anisimova et al., 2018; Madden et al., 2013). It is observed that there is growing emphasis on interdisciplinary learning, collaboration, and acquisition of 21st-century skills like critical thinking, communication, and adaptability in educational policies. The growth of STEAM programs can be observed in the curriculum development, the teacher professional development programs as well as the incorporation of new technologies to facilitate creativity-based learning processes (Leavy et al., 2023). To illustrate the point, digital virtual classrooms, gamification, and maker education have been demonstrated to improve student motivation, self-efficacy, and interdisciplinary knowledge acquisition and contribute to the global shift towards STEAM (Wannapiroon & Pimdee, 2022; Jia et al., 2021). These trends highlight a set direction, in which people strive to outgrow the stage of rote teaching and prepare students to have the creative courage to cope with ambiguity and foster creativity.

The increasing literature of empirical research reveals that STEAM education has a positive influence on the readiness of students to be innovative and creative. Meta-analyses and experimental works all indicate that STEAM methods result in significant creative thinking, problem-solving, and disciplinary application of knowledge (Ahmad et al., 2021; Suganda et al., 2021; Cheng et al., 2022). As an example, STEAM programs based on projects have been found to substantially improve both personal and team creativity of elementary and secondary learners without negatively affecting the level of content knowledge in the core scientists (core sciences) (Cheng et al., 2022; Suchikova & Kovachov, 2024). Arts-based STEM interventions like Nanoart projects or design-based learning have been reported to enhance students' comprehension, help them engage, and close the divide between scientific exploration and artistic expression (Suchikova & Kovachov, 2024). Moreover, the research findings indicate that STEAM settings foster self-efficacy, motivation, and collaboration skills, which are important factors in long-term innovation (Jia et al., 2021; Conradty et al., 2020; Conradty & Bogner, 2020). It is important to note that STEAM does not seem to be restricted in its applicability by gender or age, which implies the extensive applicability of this approach to different educational settings (Conradty et al., 2020). The overall results of these studies prove (demonstrate) that STEAM education is an effective stimulus for developing the creative and innovative abilities needed in the 21st century.

Although STEAM education is increasingly popular, and the empirical results are promising, it is still unclear how exactly it works and in what contextual conditions its success will be achieved. The years 2020-2025 have been characterized by unprecedented challenges and opportunities, such as the accelerated digitalization of education, and the necessity of innovative responses to the global issues. It is against this backdrop that the main research question that will inform this systematic review is: How did the shift from STEM to STEAM education between 2020 and 2025 affect the readiness of students to be innovative and creative? This review aims to summarize the latest studies, define the best practices, and emphasize the areas that require further research, as the ultimate aim will be to guide educational policy and practice in the age of STEAM. The next parts of this review will be structured in the following way: The Methodology section will

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present the systematic search strategy, inclusion and exclusion criteria, and the protocols of quality assessment. The Data Distribution section presents a summary of the chosen literature, such as the areas of subject, type of documents and geographical contributions. The Results and Discussion section summarizes the research question-related findings, pointing to the essential pedagogical approaches, online tools, and interdisciplinary paradigms. The part on the NOISE Analysis provides strategic information about the use of STEAM education, whereas the Limitations section addresses the limitations of the review process. Last but not least, the Conclusion will summarize the main findings and will offer the way forward in terms of future research and policy formulation.

Table 1

Evidence summary for STEAM's impact on creativity and innovation

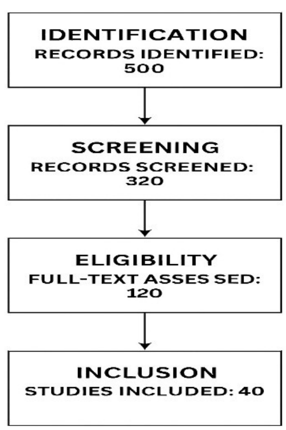
Claim	Evidence Strength	Reasoning	Papers
STEAM education enhances creative thinking and innovation more than STEM alone	Evidence strength: Strong (9/10)	Multiple studies show significant gains in creativity, problem-solving, and motivation with STEAM integration	(Wannapiroon & Pimdee, 2022; Ahmad et al., 2021; Suganda et al., 2021; Cheng et al., 2022; Jia et al., 2021; Conradty et al., 2020; Suchikova & Kovachov, 2024; Conradty & Bogner, 2020)
STEAM's impact is consistent across age and gender	Evidence strength: Moderate (7/10)	Large-scale studies report no significant differences by age or gender in creativity outcomes	(Conradty et al., 2020; Conradty & Bogner, 2020)

Detail: *9/10 = 90% of the given sources, 7/10 = 70% of the given sources*

To ensure transparency and methodological rigor, we provide both tabular and visual representations of the study selection process. Table 1 offers a detailed numerical breakdown of records identified, screened, assessed for eligibility, and ultimately included in the narrative review of STEAM education (2020–2025). In addition, Figure 1 presents a PRISMA-style diagram that visually illustrates this process, providing a clear overview of how studies were filtered at each stage. The combination of Table 1 and Figure 1 enables readers to understand both the quantitative details and the procedural flow of the review process, thereby enhancing clarity, reproducibility, and scholarly rigor.

