

STEAM in Practice and Research in Primary Schools: A Systematic Literature Review

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Abstract

STEAM education, which involves integrating science, technology, engineering, and mathematics (STEM) with the arts, has gained popularity in recent years. While the arts in STEAM education promote 21st-century skills such as creativity and offer new ways of thinking and knowing, there is currently a lack of empirical guidelines for primary schools to formulate STEAM-based learning content and assessment. This makes it challenging for educators to implement STEAM-based integrated disciplines in practice and evaluate their educational potential. This study aims to provide an up-to-date overview of STEAM primary education to promote its effective implementation. A thematic analysis of 19 studies was conducted to examine STEAM's purpose, learning content, theoretical orientations, pedagogical strategies, research methodologies, and assessments of educational outcomes. This review revealed that studies of STEAM in primary schools employed a variety of theories, such as the technological pedagogical content knowledge (TPACK) theory and experiential learning theory. Most of these studies adopted mixed methods, and their assessment methods included questionnaires, interviews, and observations. The studies found that STEAM in primary education was effective at enhancing students' attitudes, knowledge, and skills. This review also calls for educators to use the arts in STEAM learning and other transdisciplinary or interdisciplinary education to empower students to reach their full learning potential and exercise greater agency in such learning. The review contributes to the literature by providing guidelines for promoting the effective implementation of STEAM

education in primary school contexts. Finally, the review identifies important research gaps and discusses future research directions.

Keywords: STEAM education, interdisciplinary and transdisciplinary education, primary schools, systematic review, arts-based approach

1. Introduction

STEAM education, which encompasses science, technology, engineering, arts, and mathematics (Rodrigues-Silva & Alsina, 2023), evolved from the STEM reform movement (i.e., STEAM minus the A for the arts) in the United States in the early 1990s (Leavy et al., 2023). It covers all educational levels, from preschool to postdoctoral study, and from formal classroom teaching to informal and after-school activities (Gonzales & Kuenzi, 2012; Su & Yang, 2023; Su et al., 2024). STEAM's inclusion of the arts allows greater access to STEM education (Colucci-Gray et al., 2019) and increases the likelihood that it will initiate individual and social change by allowing students to better understand, identify, and tackle issues in the real world (Bass et al., 2016). It has been argued that introducing STEAM at the primary school level has increased students' motivation and engagement in STEM fields (Ortiz-Revilla et al. 2021) and prepared them for the STEM workforce (Das, 2020). Primary education is the first key stage in students' formal education and has a major influence on their personal, social, and educational development (UNESCO, 2005). At this educational level, students acquire foundational skills and knowledge in reading, writing, and mathematics while also receiving formal exposure to STEAM (Santi et al., 2021).

The addition of the arts to the original STEM framework was intended to address its limitations (Perignat & Katz-Buonincontro, 2019; Yakman & Lee, 2012) and promote the creative and innovative ideas required in the 21st century (Land, 2013). However, despite the popularity of STEAM, there is little consensus on its purpose (Perignat & Katz-

Buonincontro, 2019), learning content (Colucci-Gray et al., 2019), assessment, and reporting of learning outcomes (Anderson, 2021). Ng et al. (2022) highlight that STEAM integrates each STEM discipline with the arts to allow students to learn in an interdisciplinary manner. Others believe that STEAM is more than an instructional approach (Belbase et al., 2022) because it transcends disciplinary boundaries (Quigley et al., 2020); in this sense, STEAM is presented as a paradigm shift to achieve integrative and holistic education (Yakman & Lee, 2012) to address real-world problems (Rodrigues-Silva & Alsina, 2023). Disciplinary, interdisciplinary, transdisciplinary, and multidisciplinary integration models of STEAM education have been proposed (Ng et al., 2022), each with their own theoretical foundations and conceptualizations (White & Delaney, 2021). This has been a source of confusion for educators and researchers (Ortiz-Revilla et al., 2020), since the implementation of STEM has lacked a cohesive conceptual framework in terms of its associated pedagogical practice (Kelley & Knowles, 2016). Many STEAM educators have struggled to determine the purpose of STEAM and identify the pedagogical strategies necessary for integrating the arts into STEM education (Kang, 2019; Kwan & Wong 2021). Furthermore, there have been limited studies offering suitable ways to assess STEAM's learning outcomes (Anderson, 2021; Perignat & Katz-Buonincontro, 2019). Thus, there is a need to provide an up-to-date overview of STEAM in primary education to promote its effective implementation.

2. Literature review

2.1 From STEM to STEAM

STEM, which is an abbreviation that was coined by the National Science Foundation (NSF) in the United States in 2001, is an approach to learning and development that integrates science, technology, engineering, and mathematics (Leavy et al., 2023). In 2009, former US President Barack Obama declared that all students should receive STEM education (Krüger & Chiappe, 2021). The addition of the arts to the original STEM

framework was a key feature of STEM reform, promoting a paradigm shift by exploring transdisciplinary knowledge as well as the key principles of each discipline (Bush & Cook, 2019; Rabalais, 2014). The inclusion of the arts has promoted equal and early access to STEM for all students (Burnard et al., 2021) and has reduced gender disparities and the barriers disadvantaged students face in both STEM education and STEM careers (Leavy, 2023). Previous literature shows that the arts promote student participation at all ages (Papavlasopoulou et al., 2019), engage them in learning (Vicente et al., 2021), and help them gain new knowledge and skills (Duo-Terron et al., 2022; Lage-Gómez & Ros, 2023). However, STEAM education is often criticized as a type of definitional crisis (Perignat & Katz-Buonincontro, 2019), as evidenced by teachers' lack of clarity regarding the learning purpose of STEAM (Leavy, 2023), its theoretical–practical contradictions (Aguilera & Ortiz-Revilla, 2021), and its weak pedagogical strategies and methods (Colucci-Gray et al., 2017; Perignat & Katz-Buonincontro, 2019). There have been calls for further research on the theory and practice of STEAM (Kang, 2019), as well as more evidence-based guidelines for educators on how to implement STEAM education, particularly with existing pedagogies (Aktürk & Demircan, 2017; White & Delaney, 2021).

2.2. STEAM education in primary school contexts

Many researchers and educators have raised concerns about how to integrate STEAM at the primary school level (Lage-Gómez and Ros, 2023; Vicente et al., 2021). For example, the STEAM curriculum in Korea was implemented as a major nationwide educational policy in 2011 (Kang, 2019). Referring to the STEAM curriculum in Korea, Kim and Bolger (2017) argue that the effectiveness of STEAM in primary school settings depends heavily on the extent of teachers' conceptual understanding of the purpose of STEAM education.

