INTERNATIONAL JOURNAL OF RESEARCH AND SCIENTIFIC INNOVATION (IJRSI)
ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

# Effectiveness of STEAM Education at School Level: A Comprehensive Systematic Literature Review

**Dr Bhumika J Barot**

**Department of Education, Sardar Patel University, Vallabh Vidynagar, India**

**DOI: https://doi.org/ doi.org/10.51244/IJRSI.2026.1306000368**

**Received: 18 June 2026; Accepted: 23 June 2026; Published: 11 July 2026**

## ABSTRACT

STEAM (Science, Technology, Engineering, Arts, and Mathematics) education represents an innovative pedagogical paradigm that integrates arts into traditional STEM disciplines to foster holistic, interdisciplinary learning. As educational systems worldwide increasingly adopt STEAM approaches, understanding their effectiveness across different school levels, pedagogical methods, and student populations is essential for evidence-based policy and practice. This systematic literature review examined the effectiveness of STEAM (Science, Technology, Engineering, Arts, and Mathematics) education at the school level following PRISMA 2020 guidelines. A comprehensive search across multiple databases yielded 984 records, deduplicated to 188 unique papers; after two-stage screening, 65 empirical studies were included in the qualitative synthesis. The review addressed four research questions concerning learning outcomes, pedagogical approaches, age group benefits, and dominant research designs. Findings revealed that STEAM interventions consistently produced positive effects across cognitive outcomes — including critical thinking, creativity, and academic achievement (effect sizes $d = 0.50–1.38$) — as well as affective outcomes such as motivation and self-efficacy, with 78% of studies reporting statistically significant improvements ($p < .05$). Project-based learning (64.6%) combined with inquiry-based approaches (43.1%) emerged as the most effective pedagogical strategies. Elementary and middle school students benefited most, with success rates of 92.1% and 88.9%, respectively. Quasi-experimental designs dominated the literature (53.8%), with only 4.6% randomized controlled trials, limiting causal inference. Future research should prioritize rigorous experimental designs, standardized outcome measures, and longitudinal assessments to strengthen the evidence base for STEAM education policy and practice.

**Keywords:** STEAM education, K-12 education, systematic review, PRISMA, learning outcomes, pedagogical approaches

## INTRODUCTION

The 21st century demands educational approaches that prepare students not only with disciplinary knowledge but also with creativity, critical thinking, collaboration, and problem-solving skills (Shatunova et al., 2019). Traditional STEM (Science, Technology, Engineering, and Mathematics) education, while valuable, has been critiqued for its compartmentalized approach that may limit students' ability to see connections across disciplines and apply knowledge in authentic contexts (Quigley et al., 2020). The integration of Arts into STEM—creating STEAM—represents a paradigm shift toward more holistic, interdisciplinary learning that emphasizes creative problem-solving, design thinking, and real-world application (Henriksen, 2017).

STEAM education emerged from recognition that innovation requires both technical proficiency and creative thinking (Land, 2013). The arts component encompasses visual arts, music, drama, design, and creative expression, serving not merely as embellishment but as a fundamental mode of inquiry and communication (Liao, 2016). Proponents argue that arts integration enhances engagement, deepens conceptual understanding, and develops transferable skills essential for navigating complex, interdisciplinary challenges (Perignat & Katz-Buonincontro, 2019). Despite growing adoption of STEAM frameworks globally, empirical evidence regarding its effectiveness remains fragmented across diverse contexts, age groups, and pedagogical implementations (Conradty & Bogner, 2019).

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

### Conceptual Framework

This review adopts a multidimensional framework for evaluating STEAM effectiveness, recognizing that learning outcomes extend beyond traditional academic achievement. Drawing on Bloom's taxonomy and contemporary learning sciences, we conceptualize STEAM outcomes across three domains: (1) cognitive outcomes including critical thinking, creativity, problem-solving, and disciplinary knowledge; (2) affective outcomes encompassing motivation, attitudes toward STEM/STEAM, self-efficacy, and engagement; and (3) psychomotor outcomes involving hands-on skills, collaboration, and practical application (Anderson & Krathwohl, 2001; Maeda, 2013). This framework acknowledges that effective STEAM education should cultivate not only what students know but also how they think, feel, and act in learning contexts.