Figure 1

PRISMA-style diagram for the Study Selection Process in the STEAM Narrative Review (2020–2025)



Methodology

The development of our search query on the changing landscape of STEAM education was based on a narrative review that was conducted with a high level of rigor in compliance with the Preferred Reporting Items for a Systematic Review and Meta-Analysis (PRISMA) guidelines. Although it was within the scope to have a qualitative narrative synthesis instead of a strictly systematic quantitative procedure, PRISMA framework played a significant role in providing robust methodological rigor, transparency and replicability of our results. This systematic method that included identification, screening, eligibility, and inclusion steps helped to eliminate possible bias and improve the trustworthiness of the obtained insights substantially (Deák & Kumar, 2024; Rodrigues-Silva & Alsina, 2023; Marin-Marin et al., 2021).

Sources of Data and Strategic Search

In order to develop a strong evidence base, our literature search was specifically conducted using the scholarly databases Google Scholar, Semantic Scholar, Eric, Dimension, and Lens. The databases were selected due to their large and interdisciplinary coverage and offering a wide perspective on peer-reviewed research in the field of education, arts, engineering, and psychology. In order to encompass the latest developments, the search was narrowly focused on publications in the period between January 2020 and August 2025.

Our search strategy was a well-constructed combination of keywords and Boolean operators that were intended to help us make the most out of retrieving the relevant studies. The main search topics were STEM to STEAM, creative education and innovation pedagogy, which were applied to the titles, abstracts and keywords systematically. This general but narrow method was further refined by applying filters to English-language, peer-reviewed articles only.

Limiting the Landscape: Inclusion and Exclusion Criteria

Clear criteria were the key to the relevance and academic integrity of the studies that were used in this review. We had the following inclusion requirements:

- **Publication Type:** Peer-reviewed journal articles, conference papers, and systematic reviews.
- **Publication Period & Language:** English-language publications dated between 2020 and 2025.
- **Thematic Focus:** Explicitly centred on STEAM education, detailing the integration of arts into STEM.
- **Contextual Relevance:** Addressed educational settings such as K-12, higher education, teacher training, or informal learning environments.
- **Outcome Measures:** Examined outcomes directly related to creativity, innovation, or other 21st-century skills.

In contrast, we applied stringent exclusion criteria to ensure the focus and integrity of our review remained sharp:

- Studies lacking a clear STEAM focus (e.g., STEM-only or those without educational applications).
- Publications falling outside the specified timeframe or not submitted in English.
- Non-peer-reviewed sources, including editorials, opinion pieces, or book chapters.
- Research conducted in strictly technical or industrial contexts, as well as in non-educational settings.

Scrupulous Study Selection and Data Extraction

After the initial comprehensive search, there was the generation of a significant collection of records. The duplicate entries were carefully eliminated with the help of specialized reference management software. The selection was then done in a rigorous two-tiered fashion; i.e., first screening of titles and abstracts with regard to immediate relevance and then a subsequent review of the full text on the same to determine full eligibility based on our stipulated criteria. These screening and selection phases were done by two independent reviewers to improve objectivity and reduce bias. Any conflicts faced were managed through constructive debate or when necessary, with the involvement of a third reviewer (Deák & Kumar, 2024; Rodrigues-Silva & Alsina, 2023). The extraction of data was done systematically with the focus being on major aspects of the studies including authors, publication year, country of origin, educational setting, methodological approach, nature of interventions and outcomes that were reported relevant to creativity and innovation in the field of STEAM.

Synthesizing the Evidence: A Narrative Approach

A synthesis with a comprehensive narrative methodology was used by us, combining effectively both quantitative and qualitative information based on a large pool of study designs. Thematic analysis formed a fundamental part of the process and enabled us to identify some patterns in the pedagogical practices, the incorporation of technology, and the perceived student results. Moreover, bibliometric indicators, i.e., current trends in publications and contributions of particular countries, were summarized where possible, which provided a comprehensive, holistic picture of the state of the field (Gonzales et al., 2025; Deák & Kumar, 2024; Rodrigues-Silva & Alsina, 2023; Marzin-Marin et al., 2021).