School subjects tend to be taught in isolation from each other in the primary school context (Ortega-Torres, 2022), which can render the implementation of STEAM education difficult due to its transdisciplinary nature. Moreover, primary school teachers find integrating STEAM activities challenging because such integration requires knowledge of all STEAM subjects (Duo-Terron et al., 2022). In addition, teachers have limited knowledge and experience of integrating the arts with STEM disciplines (Uştu et al., 2022), assessing students in STEAM curricula (Chen et al., 2018), and revealing the associated learning outcomes and benefits of STEAM for primary school students (Lage-Gómez and Ros, 2021; Ortiz-Revilla et al., 2021). Since STEAM education in primary school settings is underresearched compared to STEM education (English, 2017), there is a need to review the existing research on STEAM implementation in primary school settings and offer corresponding recommendations for teachers and policy-makers.

2.3 STEAM learning and assessment standards

STEAM education originally followed the learning and assessment standards of the NSF in the United States (Bass et al., 2016). Other learning and assessment standards were subsequently included, such as those of the Programme for International Student Assessment (PISA) (Duo-Terron et al., 2022), the International Society for Technology in Education (ISTE) (Krüger & Chiappe, 2021), and the Trends in International Mathematics and Science Study (TIMSS) (White & Delaney, 2021).

Numerous efforts are currently being made to enhance students' skills and create ways of addressing pressing global issues in STEAM education (Perignat & Katz-Buonincontro, 2019). These include global initiatives such as the Partnership for 21st Century Learning (Ng et al., 2022; Krüger & Chiappe, 2021), the UNESCO Sustainable Development Goals (SDGs), and “education for sustainability” in the areas of knowledge, values, agency, and actions (Rodrigues-Silva & Alsina, 2023). Duo-Terron et al. (2022), for instance, link

their study to the development of 21st century skills such as the 4C skills (i.e., creativity, critical thinking, collaboration, and communication).

There have also been national efforts to introduce STEAM learning in local primary schools, such as the Turkish 2015-2019 Strategic Plan (Aktürk & Demircan, 2017), the Korean Ministry of Education's 2011 plan (Anderson, 2021), and the four-stage learning program of the Chicago Arts Partnership in Education in the United States (Chen et al., 2018).

Despite the existence of a variety of global, national, and local standards in relation to STEAM education, it is challenging to assess its learning outcomes, as they often involve complex and collaborative tasks that are not in line with traditional methods of testing and grading (Anderson, 2021; Krüger & Chiappe, 2021). The subject-based nature of traditional methods of testing and grading has made it difficult to assess integrated learning outcomes. Although STEAM education has recently been the focus of exhaustive research, there has been insufficient research on instruments that attempt to assess STEAM in a valid and reliable manner (Anderson 2021). This review aims to bridge this research gap.

2.4 Previous review studies on STEAM education

As shown in Table 1, previous review studies have not explored STEAM education in primary school settings. Many related studies (n=15) reveal that there are challenges in implementing STEAM in early childhood education (Aktürk and Demircan 2017; Wahyuningsih et al., 2020), in secondary school (White and Delaney, 2021), and in education in general (Aguilera & Ortiz-Revilla, 2021; Krüger & Chiappe, 2021). Despite the lack of attention received by primary school education in study reviews on STEAM education, research has highlighted the critical role of early learning in shaping future academic success (Rodrigues-Silva & Alsina, 2023).

Table 1*Previous reviews on STEAM education*

Reviews	Published year	# of articles	Period	Focus	Level
Aktürk and Demircan (2017)	2017	22	2006-2016	Methods, participants, and main findings	Early childhood education
Kang (2019)	2019	11	2012-2018	STEAM initiatives in Korea and their effects	All students
Perignat and Katz-Buonincontro (2019)	2019	44	2007-2018	The role of the arts, purpose of study, definitions of STEAM, and arts education learning outcomes	All students
Sawangmek (2019)	2019	33	2008-2018	Thai and international STEM and STEAM studies: 1) country, 2) participants, and 3) focus point of study	Early childhood education
Wahyuningsih et al. (2020)	2020	40	2007-2019	Use of STEAM and its outcomes	Early childhood education
Aguilera and Ortiz-Revilla (2021)	2021	14	2013-2020	1) Definition of STEM or STEAM education; 2) the method used to measure creativity; 3) the type of creativity measured; 4) the impact of STEM/STEAM education on creativity; 5) the justifications for the research.	All students

Anderson (2021).	2021	50	2000-2021	Design type, goal and purpose, learning outcomes	All students
Krüger and Chiappe (2021).	2021	153	1998-2019	21st-century skills and their relationship to STEAM learning	All students
Kwan and Wong (2021).	2021	63	2013-2018	Characteristics (purpose, content, and trends)	All students
Santi et al. (2021).	2021	30	2013-2020	Focus on the environmental and science components STEAM	All students
White and Delaney (2021)	2021	11	2018-2021	Pedagogical strategies and learning outcomes	Secondary school
Johnston et al. (2022)	2022	194	2012-2022	STEAM in relation to maker space	Early childhood education
Ng et al. (2022)	2022	17	2010-2021	Conceptualization of STEAM, and key factors and challenges in its implementation	Early childhood education
Leavy et al. (2023)	2023	44	2007-2018	1) The emerging technologies used in STEAM education; 2) which arts disciplines are being integrated; 3) methodological approach; 4) pedagogical motivation	All students

Rodrigues-Silva and Alsina (2023)	2023	12	2007-2022	Theoretical orientations, educational perspectives	Early childhood education
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Many previous reviews have explored questions such as the prevalence and use of emerging technologies (Leavy et al., 2023), the role of the arts (Perignat & Katz-Buonincontro, 2019), and developing students' creativity (Aguilera & Ortiz-Revilla, 2021). Although creativity is frequently mentioned as a direct learning outcome, studies rarely offer suggestions on how to measure or assess it (Perignat & Katz-Buonincontro, 2019). On the other hand, other researchers have considered clarifying the conceptual and theoretical framework of STEAM practices (Johnston et al., 2022) as well as the factors influencing the effectiveness of STEAM education (Ng et al., 2022). Although these reviews have contributed to the public understanding of STEAM across all educational levels, they have not focused on exploring its learning purpose, pedagogy, and assessment methods in relation to teaching young students. To specifically understand how STEAM education is taught in primary schools, it is important to review the theories, pedagogies, learning content, assessment methods, and learning outcomes of STEAM in primary school settings.

3. Research aims and questions

As Colucci-Gray et al. (2019) argue, STEAM education is likely to continue to gain momentum (Belbase et al., 2022). To promote the implementation of a STEAM education that does not follow the limited path of STEM education (Herro & Quigley, 2019), this review adopts research on the new science of learning (Sawyer, 2005) to formulate its own research questions and provide insights into integrated pedagogical strategies and design implementation in classroom learning (Ma & Scardamalia, 2022). The new science of learning has been widely used in educational research (Darling-Hammond et al., 2020), for example to improve the effectiveness of creative teaching (Halverson & Sawyer, 2022) and to

develop the Four Pillars of Learning framework for educational technology (Hirsh-Pasek et al., 2015). According to Towne and Shavelson (2002), theoretical frameworks are vital to scientific research in education because they help researchers align their learning goals with classroom activities. Fischer et al. (2018) argue that educational research must be based on theory, which is valuable in framing empirical research and generalizing findings across a variety of contexts. When educational activities are based on learning theories and research methodologies from the science of learning (Nesbitt et al., 2023), educators can better understand how different educational subjects are interconnected and that their integration can enhance students' learning experience (Darling-Hammond et al., 2020). The core principle of evidence-based education is that government policy and educational practices should be shaped by the findings of rigorous research (Towne & Shavelson, 2002).