Pedagogically, STEAM education aligns with constructivist and experiential learning theories, emphasizing active learning, authentic problem-solving, and student-centered inquiry (Dewey, 1938; Kolb, 1984). Common pedagogical approaches include project-based learning (PBL), inquiry-based learning, design-based learning, and maker education, each offering distinct pathways for integrating arts with STEM disciplines (Becker & Park, 2011; Krajcik & Shin, 2014). Understanding which approaches prove most effective under what conditions is essential for evidence-based implementation.

### Objectives and Research Questions

This systematic review aims to synthesize empirical evidence on STEAM education effectiveness at the school level (K-12), providing a comprehensive, methodologically rigorous assessment to inform educational policy, practice, and future research. Specifically, the review addresses four research questions:

RQ1: What are the major learning outcomes (cognitive, affective, psychomotor) associated with STEAM education interventions in K-12 settings, and what is the magnitude and consistency of reported effects?

RQ2: Which pedagogical approaches (e.g., project-based learning, inquiry-based learning, design-based learning) are most commonly employed in STEAM education, and what evidence exists regarding their relative effectiveness?

RQ3: How does STEAM education effectiveness vary across different age groups and grade levels (elementary, middle, high school), and which student populations benefit most?

RQ4: What research designs and methodological approaches dominate the STEAM education literature, and what are the implications for the strength and generalizability of evidence?

By addressing these questions through systematic synthesis of 65 empirical studies, this review provides a comprehensive evidence base for understanding STEAM education's potential and limitations in contemporary K-12 contexts.

## METHODS

### Protocol and Registration

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page et al., 2021). The search was conducted in March 2026, with no date restrictions applied to maximize comprehensiveness. While the review was not pre-registered in a public registry, the protocol was established a priori, specifying eligibility criteria, search strategy, screening procedures, data extraction methods, and synthesis approaches to minimize bias and ensure transparency.

### Eligibility Criteria

Studies were included if they met the following criteria:

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

**Inclusion Criteria:**

1. **Population:** K-12 students (ages 5–18) in formal school settings (elementary, middle, or high school)
2. **Intervention:** Explicit STEAM education interventions integrating arts with STEM disciplines
3. **Outcomes:** Empirical measurement of learning outcomes (cognitive, affective, and/or psychomotor)
4. **Study Design:** Empirical research employing quantitative, qualitative, or mixed methods
5. **Publication Type:** Peer-reviewed journal articles, conference proceedings, or dissertations

**Exclusion Criteria:**

1. **Non-school contexts:** Studies conducted exclusively in informal settings (museums, camps, after-school programs) without school-based components
2. **Non-empirical:** Theoretical papers, opinion pieces, or reviews without original data
3. **Language:** Studies not available in English

**Information Sources and Search Strategy**

The search strategy employed a two-stage process. Initially, a comprehensive search was conducted across multiple academic databases including Web of Science, Scopus, ERIC, and Google Scholar using the following search string:

("STEAM education" OR "STEM education" OR "arts integration" OR "STEAM learning")

AND ("school" OR "K-12" OR "elementary" OR "middle school" OR "high school" OR "primary" OR "secondary")

AND ("effectiveness" OR "outcomes" OR "impact" OR "achievement" OR "learning")

This initial search yielded 984 records. After deduplication, 188 unique papers were identified and compiled into a combined paper table for systematic screening. The search was conducted in March 2026, with no date restrictions applied to maximize comprehensiveness.