Table 2

Study Selection Process for STEAM Narrative Review (2020–2025)

Phase	Records Identified	Records Screened	Full-Text Assessed	Studies Included
Identification	500			
Screening		320		
Eligibility			120	
Inclusion				40

This thorough methodology guarantees that the review offers a comprehensive and impartial synthesis of the latest research on the transition from STEM to STEAM and its effects on student readiness for innovation and creativity. The process of study identification, screening, eligibility, and inclusion was adapted from the PRISMA framework, and the results are presented in tabular form for transparency (see Table 2).

Data Distribution

The STEAM (Science, Technology, Engineering, Arts, and Mathematics) research landscape has undergone a substantial growth in the past few years, which highlights its central role in modern education and innovation. The section generalizes the results of systematic reviews and bibliometric analyses that have been published in the last five years (2020-2025) and describes how research is distributed by the area of study, the type of document, and the contributions to the literature. It aims to offer an overall picture of the implementation of STEAM education and its effects on learning, creativity, and engagement in different educational institutions (Wu et al., 2022; Conde et al., 2021; Wannapiroon & Pimdee, 2022; Li et al., 2022; Amanova et al., 2025).

Some of the key themes include the effectiveness of STEAM in promoting deeper conceptual understanding, continuous learning, and the development of critical and relevant 21st-century skills needed to solve problems and collaborate and innovate (Wu et al., 2022; Conde et al., 2021; Ozkan & Topsakal, 2020; Amanova et al., 2025). The importance of the active and student-centred experience, which is intertwined with the scientific and artistic world, is also highlighted in the literature regarding the significant role played by digital tools, robots, and virtual learning environments (Gonzalez et al., 2020; Wannapiroon & Pimdee, 2022; Li et al., 2022). Moreover, effective STEAM is always associated with effective teacher training, innovative curriculum, and collaborative teaching design, which can resolve the issue of interdisciplinary integration and limited resources (Li et al., 2022; Amanova et al., 2025). This discussion will shed insight into the transformational possibilities of STEAM, as well as the aspects of its successful implementation and execution.

Subject-Areas Distribution

The recent, 2020-2025 research in STEAM is largely placed in the context of Education, with much emphasis on the practices in pedagogy, curriculum, and experiences of learners in K-12 and post-secondary settings (Liu, 2024; Leavy et al., 2023; Awwalina et al., 2025). Although the Arts are becoming more integrated, there are reviews that show a relative scarcity of focused research on certain arts disciplines in comparison with science and engineering (Leavy et al., 2023). The research in engineering is highly evident, and one of the studies that examines the intersection of engineering discipline with creative and artistic approaches (Santi et al., 2021). Psychology offers insights on attitudes, motivation, and the acquisition of 21st-century skills such as creative thinking, self-confidence, and computational thinking, usually in technologically enhanced learning settings (Al-Zahrani et al., 2024). This interdisciplinary emphasis highlights the ability of STEAM to bridge the technical and creative fields to comprehensive student growth and development.

Distribution According to Document Type

The source of scholarly dissemination in STEAM research as of 2020-2025 is) journal articles that serve as the primary medium for disseminating empirical evidence and theoretical development (Awwalina et al., 2025; Safi'i et al., 2024). Conference papers also play a significant role, particularly in such frequently changing subfields of research such as emerging technologies and AI use in STEAM education (Santi et al., 2021). In addition, the emergence of systematic reviews and bibliometric analyses delivers essential syntheses of trends in research, outlines the impactful pieces, and indicates gaps in the current literature (Liu, 2024; Leavy et al., 2023; Awwalina et al., 2025; Safi'i et al., 2024). As an example, a single bibliometric study noted that journal publications and articles were the most prevalent types of documents used because the field was relying on rigorous peer-reviewed scholarship (Awwalina et al., 2025).

Country-wise Contributions

STEAM research has proven to have a strong presence worldwide with significant input **by** from Western and Asian countries. The US is the biggest producer of publications, with Spain, Taiwan, Turkey, China, South Korea, and Indonesia following with significant contributions (Liu, 2024; Awwalina et al., 2025; Al-Zahrani et al., 2024; Santi et al., 2021; Safi'i et al., 2024). Spain and South Korea are especially active in the implementation of AI and emerging technologies in the sphere of STEAM education (Liu, 2024; Al-Zahrani et al., 2024). Indonesia has shown a marked increase in STEAM-related scholarship, especially concerning language teaching and curriculum innovation (Safi'i et al., 2024). Emerging contributors include Jordan and Portugal, signalling the widespread adoption and adaptation of STEAM frameworks across diverse educational systems and cultural contexts (Liu, 2024; Awwalina et al., 2025). The combined results of these distributions are summarized in Table 3, which provides a comparative overview of the main subject areas, document types, and country-level contributions to STEAM research between 2020 and 2025.