Therefore, the current review aims to examine how STEAM education is implemented in primary schools. Five research questions (RQs) are formulated:

RQ1: What is the purpose of STEAM education in primary schools?

RQ2: What is the learning content of STEAM education in primary schools?

RQ3: What are the theoretical orientations and pedagogical strategies of primary school STEAM education?

RQ4: What are the research and assessment methods used in primary schools for STEAM education?

RQ5: What are the learning outcomes of STEAM education in primary schools?

4. Methodology

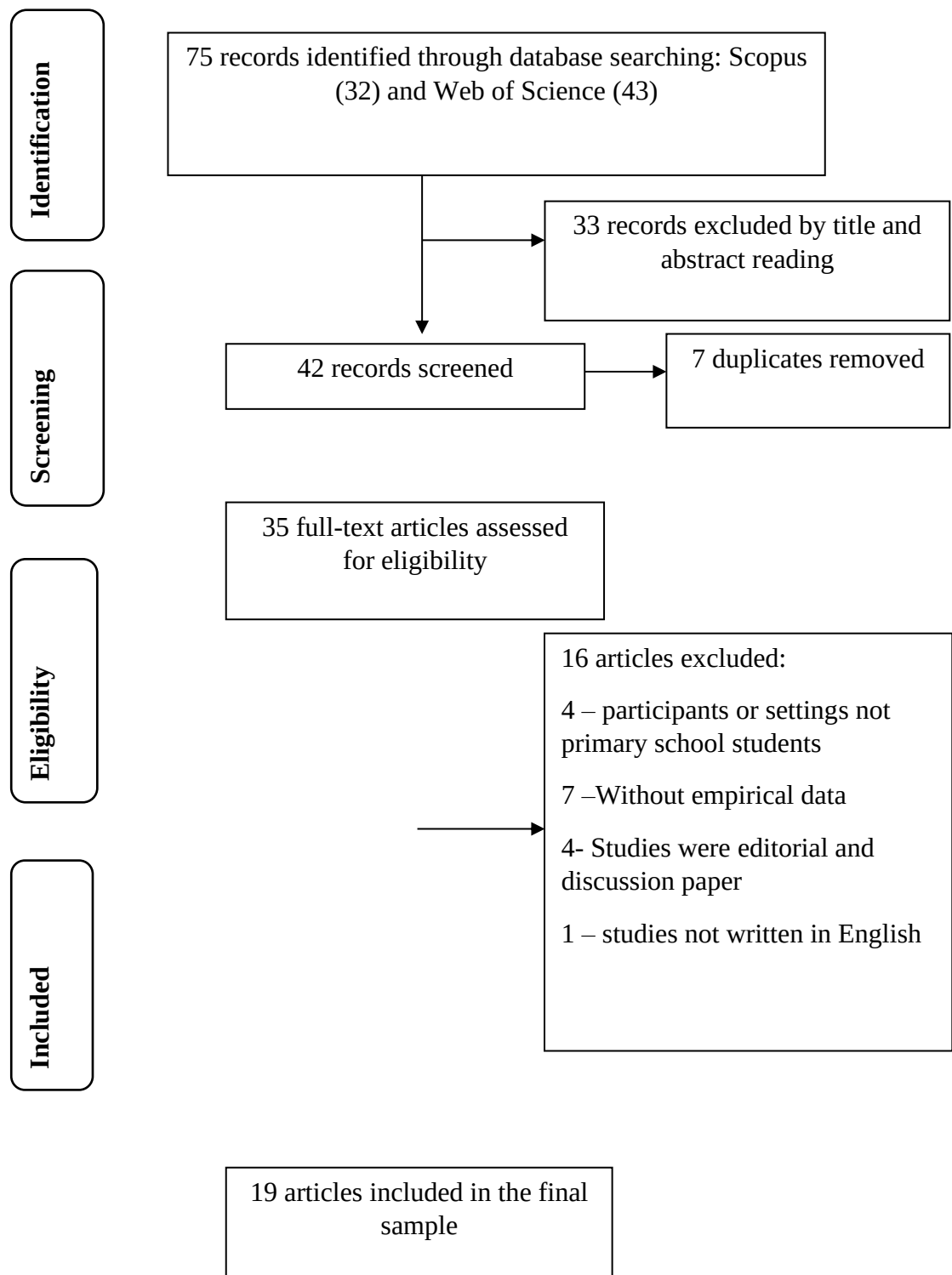
This review followed the preferred reporting items for systematic review (PRISMA) guidelines (Moher et al., 2011). Galvan and Galvan's (2017) three-step process was also followed for conducting review studies, namely, searching, scanning, and writing.

4.1 Literature search

Two electronic databases, Scopus and the Web of Science, were used for a literature search beginning in May 2023. The search strings used in this review were as follows: "Scienc*" AND "Technolog*" AND "Engine*" AND "Art*" AND "Math*") OR ("STEAM") AND "Primary education" OR "Elementary education". A total of 75 studies were retrieved, 43 of which were from the Web of Science and 32 from Scopus (Figure 1).

Figure 1

PRISMA Diagram of Included Articles in the Review



4.2 Inclusion and exclusion criteria

The following three inclusion criteria were used for this systematic review: (1) the study focused on STEAM in primary education, (2) the study included empirical data, and (3) the study was written in English.

The following studies were excluded: (1) studies irrelevant to the research topic (n = 33); (2) duplicate studies (n = 7); (3) studies not focused on primary education (n = 4); (4) studies that were not research studies (n = 7); (5) studies that were editorial and discussion papers (n = 4); and (6) studies not written in English (n = 1). After applying the exclusion criteria, 19 studies were thoroughly reviewed.

4.3 Data analysis

The first and second authors independently coded and evaluated the 19 studies. The coding reliability was established through multiple rounds of discussion between the coders, who were the first and second authors. The authors independently coded all articles and compared their coding results, which showed an interrater reliability of 83%. To achieve an interrater reliability of more than 80%, disagreements were settled by discussions between the two researchers.

4.4 Data charting and collation

The 19 selected studies on STEAM education in primary school settings were closely analyzed. The purpose, learning content, theoretical orientation, pedagogical strategies, research and assessment methods, and learning outcomes of primary school STEAM education are discussed in the Results section below.

5. Findings

RQ1: What is the purpose of STEAM education in primary schools?

Belbase et al.'s (2022) four purposes of STEAM education were used to code the review studies (Table 2): (1) processes (e.g., pedagogical strategies and tools), (2) priorities

(e.g., curriculum reform, design, and integration), (3) prospects (e.g., learning objectives and benefits), and (4) problems (e.g., critiques and challenges). As shown in Table 3, seven studies focused on processes, five focused on priorities, four on prospects, and three on problems.