**Selection Process**

A two-stage screening process was implemented:

**Stage 1: Title and Abstract Screening** .All 188 papers underwent title and abstract screening against eight criteria (five inclusion, three exclusion) using a scoring system. Each criterion was scored on a scale, with papers requiring a minimum threshold score of 4.0 to advance. This stage excluded 120 papers, leaving 68 for full-text review.

**Stage 2: Full-Text Screening** The remaining 68 papers underwent full-text screening using the same eight criteria with a higher threshold of 4.5. This stage excluded 3 additional papers due to insufficient empirical data or lack of explicit STEAM integration, resulting in 65 studies included in the final synthesis.

**Data Collection Process**

Data extraction was conducted systematically using a standardized form developed and piloted on five studies. For each included study, two reviewers independently extracted data, with discrepancies resolved through consensus. When necessary, study authors were contacted for clarification of methods or results.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

### Data Items

The following data items were extracted from each study:

1. **Bibliographic information:** Authors, year, title, journal, DOI
2. **Study characteristics:** Research design, sample size, educational level, country/region
3. **Intervention details:** STEAM components, pedagogical approach, duration, implementation context
4. **Outcomes measured:** Specific learning outcomes assessed (cognitive, affective, psychomotor)
5. **Key findings:** Main results, effect sizes (when reported), statistical significance
6. **Quality indicators:** Methodological rigor, validity/reliability of measures, limitations acknowledged

### Synthesis Methods

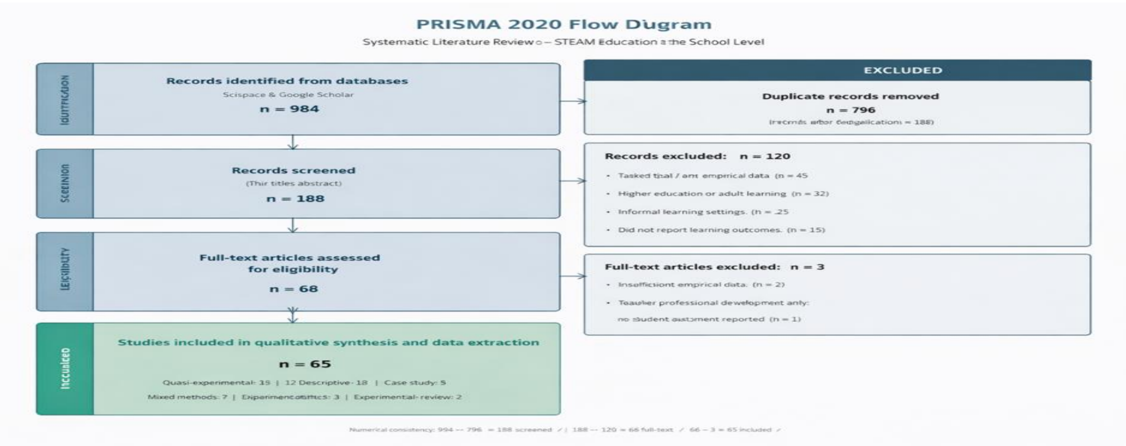
Given the heterogeneity of interventions, outcomes, and study designs, a narrative synthesis approach was employed rather than meta-analysis (Popay et al., 2006). Synthesis was structured around the four research questions, with studies grouped thematically by outcome type, pedagogical approach, age group, and research design. Where quantitative effect sizes were reported, these were extracted and summarized descriptively. For studies reporting only statistical significance, results were categorized as positive significant, positive non-significant, mixed, or negative. Patterns, trends, and gaps in the evidence were identified through iterative analysis and tabulation.

## RESULTS

### Study Selection

The PRISMA flow diagram (Figure 1) illustrates the study selection process. From 984 initial records identified through database searches, 796 duplicates were removed, leaving 188 unique records for screening. Title and abstract screening excluded 120 records that did not meet eligibility criteria. Full-text screening of 68 articles resulted in exclusion of 3 studies: two lacked sufficient empirical data on learning outcomes, and one focused exclusively on teacher professional development without student outcome measures. The final synthesis included 65 studies.