Table 3

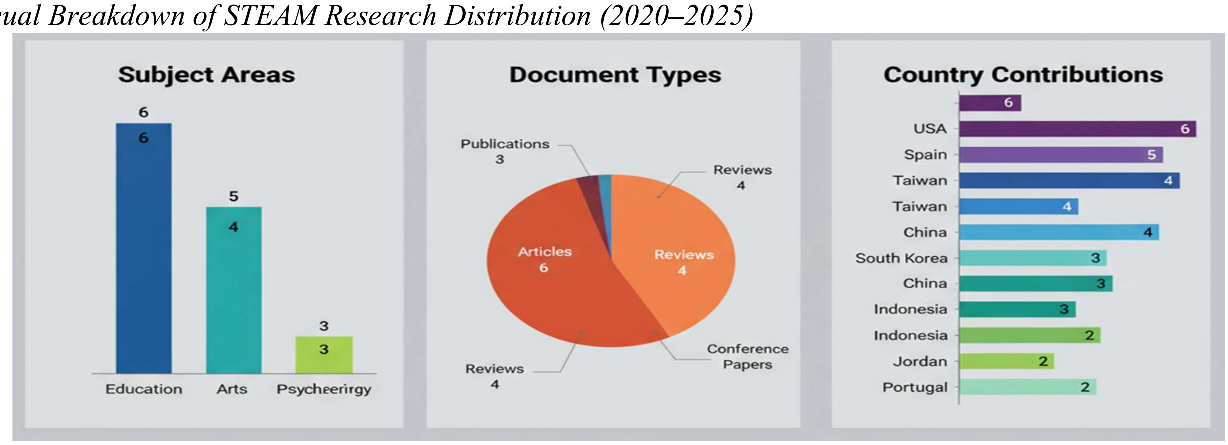
Overview of STEAM Research Distribution by Country, Subject Area, and Document Type (2020–2025)

Country	Main Subject Areas	Document Types	Notable Trends/Focus
USA	Education, Engineering	Articles, Reviews	Leading publication volume, SDGs
Spain	Education, Technology	Articles, Reviews	AI in STEAM, teacher attitudes
Taiwan	Education, Arts	Articles	K-12, post-secondary, attitudes
Turkey	Education, Engineering	Articles, Conference	K-12, technology integration
China	Engineering, Technology	Articles	Emerging tech, SDGs
South Korea	Science, Engineering	Articles, Conference	Productive in science-arts convergence
Indonesia	Education, Arts	Articles, Reviews	Language teaching, curriculum
Jordan	Education	Articles	K-12, teacher attitudes
Portugal	Education, Arts	Articles	STEAM integration in curriculum

To visually represent these distributions, Figure 2 illustrates the comparative activity across subject areas, document types, and leading countries.

Figure 2

Visual Breakdown of STEAM Research Distribution (2020–2025)



STEAM Education: Impact on Innovation and Creativity

The evidence overwhelmingly points to STEAM education's significant positive impact on fostering innovation and creativity across various educational levels and contexts. Table 4 summarizes key studies highlighting these effects.

Table 4

Representative Studies on STEAM Education's Impact on Innovation and Creativity

Study/Authors	Population & Context	Intervention/Approach	Key Outcomes
Wannapiroon & Pimdee (2022)	Thai undergraduates	Digital virtual classroom with STEAM and gamification	Increased creativity and innovation vs. traditional methods; high expert approval
Kuo (2024)	6th grade, Taiwan	STEAM + Project-Based Learning (PBL)	Improved creative thinking (divergent, original, evaluative); outperformed control
Wang & Rahim (2024)	Art college students, China	STEAM curriculum	Enhanced innovation, creative self-efficacy, engagement, and performance
Shatunova et al. (2019)	Schoolchildren & university students, Russia	Project-based STEAM in “creative spaces”	Improved project management, system thinking, art creativity, teamwork, adaptability
Filipe et al. (2024)	9th-10th grade, Portugal	Integrated STEAM (iSTEAM) for soundtrack creation	Boosted creativity in problem-solving, digital competence, and engagement
Mariana & Kristanto (2023)	8th grade, Indonesia	STEAM + Computational Thinking	Developed critical and creative thinking, flexibility, and design aesthetics
Chang et al. (2023)	7th grade, Taiwan	STEAM Project-Based Learning	Significant gains in creativity (fluency, flexibility, originality, elaboration)
Zhan et al. (2022)	Middle school, China	STEAM with association interventions	Remote association most effective for creative thinking; close for aptitude/design
Ozkan & Topsakal (2019)	7th grade, Turkey	STEAM design process	Significant improvement in verbal and figural creativity vs. control
Sangwaranatee et al. (2024)	Grade 12, Thailand	STEAM + Engineering PBL	Enhanced creativity, innovation, and collaborative behaviour
Aguilera & Ortiz-Revilla (2021)	Systematic review	STEM vs. STEAM interventions	Both improve creativity; evidence for STEAM’s superiority is mixed
Gu et al. (2023)	University students, China	STEAM-based creativity training	Significant gains in creative ability and self-efficacy
Zhao & Abdullah (2025)	Undergraduates, China	STEAM + Problem-Based Learning	Improved creative thinking, engagement, and interdisciplinary application
Wilson et al. (2021)	K-12, USA	Transdisciplinary STEAM lessons	Increased creativity, problem-solving, collaboration, and engagement