Table 2:

Four purposes of STEAM education (adapted and modified from Belbase et al. 2022)

Type of purpose in STEAM implementation	Descriptions	Studies	n
Prospects	The STEAM education movement, STEAM's learning objectives, and its benefits	Bass et al. (2016); Ortiz-Revilla et al. (2021); Ortiz-Revilla and Greca (2021); Potvin et al. (2023)	n = 4
Priorities	Curriculum integration and curriculum reform	Duo-Terron et al. (2022); Lage-Gómez and Ros (2021, 2023); Quigley et al. (2020); Vicente et al. (2021)	n = 5
Processes	Pedagogical strategies, educational tools, and assessment methods	Chen et al. (2018); Das (2020); Espigares-Gámez et al.(2020); Fernández-Oliveras et al. (2021); Guenaga et al. (2017); Jurado et al. (2020); Menacho et al. (2021)	n = 7
Problems	Critiques and challenges	Díaz-Noguera (2019); Ortega-Torres (2022); Shively et al. (2021)	n = 3

Table 3

The purposes of STEAM in primary education settings

Authors	Purpose	Focus
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Bass et al. (2016).	Prospects	To implement a digital pathway program with game and project-based design to prepare students for STEAM careers and to investigate how factors such as student community, course environment, and instruction style affect student engagement and outcomes
Chen et al. (2018)	Process	To understand the effectiveness of the project “The STEAM Education of Flying and Assembly of Drones” in developing students' creative thinking, practical assembly skills, and active learning behaviours
Díaz-Noguera (2019)	Problems	1) To understand the perceptions of future primary school teachers regarding the use of technologies in STEAM; 2) analyze the reasons for teaching the arts as part of STEAM; and 3) investigate the consistency and reliability of the Gender Skill Applications Attitude Scale (GISAAS)
Das (2020)	Process	To implement a project-based STEAM curriculum
Duo-Terron et al. (2022)	Priorities	To examine the use of STEAM in the enhancement of linguistic and mathematical skills
Espigares-Gámez et al. (2020)	Process	To investigate the effectiveness of using a Jamaican game-based approach through a Micro Play Project to promote STEAM skills
Fernández-Oliveras et al. (2021)	Process	To design, create, and implement a microplay hands-on activity for the promotion of scientific-mathematical enculturation
Guenaga et al. (2017)	Process	To explore the "make world" computer programming activity to develop computational thinking and STEAM skills
Jurado et al. (2020)	Process	1) To provide training to teachers on the use and construction of robotics for STEAM teaching; 2) evaluate teachers' teaching processes and students' learning outcomes; and 3) identify potential for future implementation
Lage-Gómez and Ros (2021).	Priorities	To examine the use of the arts in STEAM projects

Lage-Gómez and Ros (2023).	Priorities	To investigate the relationship between creativity, transdisciplinary integration, and student motivation in three transdisciplinary STEAM projects
Menacho et al. (2021).	Process	Using STEAM Halloween activities to empower parents with using the arts to enhance their teaching of their children with STEAM Halloween activities
Ortega-Torres (2022)	Problems	To compare the knowledge and perceptions regarding STEAM education of teachers with different types of university education
Ortiz-Revilla et al. (2021)	Prospects	To investigate the effect of an integrated STEAM approach on seven competencies: knowledge, know-how, attitudes, context, effective communication, awareness, and nature of disciplinary knowledge
Ortiz-Revilla and Greca (2021)	Prospects	To understand student attitudes toward science and engineering after STEAM activities
Potvin et al. (2023)	Prospects	To investigate the strength and limitation of Project STRIDE in promoting STEAM education for low income and minority young students
Quigley et al. (2020)	Priorities	To examine how teachers design a STEAM curriculum and their role in teaching it
Shively et al. (2021)	Problems	To investigate the experience of future teachers in designing and implementing a STEAM maker workshop
Vicente et al. (2021)	Priorities	To evaluate the effectiveness of a STEAM curriculum using educational robotics

Seven studies focus on the *process* of implementing STEAM, including the adoption of various pedagogical strategies, such as project-based learning (Das, 2020), game-based learning (Espigares-Gámez et al., 2020; Fernández-Oliveras et al., 2021), collaborative

maker-space learning (Guenaga et al., 2017), and technologically enhanced learning (Jurado et al., 2020; Menacho et al., 2021; Chen et al., 2018). These processes, with the careful selection of pedagogies, can increase students' academic achievement and skills development. For example, Das (2020) recommends hands-on project-based learning to empower students to be problem solvers and creative thinkers and to engage them in learning the key skills that they will need in the future.

Five studies focus on *priorities* in STEAM curriculum design. These include the integration of the arts (Lage-Gómez & Ros, 2021), the examination of the teacher's role (Quigley et al., 2020), and the use of educational robotics (Vicente et al., 2021) in educational reform. For example, integrating the arts into STEAM education is seen as a priority because it overcomes disciplinary boundaries and promotes creativity (Lage-Gómez & Ros, 2021). Lage-Gómez and Ros (2023) also prioritize the importance of integrating the arts, investigating the relationship between creativity, transdisciplinary integration, and students' motivation.

The third most common type of purpose is *prospects*, which focuses on clearly stating learning objectives and ensuring that learning outcomes and benefits align with the learning purpose. For example, Bass et al. (2016) focus on preparing students for STEAM careers, discussing ways to narrow the gap between students' socioeconomic background and their academic achievement in STEAM education by implementing a digital pathway program to equip them with STEAM knowledge and skills. On the other hand, Ortiz-Revilla et al. (2021) investigate the effects of STEAM on seven students' competencies (knowledge, know-how, attitudes, context, effective communication, awareness, and the nature of disciplinary knowledge), and promote improving the quality of STEAM education, as well as active citizenship, social inclusion, and employment.

The remaining studies (n = 3) investigate the challenges that future teachers may face. Díaz-Noguera (2019) examines teachers' perceptions of the use of technology, their attitudes toward gender differences in STEAM education, and the role of arts-based approaches in combating gender stereotypes in educational contexts. Ortega-Torres (2022) compares the STEAM education knowledge of trainee teachers with a degree in primary education and those with a degree in secondary education, while Shively et al. (2021) explore trainee teachers' challenges in designing STEAM-maker workshops and offer insights into future professional development and training.

RQ2: What is the learning content of STEAM education in primary schools?

Most of the studies focus on transdisciplinary STEAM learning (n = 8), promoting a balanced relationship among the STEAM disciplines and a closer integration of STEAM with real-world problems. Others prioritize technology (STEAM) (n = 7), mathematics (STEAM) (n = 2), or mathematics and science (STEAM) (n = 2). The details are provided in Tables 4 and 5.