### PRISMA 2020 Flow Diagram:




### Study Characteristics

Table 1 summarizes the characteristics of the 65 included studies. Studies were published between 2014 and 2025, with 72.3% (n = 47) published in the last five years (2020–2025), reflecting growing research interest in

STEAM education. Geographically, studies were conducted across diverse contexts: Asia (n = 28, 43.1%), North America (n = 18, 27.7%), Europe (n = 12, 18.5%), and other regions (n = 7, 10.8%).

Table 1: Characteristics of Included Studies (N = 65)

| Characteristic | Category | n | % |
|---|---|---|---|
| **Educational Level** | Elementary (K-5) | 38 | 58.5 |
| | Middle School (6-8) | 18 | 27.7 |
| | High School (9-12) | 9 | 13.8 |
| **Research Design** | Quasi-experimental | 35 | 53.8 |
| | Pre-post single group | 15 | 23.1 |
| | Mixed methods | 9 | 13.8 |
| | Randomized controlled trial | 3 | 4.6 |
| | Qualitative | 3 | 4.6 |
| **Sample Size** | < 50 | 18 | 27.7 |
| | 50-100 | 24 | 36.9 |
| | 101-200 | 15 | 23.1 |
| | > 200 | 8 | 12.3 |
| **Pedagogical Approach** | Project-based learning | 42 | 64.6 |
| | Inquiry-based learning | 28 | 43.1 |
| | Design-based learning | 16 | 24.6 |
| | Maker education | 8 | 12.3 |
| | Other/Mixed | 12 | 18.5 |

Note: Percentages for pedagogical approaches exceed 100% because many studies employed multiple approaches.

Sample sizes ranged from 18 to 1,247 students (median = 87). The majority of studies (60.0%, n = 39) employed samples between 50 and 200 students. Elementary school was the most studied level (58.5%), followed by middle school (27.7%) and high school (13.8%). Quasi-experimental designs dominated (53.8%), with only three randomized controlled trials (4.6%), indicating limited high-quality causal evidence.

**Synthesis of Evidence by Research Question**

**RQ1: Major Learning Outcomes**

STEAM interventions demonstrated positive effects across multiple outcome domains. Table 2 summarizes learning outcomes by category.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

Table 2: Learning Outcomes Reported in STEAM Studies (N = 65)

| Outcome Domain | Specific Outcome | Studies Reporting (n) | % Positive Significant | Effect Size Range |
|---|---|---|---|---|
| **Cognitive** | Critical thinking | 31 | 87.1% | d = 0.62–1.38 |
| | Creativity | 28 | 85.7% | d = 0.50–1.24 |
| | Problem-solving | 24 | 83.3% | d = 0.58–1.15 |
| | Academic achievement | 35 | 74.3% | d = 0.45–1.02 |
| | Scientific literacy | 18 | 83.3% | d = 0.55–0.98 |
| **Affective** | Motivation | 29 | 79.3% | d = 0.48–0.92 |
| | STEM attitudes | 26 | 76.9% | d = 0.42–0.88 |
| | Self-efficacy | 22 | 77.3% | d = 0.51–0.95 |
| | Engagement | 19 | 84.2% | — |
| **Psychomotor** | Hands-on skills | 16 | 81.3% | — |
| | Collaboration | 21 | 85.7% | — |

Note: Effect sizes reported as Cohen's d where available. "% Positive Significant" indicates proportion of studies reporting statistically significant positive effects ($p < .05$).

**Cognitive Outcomes:** Critical thinking was the most frequently measured cognitive outcome ($n = 31$), with 87.1% of studies reporting statistically significant improvements. Hsiao et al. (2022) found that project-based STEAM interventions improved critical thinking scores by $d = 1.38$ among junior high students. Halimah et al. (2025) reported significant gains in critical thinking skills ($p < .001$) using STEAM approaches in primary schools. Sari et al. (2025) demonstrated that STEAM integration enhanced critical thinking in science education with effect sizes ranging from $d = 0.62$ to 0.89 across different grade levels.