Study/Authors	Population & Context	Intervention/Approach	Key Outcomes
Wised & Inthanon (2024)	Systematic review	STEAM-based programs	Enhanced critical thinking, creativity, problem-solving, and real-world skills
Zakaria & Osman (2024)	Systematic review	STEAM in primary education	Most effective for creativity and problem-solving, including disadvantaged groups
Erol et al. (2022)	Early childhood, Turkey	STEAM with tales and engineering design	Improved creativity and problem-solving skills
Nur et al. (2023)	Early childhood, Indonesia	STEAM model implementation	Increased creativity, flexibility, and collaboration

Table 5
Key Dimensions and Supporting Evidence for STEAM's Educational Impact

Dimension	Evidence Summary	Representative Studies
Creative Thinking	Consistently improved across age groups and contexts; includes fluency, flexibility, originality	(Kuo, 2024; Filipe et al., 2024; Chang et al., 2023; Ozkan & Topsakal, 2019; Gu et al., 2023; Zhao & Abdullah, 2025; Wilson et al., 2021)
Innovation Skills	Enhanced through project-based, interdisciplinary, and digital approaches	(Wannapiroon & Pimdee, 2022; Siwen & Rahim, 2024; Shatunova et al., 2019; Sangwaranatee et al., 2024; Wised & Inthanon, 2024; Zakaria & Osman, 2024)
Problem-Solving	STEAM fosters real-world, collaborative, and adaptive problem-solving	(Filipe et al., 2024; Mariana & Kristanto, 2023; Zhan et al., 2022; Ozkan & Topsakal, 2019; Wised & Inthanon, 2024; Zakaria & Osman, 2024; Erol et al., 2022)
Engagement & Self-Efficacy	Increased motivation, engagement, and creative self-efficacy	(Wannapiroon & Pimdee, 2022; Siwen & Rahim, 2024; Filipe et al., 2024; Gu et al., 2023; Wilson et al., 2021; Nur et al., 2023)
Collaboration	Promoted through team-based and transdisciplinary projects	(Shatunova et al., 2019; Sangwaranatee et al., 2024; Wilson et al., 2021; Nur et al., 2023)

Table 5 summarizes the key educational dimensions influenced by STEAM, including creative thinking, innovation skills, problem-solving, engagement, and collaboration, along with relevant supporting studies.

Discussion

Thematic Synthesis of Findings

The period between 2020 and 2025 marks a pivotal shift from STEM to STEAM education, fundamentally reshaping how we prepare students for an innovation-driven world. The synthesis of our recent systematic reviews and empirical studies shows that the combination of arts with the classic fields of STEM helps to form more comprehensive, flexible, and student-focused learning. The paper will discuss three important dimensions, including the development of teaching practices, the critical role of digital technology, and the substantial impact on creativity and innovation among students, in the framework of contemporary teaching practices.

Evolving Teaching Approaches: Embracing Flexibility

Although traditional STEM education has been effective in terms of teaching technical skills, it has been criticized because of its narrow focus and inability to encourage creativity and innovative thinking. The shift to STEAM represents a significant transformation towards flexible learning, interdisciplinary learning, and students gaining control of their education. Recent studies point to the fact that project-based, challenge-based, and collaborative learning are included in STEAM. These approaches are more sensitive to students' diverse interests and their practical problem-solving requirements (Belbase et al., 2021; Amanova et al., 2025; Prahani et al., 2023).

For example, it has been found that creative spaces and collaborative instruction enable students to solve real, cross-disciplinary assignments that integrate scientific investigation as well as artistic representation. It fosters such fundamental competencies as flexibility, collaboration, and readiness to make creative decisions (Shatunova et al., 2019; Chen & Ding, 2024). Computational Pedagogy, Content Integration, and Iterative Design (CPACK) and Design Thinking are frameworks that are increasingly applied to guide students and teachers in the process of solving complex, open-ended problems (Chen & Ding, 2024; Li et al., 2022). This flexible mode of teaching is essential to the creation of the 21st-century skills of our fast digital society.