As shown in Table 4, the most common learning focus is transdisciplinary STEAM education, which includes balanced teaching of each of the five STEAM disciplines (Ortega-Torres, 2022; Ortiz-Revilla et al., 2021; Ortiz-Revilla & Greca, 2021). To encourage student engagement, Das (2020) designed two activities, “Experimental Playscapes” and “Farming of the Future”, whose objective was to empower students with the agency to build a sustainable world. Similarly, other studies have used STEAM education to encourage students to explore real-world issues regarding the weather (Shively et al., 2021), ecological farming (Das, 2020), fishing (Quigley et al., 2020), and food and nutrition (Potvin et al., 2023).

Table 4

The learning content of STEAM education in primary schools

Learning content	Sample studies	n
STEAM	Das (2020); Ortiz-Revilla et al. (2021); Potvin et al. (2023)	n = 8
Technology-focused STEAM	Bass et al. (2016); Guenaga et al. (2017); Menacho et al. (2021)	n = 7
Mathematics- and science-focused STEAM	Espigares-Gómez et al.(2020); Fernández-Oliveras et al. (2021)	n = 2
Mathematics-focused STEAM	Lage-Gómez and Ros (2021); Lage-Gómez and Ros (2023).	n = 2

Table 5

The learning focuses of STEAM education in primary schools

Authors	Learning focuses	Learning details
Bass et al. (2016)	ICT, technology, and robotics	Digital media production course
Chen et al. (2018)	ICT, technology, and robotics	“The STEAM Education of Flying of UAV and Assembly of Drone” course
Díaz-Noguera (2019)	ICT, technology, and robotics	Gender gap innovation project
Das (2020)	STEAM (transdisciplinary)	“Experimental Playscapes” and “Farming of the Future”
Duo-Terron et al. (2022)	ICT, technology, and robotics	STEAM-education programs such as a “musical inventions” activity
Espigares-Gómez et al. (2020)	Mathematics and science	“Micro play project” with four games: brown girl in the ring, dandy shandy, marbles, and dominoes
Fernández-Oliveras et al. (2021)	Mathematics and science	“Playful micro project” with three games: “the dog and the goats”, “the towers of the Alhambra”, and “Mijnlieff”
Guenaga et al. (2017)	ICT, technology, and robotics	Computer science and computer programming maker world project (http://makeworld.eu).
Jurado et al. (2020)	ICT, technology, and robotics	Learn to construct and program robots

Lage-Gómez and Ros (2021)	Mathematic	Fractals and graphs STEAM project with two field trips to National Museum of Natural Sciences, and a classroom workshop in the Museum of Mathematics, both in Madrid, Spain
Lage-Gómez and Ros (2023)	Mathematic	Fractals, Graphs and Lewis Carroll's Alice books STEAM projects
Menacho et al. (2021)	Arts, ICT, technology, and robotics	Halloween robotics workshop
Ortega-Torres (2022)	STEAM (transdisciplinary)	Teachers' training contents include: 1) defining STEM and understanding why it uses a project-based approach? 2) the self efficacy concept in STEM and STEAM approaches; 3) good practice in designing a STEAM project
Ortiz-Revilla et al. (2021)	STEAM (interdisciplinary and transdisciplinary)	STEAM didactic unit (STEAM DU) involving 16 sessions covering content from the natural sciences, mathematics, and the arts
Ortiz-Revilla and Greca (2021)	STEAM (transdisciplinary)	Design an artificial lighting prototype
Potvin et al. (2023)	STEAM (transdisciplinary)	A STEAM nutrition "Project STRIDE"
Quigley et al. (2020)	STEAM (transdisciplinary)	Learning contexts, and topics such as "fishing"
Shively et al. (2021)	STEAM (transdisciplinary)	Weather-focused maker workshop using four strategies: explore, discover, envision, implement
Vicente et al. (2021)	ICT, technology, and robotics	"Sustainable City" project consisting of presentation and implementation of the project, and presentation of the product

Some researchers focus on teaching one or two STEAM disciplines. Technology-focused STEAM content is the second most common teaching focus in the selected studies. Digital media courses (Bass et al., 2016), flying drone projects (Chen et al., 2018), robotics programs (Jurado et al., 2020; Vicente et al., 2021), and computer programming projects (Guenaga et al., 2017) have been implemented in primary schools to empower students to

combine concepts from multiple disciplines to study technologies such as robotics and information communications technology (ICT).

A few studies use the mathematical concepts of fractals and graphs (Lage-Gómez & Ros, 2021) and Lewis Carroll's Alice books (Lage-Gómez & Ros, 2023) to encourage students to learn about the humanities and science and technology. Espigares-Gámez et al. (2020) and Fernández-Oliveras et al. (2021), on the other hand, employ a "Micro Play Project", which uses games to develop students' mathematical and scientific thinking.

RQ3: What are the theoretical orientations and pedagogical strategies of primary school STEAM education?

Over half of the 19 studies implicitly or explicitly describe their theoretical orientations (n = 10) and pedagogical strategies (n = 13). Two of the studies used the Technology, Pedagogy, and Content Knowledge Model (TPACK) (Table 6), while constructivist methodologies, such as those employed by project-based (N = 6) and problem-based (N = 3) approaches, are the most common pedagogical strategies (Table 7).

Table 6

Theoretical frameworks mentioned in the selected articles

Theory	Studies	n
Technological pedagogical content knowledge (TPACK) model	Jurado et al. (2020) Shively et al. (2021)	n = 2
Activity theory	Lage-Gómez and Ros (2021)	n = 1
Augmented theory of successful intelligence	Lage-Gómez and Ros (2023)	n = 1
Bloom's taxonomy	Guenaga et al. (2017)	n = 1
Connected learning theory	Quigley et al. (2020)	n = 1
Experiential learning theory	Shively et al. (2021)	n = 1

Reasoned action model	Ortiz-Revilla and Greca (2021)	n = 1
Social constructivist perspective	Fernández-Oliveras et al. (2021)	n = 1
Technology acceptance model	Chen et al. (2018)	n = 1
Triadic network approach; Vergnaud's conceptual fields theory	Ortiz-Revilla et al. (2021)	n = 1

Table 7

Pedagogical strategies mentioned in the selected articles

Pedagogical strategies	Sample studies	n
Project-based	Bass et al. (2016); Das (2020); Vicente et al. (2021)	n = 6
Problem-based	Chen et al. (2018); Quigley et al. (2020); Ortiz-Revilla and Greca. (2021)	n = 3
Game-based/ gamification	Espigares-Gómez et al.(2020); Fernández-Oliveras et al. (2021); Guenaga et al. (2017)	n = 3
Technology-enhanced	Guenaga et al. (2017); Jurado et al. (2020)	n = 2

Ten studies use theories, such as activity theory (Lage-Gómez & Ros, 2021), the augmented theory of successful intelligence (Lage-Gómez & Ros, 2023), and connected learning theory (Quigley et al., 2020), to guide their research. The TPACK model is used by two studies to conceptualize their research design (Jurado et al., 2020; Shively et al. 2021). Jurado et al. (2020) use the TPACK model to design teachers' professional training for improving their Technological, Pedagogical and Content Knowledge to effectively deliver STEAM education to students.