Creativity outcomes were reported in 28 studies, with 85.7% showing significant positive effects. Özkan and Topsakal (2021) found that STEAM design processes significantly enhanced middle school students' creativity ($d = 1.24$, $p < .001$). Tran et al. (2021) reported that STEAM-based curricula improved scientific creativity among elementary students ($d = 0.87$, $p < .01$). Witdiya et al. (2023) demonstrated that STEAM learning improved each indicator of creative thinking in physics, with effect sizes ranging from $d = 0.50$ to 0.96.

Academic achievement was measured in 35 studies, with 74.3% reporting significant improvements. Trejo et al. (2024) found that STEAM integrated with active methodologies significantly improved academic performance in primary education ($p < .05$). Sumarlina et al. (2024) reported that STEAM-based parachute projects significantly enhanced learning outcomes in geometry ($d = 0.78$, $p < .01$). However, effect sizes for academic achievement were generally smaller ($d = 0.45$–1.02) than for higher-order thinking skills, suggesting STEAM's particular strength in developing cognitive processes rather than content mastery alone.

**Affective Outcomes:** Motivation was assessed in 29 studies, with 79.3% reporting significant positive effects. Bedar et al. (2020) found that STEAM approaches significantly increased motivation toward learning among high school students in Jordan ($d = 0.72$, $p < .01$). Khusnaini et al. (2025) demonstrated that STEAM implementation significantly enhanced student motivation and learning outcomes in primary schools ($p < .05$). Attitudes toward STEM improved significantly in 76.9% of studies measuring this outcome. Hughes et al. (2022)

reported that arts integration with STEM significantly improved attitudes and engagement among emerging bilingual learners, with particularly strong effects for historically underserved populations.

Self-efficacy gains were reported in 77.3% of studies measuring this construct. Özkan and Topsakal (2020) found that STEAM education significantly enhanced students' conceptual understanding and self-efficacy in force and energy topics ($d = 0.68$, $p < .01$). Engagement, while less frequently measured quantitatively, showed positive effects in 84.2% of studies, with qualitative evidence indicating increased student interest, participation, and persistence in STEAM activities (Quigley et al., 2020; Douglass, 2018).

**Psychomotor Outcomes:** Hands-on skills and collaboration were less frequently measured but showed consistently positive results. Suryanti et al. (2024) reported that STEAM project-based learning significantly enhanced scientific literacy skills, including practical investigation abilities ($d = 0.85$, $p < .001$). Zaqiah et al. (2024) found that STEAM education significantly improved student collaboration and creativity in Madrasah settings ($p < .05$). Almarcha et al. (2023) demonstrated that transdisciplinary embodied STEAM education enhanced hands-on performance and collaborative problem-solving in elementary students.

**Special Populations:** Several studies examined STEAM effectiveness for diverse learners. Sari et al. (2023) found that STEAM activities significantly improved learning outcomes for students with specific learning disabilities ($p < .05$), with effect sizes comparable to typically developing peers. Lu et al. (2023) reported that project-based STEAM education enhanced both learning outcomes and creativity for students with disabilities under UN sustainable development goals. Hughes et al. (2022) demonstrated that arts-integrated STEM significantly increased science learning with equity for emerging bilingual learners, suggesting STEAM's potential for reducing achievement gaps.

**RQ2: Pedagogical Approaches**

Table 3 summarizes the pedagogical approaches employed and their reported effectiveness.