The Strength of Digital Resources and Contexts

The interdisciplinary vision of STEAM has been achieved with the help of digital tools and platforms. It has been reviewed those technologies such as GeoGebra to visualize mathematics, Scratch to create and code creatively, and FabLab to design and make are widely used (Leavy et al., 2023; Deak & Kumar, 2024). These platforms do not just connect arts with technology, but also make the creative learning experiences more accessible. FabLabs and makerspaces allow students to prototype, experiment, and work together on real-world projects to reflect the essentials of design thinking and innovation (Deák & Kumar, 2024).

Virtual Classroom Learning Environments (VCLEs) or gamified platforms serve to provide further engagement, motivation, and self-efficacy, especially in combination with culturally relevant and inclusive pedagogies (Wu et al., 2022; Hsiao & Su, 2021). Such tools are typically integrated following frameworks such as the Culturally Sustaining Education Framework (CSEF), which also makes digital innovation accessible and meaningful among a wide range of students (Deák & Kumar, 2024). Nevertheless, as the reviews also observe, there is still a certain gap in the specific cultivation of arts-related competencies, which indicates the necessity of more purposeful and comprehensive incorporation of the A in STEAM (Leavy et al., 2023).

Creativity & Innovation Outcomes: Empirical Evidence and Student Impact

In numerous empirical studies, the significance of STEAM education is emphasized when it comes to the development of creativity, innovation, and higher levels of problem-solving skills in students. The results of the experimental paradigm have shown that students in STEAM-enhanced educational programs that promote engineering design challenges, construction of digital narratives, and collaborative art-science projects show significantly higher scores on divergent thinking, conceptual synthesis, and intrinsic motivation, compared to students studying in traditional STEM programs (Ozkan & Topsakal, 2020; Erol et al., 2022). As an example, an empirical study of STEAM programs in early childhood has shown a substantial improvement in creative ideation and problem-solving skills with a strategic combination of storytelling and engineering design (Erol et al., 2022). In secondary and tertiary educational settings, it was found that project-based STEAM interventions are associated with enhanced learning outcomes, increased affective engagement, and strong development of cross-functional competencies essential in the future career path (Amanova et al., 2025; Chen & Ding, 2024). Moreover, it is not only cognitive development, but also promising attitudinal change, long-term learning attitudes, and high self-efficacy that are promoted by STEAM, which is supported by the research using ARCS model and technology acceptance models (Wu et al., 2022). Despite such achievements, systematic reviews present the need for more methodologically rigorous, longitudinal, and arts-focused research projects in order to fully outline the broad impact of STEAM on innovation and creativity (Leavy et al., 2023; Perignat & Katz-Buonincontro, 2019).

Theoretical Underpinning: CPACK, Design Thinking, CSEF

The successful implementation of STEAM pedagogy is conditional on a number of modern theoretical frameworks. CPACK model assumes an integrative model that emphasizes the use of computational thinking, domain-specific knowledge, and an iterative design process and, therefore, provides educators and learners with a solid scaffold to solve complex interdisciplinary problems (Chen and Ding, 2024). A heuristic, Design

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Thinking, which is a common approach to creative problem-solving in FabLab and makerspace settings, is a flexible yet structured approach to creative problem-solving, stimulating empathic insight, intuitive ideation, high-speed prototyping and critical thinking (Deák & Kumar, 2024; Li et al., 2022). Simultaneously, the Culturally Sustaining Education Framework (CSEF) is a critical meta-framework whereby STEAM programs are inherently inclusive, equitable, and highly responsive to the diverse cultural ontology of every learner, and, by extension, optimize the potential of STEAM education (Deák & Kumar, 2024). Together, these frameworks are important conceptual frameworks, which help to conceptualize, implement, and assess STEAM programs, so that they are innovative in nature and available to all.

Summary

The historical process of STEM to STEAM development in 2020-2025 has demonstrably enhanced the agility in pedagogy, the synergistic opportunities of digital innovations, and the empirical increase in student innovativeness and creativity. The long-term investigation of the subject and a wise, strategic integration of the arts are the key to the full realization of the potential of STEAM to prepare the future generations of people to face the emerging complexities of the world.

NOISE Analysis

Needs: Curricular Reform and Pedagogical Specialization

This rapid development of the STEAM education implies the urgent reconsideration and thorough redesign of the current curricula to truly incorporate artistic subjects in science, technology, engineering, and mathematics (see Table 6). The conventional system of education is often characterized by a certain rigidity and insularity of discipline, which hinders the development of emergent creativity and innovation. The urgency of intensive teacher professional development and upskilling, especially in advanced digital literacy and culturally sustaining pedagogies, is emphatically highlighted by systematic reviews. This kind of training is central to ensure that educators are skilled to provide effective STEAM content and are also flexible in embracing new technological affordances (Deák & Kumar, 2024; Leavy et al., 2023; Martín-Cudero et al., 2024). Without a well-grounded professional development program, teachers can face serious challenges in implementing STEAM pedagogy, or in utilizing digital resources to achieve creative learning results.