A few studies have incorporated theories to inform their data collection and analysis. Chen et al. (2018), following the technological acceptance model, investigate students'

acceptance of the use of technology at each learning stage by examining their learning motivation and attitudes to assess learning effectiveness. Guenaga et al. (2017), on the other hand, consider the cognitive categories in Bloom's taxonomy.

Regarding the pedagogical perspective, six studies adopt project-based learning, and three adopt problem-based learning. Project-based learning is based on the theory of constructivism, which perceives learning as a process of constructing knowledge through relevant and authentic real-life experience. Das (2020) integrates hands-on project-based design with an engineering curriculum. Vicente et al. (2021) design, implement, and validate a "Sustainable City" project through educational robotics. Their project consists of an educational robotics kit with an object simulating a city and a robot programmed to travel on it.

Problem-based learning is another approach that allows students to think critically and solve problems. In this approach, students are collectively engaged in understanding learning content via real-life examples and contexts. For example, Ortiz-Revilla and Greca (2021) presented students with a specific challenge: "How to design a prototype for lighting the room in which I study?". An inquiry-based teaching and engineering design was used as the methodology.

RQ4: What are the research and assessment methods used in primary school for STEAM education?

Most of the studies adopted mixed methods ($n = 9$), followed by quantitative ($n = 5$) and qualitative methods ($n = 5$), as shown in Table 8. Six of the nine mixed-methods studies used questionnaires, surveys, and observations, or interviews. The most common assessment methods were questionnaires, surveys, or classroom tests ($n = 14$), observations ($n = 9$), and interviews ($n = 7$), as shown in Table 9.

Table 8*Research and assessment methods in STEAM education in primary school settings*

Authors	Research methods	Assessment method
Bass et al. (2016)	Qualitative method	Interviews, observations, artifacts
Chen et al. (2018)	Mixed method	Survey, artefacts, and competition
Díaz-Noguera (2019)	Mixed method	Pre and post test and students' opinions
Das (2020)	Mixed method	Survey and observations
Duo-Terron et al. (2022)	Quantitative method	Assessment test
Espigares-Gámez et al.(2020)	Qualitative method	Video recording and games
Fernández-Oliveras et al. (2021)	Qualitative method	Observations and video recording
Guenaga et al. (2017)	Quantitative method	Questionnaires, interviews, observations, and video recordings
Jurado et al. (2020)	Mixed method	Questionnaires, observations, and interview
Lage-Gómez and Ros (2021)	Mixed method	Questionnaires, observation, video recordings, interviews, and classroom journals
Lage-Gómez and Ros (2023)	Mixed method	Questionnaires, interviews, observations, and video recordings
Menacho et al. (2021)	Quantitative method	Survey
Ortega-Torres (2022)	Mixed method	Questionnaire and interview
Ortiz-Revilla et al. (2021)	Mixed method	Field notes and assessment tests
Ortiz-Revilla and Greca (2021)	Quantitative method	Assessment tests
Potvin et al. (2023)	Mixed method	Survey and interview
Quigley et al. (2020)	Qualitative method	Unit plans, reflections, observations, and field notes
Shively et al. (2021)	Qualitative method	Lesson plans, instructor observation notes, reflective journal entries, and discussions

Vicente et al. (2021)	Quantitative method	Assessment test
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Table 9

The various assessment methods of the selected studies

Assessment method	n	Sample studies
Questionnaires, surveys, or tests	14	Duo-Terron et al. (2022); Guenaga et al. (2017); Ortiz-Revilla et al. (2021)
Observations	9	Bass et al. (2016); Das (2020); Fernández-Oliveras et al. (2021)
Interviews	7	Bass et al. (2016); Jurado et al. (2020); Potvin et al. (2023)
Field notes	3	Ortiz-Revilla et al. (2021); Quigley et al. (2020); Shively et al. (2021).
Artefacts	2	Bass et al. (2016); Chen et al. (2018).
Games or competitions	2	Chen et al. (2018); Espigares-Gámez et al. (2020)
Lesson plans	2	Quigley et al. (2020); Shively et al. (2021)
Reflections	2	Quigley et al. (2020); Shively et al. (2021)

Questionnaires, surveys, and classroom tests are often used as quantitative instruments for understanding teachers' attitudes (Díaz-Noguera, 2019) and their prior knowledge of designing and implementing STEAM education (Ortega-Torres, 2022). They can also be used to assess students' attitudes (Lage-Gómez & Ros, 2023), self-efficacy (Das, 2020), academic competence (Duo-Terron et al., 2022; Ortiz-Revilla et al., 2021), and learning effectiveness (Chen et al., 2018).

For example, employing the Gender Innovation Skill Applications Attitude Scale, Díaz-Noguera (2019) uses questionnaires to assess future teachers' attitudes regarding the relevance of their STEAM education and their level of satisfaction with it. In addition, Lage-Gómez and Ros (2021) use BRAINS (Behaviors, Related Attitudes, and Intentions toward

Science) test surveys (which statements such as, *“I will not pursue an engineering-related career in the future”*) to rate students’ attitudes toward science and engineering (Ortiz-Revilla et al., 2021). While many researchers have relied on questionnaires and surveys for assessment, a few have adopted objective tests for evaluation. Duo-Terron et al. (2022) designed survey tests measuring mathematical competence (e.g., in calculation and problem resolution) based on the criteria of the National Institute of Educational Evaluation, whereas Ortiz-Revilla et al. (2021) use questionnaires to examine students’ competence in areas such as mathematics, linguistics, and science and technology.

Observations were used to analyze students’ learning outcomes (Espigares-Gómez et al., 2020; Fernández-Oliveras et al., 2021), discipline integration, classroom environment (Quigley et al., 2020), student engagement (Bass et al., 2016), and teachers’ performance (Jurado et al., 2020). Fernández-Oliveras et al. (2021), for example, evaluate students’ learning outcomes using a more systematic observation checklist with 21 categories (e.g., evidence of identifying flat shapes and three-dimensional bodies, making relationships of order, and ascertaining geometric aspects). Several researchers have observed students’ engagement and interactions with teaching staff (Bass et al., 2016), as well as teachers’ level of enthusiasm and computational and pedagogical skill (Jurado et al., 2020).

Interviews have been used to validate quantitative (Ortega-Torres, 2022; Potvin et al., 2023; Jurado et al., 2020) and qualitative data (Bass et al., 2016). For example, viewing the evaluation of a STEAM curriculum development as vital, Potvin et al. (2023) conducted interviews with nine community partners and educational experts to determine the accuracy and validity of their responses to four interview questions (i.e., *“Overall, what was your impression of the curriculum?”*; *“What did you like about the curriculum?”*; *“What do you think will be challenges to the curriculum?”*; *“After reviewing this curriculum, would you feel confident teaching it?”*). On the other hand, Bass et al. (2016) synthesize interviews to

triangulate the perspectives of two teaching staff members (e.g., regarding their accomplishments and challenges as well as the contextual factors affecting STEAM implementation), students (e.g., regarding their best learning experiences in the Digital Pathway STEAM project), and teachers (e.g., regarding challenges in instructor recruitment, course design, and student engagement and retention).