Opportunities: Transdisciplinary Praxis and Creative Actualization

STEAM education offers material prospects into (significant opportunities for) transdisciplinary learning, where students have the capability of developing epistemic connections among different fields, and using synthesized knowledge to tackle complex and real-world problems. The mindful inclusion of the arts into STEM does not only trigger the creative mind but also drives the acquisition of critical thinking skills, synergy, and adaptive resilience as the main components of the 21st century (Deák & Kumar, 2024; Leavy et al., 2023; Gonzalez et al., 2020). At the same time, the new technologies, including sophisticated robotics, simulators, and specialized makerspaces, greatly expand the boundaries of creative expression and creative production. Additionally, the implementation of the paradigms of project-based and challenge-based learning has significantly increased student engagement and conceptual internalization (Conde et al., 2021; Wannapiroon & Pimdee, 2022; Martín-Cudero et al., 2024).

Improvements: Policy Architecture and Digital Infrastructure Investment

In order to realize the transformative potential of STEAM in its entirety, we cannot go without solid policy support. It includes the formulation of clear principles of curricular integration, specific financial resources devoted to the development of teacher training programs, and the creation of incentive systems to promote the use of STEAM models in educational institutions (Perales & Aróstegui, 2021; Martinez-Cudero et al., 2024). Additionally, significant investment in advanced digital infrastructure such as ubiquitous access to computers, high-bandwidth internet connectivity, and advanced digital platforms (e.g., GeoGebra, Scratch, FabLab) is of paramount importance in the provision of equal participation and the efficient utilization of technology in innovative learning environments (Deák & Kumar, 2024; Leavy et al., 2023; Conde et al., 2021). Institutions and faculty of educational organizations are also advised to hire dedicated technology specialists, incorporate gamification, and institutionalize continuous reflective practice and methodology refinement (Deák & Kumar, 2024).

Strengths: Integrated Learning and Increased Student interaction/engagement

The key asset of STEAM education is its inherent pedagogical paradigm that is holistic and inherently promotes both cognitive and affective learning spheres. By the symbiotic combination of technical and artistic sensitivity, STEAM inherently develops high levels of student interest, increased motivation, and strong self-efficacy (Deák & Kumar, 2024; Leavy et al., 2023; Conde et al., 2021; Wannapiroon & Pimdee, 2022). The results of empirical case studies consistently indicate that students who are exposed to the STEAM programs have developed high levels of problem-solving skills, enhanced conceptual understanding as well as enduring attitudes towards lifelong learning. The Culturally Sustaining Education Framework (CSEF) also helps to support the fundamental nature of STEAM as an inclusive field and its sensitivity to the diverse cultural backgrounds of different student groups (Deák & Kumar, 2024). Table 6 presents a NOISE analysis of STEAM education research from 2020 to 2025, highlighting key needs, opportunities, improvements, and strengths identified in recent scholarship across various studies.

Table 6

NOISE analysis summary for STEAM education research (2020–2025)

Dimension	Key Points	Citations
Needs	Curriculum redesign, teacher digital upskilling, inclusive pedagogy	(Deák & Kumar, 2024; Leavy et al., 2023; Martín-Cudero et al., 2024)
Opportunities	Interdisciplinary learning, creativity, emerging tech, project-based models	(Deák & Kumar, 2024; Leavy et al., 2023; Conde et al., 2021; Wannapiroon & Pimdee, 2022)
Improvements	Policy support, digital infrastructure, tech experts, gamification, ongoing adaptation	(Deák & Kumar, 2024; Perales & Aróstegui, 2021; Martín-Cudero et al., 2024)
Strengths	Holistic learning, student engagement, motivation, self-efficacy, inclusivity	(Deák & Kumar, 2024; Leavy et al., 2023; Conde et al., 2021; Wannapiroon & Pimdee, 2022)