RQ5: What are the learning outcomes of STEAM education in primary schools?

Most studies reveal that STEAM education is effective at enhancing attitudes, knowledge, and skills (Table 10). Three studies do not report students' learning outcomes, as their focus is on teachers' perspectives and the curriculum design of STEAM education.

Table 10

Learning outcomes in STEAM primary education

Outcomes	Details	Studies
Attitudes	Students stayed engaged.	Bass et al. (2016)
	Increase students' interest in the arts, mathematics, science, and technology.	Chen et al. (2018)
	Positive teachers' attitude towards initiatives addressing gender issues.	Díaz-Noguera (2019)
	The platform is suitable for learning science; students' perception and enhanced interests.	Guenaga et al. (2017)
	Teachers perceived the training enhanced their confidence in teaching.	Jurado et al. (2020)
	High degree of student motivation and satisfaction.	Lage-Gómez and Ros (2021)
	Increased students' motivation and active participation.	Lage-Gómez and Ros (2023)
	Class instructors perceived that all students enjoyed the activities.	Menacho et al. (2021)

	Increased students' positive attitudes towards science and their intention to continue studying science.	Ortiz-Revilla et al. (2021)
	Increased students' intentions to pursue careers in science and engineering compared to the control group.	Ortiz-Revilla and Greca (2021)
	Educational professionals said that the curriculum was "relevant", "fun", and "informed".	Potvin et al. (2023)
	Enhanced students' interest and motivation.	Vicente et al. (2021)
Knowledge	Deepened students' comprehension of drones, flight safety, and flying ethics.	Chen et al. (2018)
	Enhanced students' linguistic and mathematical competence in terms of speaking, oral comprehension, and calculation.	Duo-Terron et al. (2022)
	Students gained logical-mathematical knowledge and understanding.	Espigares-Gómez et al. (2020)
	Students gained mathematical and scientific knowledge.	Fernández-Oliveras et al. (2021)
	Students received a high mark of 7.1–7.7 out of 10 in the final evaluation criteria.	Jurado et al. (2020)
	Enhanced students programming, robotics, Scratch, and Crumble knowledge and experience.	Menacho et al. (2021)
	Developed students' competence in three areas: 1) mathematics and science and technology, 2) linguistic communication, and 3) cultural awareness.	Ortiz-Revilla et al. (2021)
	Overall assessment was satisfactory, with students achieving an average of 7.2 points out of 10.	Vicente et al. (2021)
Skills	Beneficial effect on students' independent learning, cross-domain learning, and creative thinking.	Chen et al. (2018)
	Students learned how to use power tools and digital software, and developed engineering skills, soft skills (such as	Das (2020)

project management), and time management.

Students demonstrated abilities in the development of hypotheses, planning, spotting similarities, spatial awareness, and understanding of the concept.

Espigares-Gómez et al. (2020)

Promoted students' creativity.

Lage-Gómez and Ros (2023)

Promoted students' linguistic communication skills.

Ortiz-Revilla et al. (2021)

Promoted students' creativity and problem-solving skills.

Vicente et al. (2021)

In terms of teachers' perspectives and the curriculum design of STEAM, this review reveals that trainee primary teachers have limited knowledge of STEAM education. However, they view the implementation of STEAM in primary schools as important (Ortega-Torres, 2022). Quigley et al. (2020) argue that it is crucial for teachers to be involved in the design of problem-based STEAM curricula involving innovative educational technologies. In addition, Shively et al. (2021) find that the use of maker pedagogy allows teachers to experience the field of education as both an educator and a learner, supporting their reflection, critique, and revision.

In terms of students' learning outcomes, STEAM education can enhance students' attitudes, knowledge, and skills. These are discussed as follows:

Attitudes

STEAM education has enhanced students' interest in science (Chen et al., 2018; Vicente et al., 2021), their motivation to study science (Lage-Gómez & Ros, 2021; Lage-

Gómez & Ros, 2023), and their attitudes toward science (Ortiz-Revilla et al., 2021). For example, in Guenaga et al. (2017), almost 80% of student participants believed that STEAM was suitable for learning science. An increase in students' interest was evident in their feedback, e.g., "*Technology is fascinating*" and "*A career in STEM is interesting*". Students who participated in STEAM learning expressed a greater intention to pursue careers in science and engineering than did those in the control group (Ortiz-Revilla & Greca, 2021).

Knowledge gained

Some of the papers show that STEAM education improved students' knowledge (Vicente et al., 2021) of mathematics (Duo-Terron et al., 2022; Espigares-Gámez et al., 2020), science (Fernández-Oliveras et al., 2021), and technology (Menacho et al., 2021), while one study reports an increase in transdisciplinary knowledge through tasks related to drones, ethics, and aviation safety (Chen et al., 2018). Through the creation of connections between environmental elements and the construction of scientific learning about concepts, properties, or processes in the form of rules or patterns in STEAM education, students develop logical mathematical understanding and decision-making skills (Espigares-Gámez et al., 2020). In Fernández-Oliveras et al.'s (2021) study, most students reported that their scientific knowledge had improved in areas such as recognizing the length and surface, and in Menacho et al.'s (2021) study, students reported an improvement in their programming and robotics abilities. Interestingly, although Ortiz-Revilla et al.'s (2021) STEAM activities focused on electricity and data processing, more than 75% of the students achieved high competence in cultural awareness.

Skills acquisition

Some of the studies show that students acquired creativity, critical reasoning (Lage-Gómez & Ros, 2023), problem-solving skills (Vicente et al., 2021), communication skills (Ortiz-Revilla et al., 2021), technological and engineering skills (Das, 2020), and other soft

skills (Espigares-Gómez et al., 2020). According to Espigares-Gómez et al. (2020), students also developed the ability to form hypotheses and plans. Students were taught practical, everyday skills, including how to use drills and machinery (such as a bandsaw and lathe), as well as project and time management (Das, 2020). In addition, the use of the arts in STEAM education plays an integrating role (Lage-Gómez and Ros., 2021) in supporting the development of students' computational thinking skills (Guenaga et al., 2017) and programming robotic skills (Jurado et al., 2020).

6. Discussion

This review reveals that, since 2016, there has been an increase in publications on STEAM education in primary school settings and that this trend peaked in 2021. Most of these publications are from the United States, which is consistent with the findings of Santi et al. (2021), while Spain is emerging as the most productive country for the publication of academic articles on STEAM in primary school settings.

The review's findings reveal that studies have employed a variety of theories, such as TPACK, to inform their research design, while constructivist methodologies, such as project-based and problem-based learning, have been dominant. This finding is consistent with White and Delaney (2021), who state that STEAM education is closely related to project-based and problem-based learning and to real-world contexts. This finding also echoes Kwan and Wong (2021), who point to STEAM's increasingly extensive use of educational technology.

This review reveals a growing tendency in research on STEAM in primary education to use mixed methods to triangulate their results, which is in contrast to the findings of Anderson (2021), who reports a low number of quantitative studies. This review also shows that a variety of quantitative methods are often adopted, such as subjective self-report questionnaires and objective classroom knowledge tests (Duo-Terron et al., 2022).

Nevertheless, there is limited research assessing the learning outcomes of STEAM's transdisciplinarity, that is, its combined teaching of its constituent disciplines.

The findings of this review are in line with the conclusion of previous reviews that the main impetus for STEAM education is generally the same as that for STEM (Krüger & Chiappe, 2021): to equip students with future-oriented skills for employability (Belbase et al., 2022). The review shows that one principal goal of STEAM education has been to consider the diversity and genuine needs of students, prepare them to become contributing members of a global knowledge economy (Dewey, 1974), and empower them to be agentic citizens in pursuing their own goals and contributing to the betterment of society (Yakman & Lee, 2012). In addition, the review highlights two themes of STEAM education that emphasize the importance of raising awareness of the impact of human actions on nature and other humans. For example, Vicente et al. (2021) explore the goal of sustainability in STEAM education, particularly regarding the building of a sustainable city project. Meanwhile, Díaz-Noguera (2019) examines the inclusivity of STEAM education, focusing on questions about tackling gender bias.

Finally, this review demonstrates that, from the perspective of a number of studies (e.g., Chen et al., 2018; Lage-Gómez & Ros, 2021), the arts allow a paradigm shift from STEM's content-based epistemology to STEAM's student-centered curriculum for acquiring 21st century skills (i.e., creativity, collaboration, communications, and critical thinking) and other transdisciplinary knowledge (Aróstegui & Kyakuwa, 2021).

6.1 Recommendations for educators

This review identifies the potential advantages of using educational tools such as robots and games to familiarize students with STEAM concepts and increase their motivation

and engagement (Su et al., 2023). To create meaningful learning experiences for students, age-appropriate educational tools and pedagogies should be adopted.

Implementing STEAM education is challenging and may exceed the current capacity of teachers. Educators should evaluate the purpose and content of their current teaching, assess their knowledge base, and design and develop teacher training programs.

STEAM education should include theoretical foundations and pedagogical strategies for its effective implementation in the classroom. Educators may also benefit from establishing a platform for exchanging thoughts, sharing STEAM lesson plans, and teaching resources. Partnerships with business and science communities are recommended to foster deeper collaboration through seminars and workshops that develop skills, offer expert input, and provide access to the latest technology (e.g., STEAM educational tools and teaching materials).

6.2 Future directions

This review enhances the existing body of knowledge by identifying a number of areas that could be explored by future research on STEAM primary education. First, robotics, drones, games, and game-based approaches are presented by this study as learning opportunities. Future research may explore these possibilities and, in particular, consider how technology and games can be employed in an imaginative way to develop students' creativity. To some extent, STEAM education can enhance students' disciplinary knowledge and skills, and the use of an arts-based approach in other disciplines, such as artificial intelligence literacy education, may also be worth exploring (Yim, 2023).

Second, researchers may further explore interdisciplinary education, such as STEAM education and AI literacy education (e.g., Yim & Su, 2024), in fostering dialogic spaces for creative collaboration (Wegerif, 2007) and for transdisciplinary conversation on issues of

ethics, relationality, and sustainability (Guyotte, 2020; Yim, 2024a). Third, this review reveals that empirical studies on female students are limited to certain primary school students (Ortiz-Revilla et al., 2021), and students with disabilities and special needs are underexplored. In this regard, the use of the arts-based approach in the transdisciplinary learning context as a means to promote inclusive education may be worth exploring (Yim, 2024b). Fourth, primary school teachers' perceptions and readiness regarding STEAM implementation could be further investigated. Fifth, despite the number of questionnaires and surveys available to evaluate primary school students' learning outcomes, only a few of them have been validated (Díaz-Noguera, 2019). More research (e.g., randomized controlled studies and design-based research) and data analysis procedures (e.g., t-tests, structural equation modeling, and item response theory) are suggested to validate the quality of STEAM assessments. Future research could include standardized STEAM assessments, especially surveys and questionnaires, and assess the validity and reliability of the assessment scales.

Finally, to advance the STEAM educational field in primary schools, priority should be placed on proposing definitive frameworks with clear purposes and learning contents that also include theoretical orientations and pedagogical strategies to guide educators and researchers. The purpose of this review is to inspire scholars, educators, and government officers to begin clearly defining and setting clear purposes, content and related short-term and long-term learning outcomes for the implementation and evaluation of STEAM learning in the future.

7. Conclusion and limitations

This study enriches the literature by providing a comprehensive analysis of the purpose, learning content, theoretical orientations, pedagogical strategies, research methodologies, assessments, and learning outcomes of STEAM in primary education. It also

contributes by providing guidelines for promoting the effective implementation of STEAM education in primary school contexts. This review calls for educators and researchers to consider STEAM's arts component to empower students to achieve their full potential and exercise greater agency in their STEAM learning and other transdisciplinary education.

This review has several limitations. First, given that the number of selected studies was relatively small, there may be gaps in the research findings. In addition, although the review used the most reputable academic databases to find relevant studies, its search and screening process may nevertheless have been affected by the subjective judgment of its authors. Finally, since the current study is a systematic review and does not report the effect sizes of existing empirical studies, future research could investigate these sizes through a meta-analysis to provide further insights into STEAM integration and implementation.

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Appendix

Authors	Year	Participants	Number of participants	Country
Bass et al. (2016)	2016	Young students	146	USA
Chen et al. (2018)	2018	Primary school students	30	Taiwan
Díaz-Noguera (2019)	2019	Future primary school teachers	1533	Spain
Das (2020)	2020	Aged 6-13	14	USA
Duo-Terron et al. (2022)	2022	Grade 3	242	Spain
Espigares-Gámez et al.(2020).	2020	Early childhood and primary school students	-	Jamaica
Fernández-Oliveras et al. (2021)	2021	Aged 8-12	32	Spain
Guenaga et al. (2017)	2017	Aged 10-12	524	Spain, Greece, and Poland
Jurado et al. (2020)	2020	Aged 4-6	75	Spain
Lage-Gómez and Ros (2021)	2021	Aged 11-12	111	Spain
Lage-Gómez and Ros (2023)	2023	Aged 11-12	152	Spain
Menacho et al. (2021)	2021	Aged 8-12	A group of 16, including parents and children.	Spain
Ortega-Torres (2022)	2022	Future teachers	83 primary education degree and 91 secondary education degree teachers.	Spain
Ortiz-Revilla et al. (2021)	2021	Grade 6, aged 11-13	121	Spain

Ortiz-Revilla and Greca (2021)	2021	Grade 6 (treatment) and grade 5 (control)	258	Spain
Potvin et al. (2023)	2023	Community experts and educational specialists for low-income grade 4 and 5 students	9	USA
Quigley et al. (2020)	2020	K-5 primary school teachers	23	USA
Shively et al. (2021)	2021	K-5 future primary school teachers	4 teachers and their 10 students from grade K-5.	USA
Vicente et al. (2021)	2021	Grade 5	30	Spain