Limitations

There are a number of methodological limitations associated with this systematic review. First and foremost, this time range (2020–2025) and the use of 5 large bibliographic databases (Google Scholar, Semantic Scholar, Eric, Dimension, and Lens) may have inadvertently limited the scope of the results since it might not have captured the relevant works published beyond the specified period or in different repositories (Deák & Kumar, 2024; Leavy et al., 2023). Secondly, a careful selection of keywords that also focused on such terms as STEM to STEAM, creative education, and innovation pedagogy could have inadvertently excluded the literature that used other nomenclature or prioritized separate fields of arts or technology, thereby potentially creating gaps in the retrieved scholarly corpus (Leavy et al., 2023; Marín-Marin et al., 2021). Third, the inclusion and exclusion criteria that were adopted, namely, the limitation to English-language, peer-reviewed articles and formal learning settings, might be a source of systematic bias, narrowing the range of scholarship and views to represent non-English-speaking scholarly traditions or less formal learning settings (Deák & Kumar, 2024; Leavy et al., 2023). Moreover, the very construction and future use of analytical frameworks (e.g., NOISE, CSEF) is bound to influence the interpretive lens through which the findings are viewed because these analytical systems themselves are coloured by specific theoretical biases and priorities. Lastly, the dynamic and constantly changing nature of STEAM education suggests that certain innovative practices or new technologies may not be visible in the existing academic literature yet, therefore, highlighting the need for continuous, dynamic updating of the field of knowledge in the given direction (Deák & Kumar, 2024; Leavy et al., 2023; Martino-Cudero et al., 2024).

Conclusion

This comprehensive review unequivocally demonstrates that STEAM education, when meticulously conceptualized and diligently implemented, possesses a formidable capacity to catalyse a transformative shift in learning paradigms by fostering creativity, innovation, and holistic student development. The strategic integration of the arts into existing STEM subjects directly both responds to vital requirements in curricular reform and advanced educator expertise, and also offers a wealth of opportunities for transdisciplinary study and the establishment of key competencies of the 21st century. These developments cannot be maintained without a strong policy support and directed investment in advanced digital infrastructure to ensure equitable access to high-quality STEM learning opportunities. Despite the recognized constraints in the aspects of time range, chosen databases, and keyword specificity, the cumulative evidence strongly supports the intrinsic strengths of STEAM in increasing the level of student engagement, intrinsic motivation, and inclusivity. Further academic research should aim to broaden the area of investigation, examine different educational settings, and directly inform policy development to entrench STEAM concepts solidly into the education systems of the world. This will ensure that every learner is best equipped to deal with the multifaceted problems and limitless opportunities that are the hallmark of an ever-changing, innovative, and globalized society.

Future Research Directions

The prospects of future studies are outlined by emerging academia in STEAM education between 2020 and 2025. First and foremost, there is an unquestionable necessity to theorize and empirically support effective theoretical constructs that specifically address the approach to STEAM-based pedagogy. Specifically, these frameworks should be in place to deal with the complexities that underpin successful outcomes in interdisciplinary integration and development of advanced digital skills, which support sustainable innovation (Deák & Kumar, 2024; Bhattacharjya, 2025). Extending research into transdisciplinary models, which transcend mere subject integration to foster resilience and adaptability in the face of pervasive automation and evolving workforce dynamics, will be foundational for preparing learners for prospective societal and economic demands (Bhattacharjya, 2025).

Secondly, future inquiries ought to prioritize the diversification of research contexts and methodological approaches. This includes broadening the range of academic journals, research objectives, and the specific STEAM elements under scrutiny, as well as consciously incorporating underrepresented learner populations such as early childhood cohorts, gifted students, and those from non-Western or resource-constrained settings (Lee, 2025; Lazić, 2024; Tran et al., 2024). A concomitant need exists for an increased prevalence of longitudinal and mixed-methods research designs to comprehensively capture the long-term cumulative impacts of STEAM interventions on creativity, advanced problem-solving, and the enduring disposition towards continuous learning (Chen, 2025; Wu et al., 2022).

Thirdly, researchers are strongly encouraged to rigorously explore the transformative role of emergent technologies, including artificial intelligence, immersive virtual reality, and expansive open educational resources, in augmenting STEAM learning experiences and facilitating the open, networked co-construction of knowledge (Ramírez-Montoya et al., 2025; Al-Zahrani et al., 2024). Investigating effective strategies for the equitable integration of these technologies into both curricula and teacher professional development programs will be pivotal for scaling STEAM education initiatives globally.

Finally, future research must proactively address the multifaceted challenges inherent in policy formulation and implementation. This encompasses the development of effective strategies for comprehensive curriculum redesign, innovative models for teacher professional development, and the creation of resilient digital infrastructures (Ramírez-Montoya et2025; Deák & Kumar, 2024; Bhattacharjya, 2025). Collaborative, cross-sectoral investigations involving educators, policymakers, and industry stakeholders are crucial for identifying best practices and informing evidence-based reforms that ensure STEAM education remains acutely responsive, inclusively designed, and optimally future-ready.

By diligently pursuing these delineated research directions, the field can significantly deepen its nuanced understanding of STEAM's profound transformative potential and actively contribute to the development of innovative, equitable, and sustainable educational ecosystems worldwide.

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Conflicts of Interest

The author declare no conflict of interest.

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