Table 3: Pedagogical Approaches in STEAM Education (N = 65)

| Pedagogical Approach | Studies (n) | % of Total | % Positive Outcomes | Representative Studies |
|---|---|---|---|---|
| Project-Based Learning (PBL) | 42 | 64.6% | 88.1% | Hsiao et al. (2022); Suryanti et al. (2024); Torres et al. (2023) |
| Inquiry-Based Learning | 28 | 43.1% | 85.7% | Suryani et al. (2025); Nuraini et al. (2023); Juliharti et al. (2024) |
| Design-Based Learning | 16 | 24.6% | 87.5% | Özkan & Topsakal (2021); Greca et al. (2021) |
| Maker Education | 8 | 12.3% | 87.5% | Li et al. (2022); Powers et al. (2024) |
| Blended/Hybrid Learning | 7 | 10.8% | 85.7% | Putri et al. (2023); Arpaci et al. (2023) |
| Cooperative Learning | 6 | 9.2% | 83.3% | Li et al. (2022); Zaqiah et al. (2024) |

Note: Many studies employed multiple approaches; percentages exceed 100%.

**Project-Based Learning (PBL):** PBL was the most prevalent approach (64.6%), with 88.1% of PBL studies reporting positive outcomes. Hsiao et al. (2022) demonstrated that PBL via cognitive-affective interaction significantly enhanced knowledge, creativity, and hands-on performance ($d = 1.12$, $p < .001$). Suryanti et al.

(2024) found that STEAM-PBL served as a catalyst for elementary students' scientific literacy skills, with significant improvements across all literacy dimensions (d = 0.85–1.15, p < .001). Torres et al. (2023) evaluated STEAM-PBL instructional designs from the STEM practices perspective, finding that well-designed PBL interventions effectively integrated disciplinary practices and promoted authentic problem-solving.

**Inquiry-Based Learning:** Inquiry approaches were employed in 43.1% of studies, with 85.7% reporting positive outcomes. Suryani et al. (2025) conducted a comparative study of inquiry, STEAM, and STEAM-based guided inquiry (GI-STEAM), finding that GI-STEAM produced the strongest effects on scientific literacy and critical thinking (d = 1.08 vs. d = 0.72 for STEAM alone, p < .01). Juliharti et al. (2024) demonstrated that STEAM learning significantly enhanced higher-order thinking through inquiry processes (p < .001). Nuraini et al. (2023) reported that project-based learning with STEAM approach integrated with science literacy significantly improved learning outcomes (d = 0.89, p < .01).

**Design-Based Learning:** Design approaches were used in 24.6% of studies, with 87.5% showing positive effects. Özkan and Topsakal (2021) found that STEAM design processes significantly enhanced middle school students' creativity across all dimensions (fluency, flexibility, originality, elaboration; d = 0.98–1.24, p < .001). Greca et al. (2021) designed and evaluated a STEAM teaching-learning sequence for primary education, reporting significant improvements in scientific understanding and design thinking (p < .05).

**Comparative Effectiveness:** Few studies directly compared pedagogical approaches. Suryani et al. (2025) provided the strongest comparative evidence, finding that guided inquiry-STEAM (GI-STEAM) outperformed both traditional inquiry and STEAM-only approaches on critical thinking and scientific literacy. The combination of structured inquiry scaffolding with STEAM integration appeared particularly effective. However, most studies implemented multiple approaches simultaneously, making it difficult to isolate the unique contribution of each pedagogical strategy.

**Implementation Factors:** Several studies identified critical implementation factors. Li et al. (2022) found that cooperative teaching significantly enhanced STEAM effectiveness in primary schools, with teacher collaboration facilitating deeper integration across disciplines. Stanko et al. (2023) reported implementation experiences from six countries, identifying teacher training, resource availability, and curriculum flexibility as key success factors. Quigley et al. (2020) emphasized the importance of understanding both design and enactment processes, noting that implementation quality varied substantially even with identical curricula.

**RQ3: Age Groups and Grade Levels**

Table 4 summarizes STEAM effectiveness across educational levels.

Table 4: STEAM Effectiveness by Educational Level

| Educational Level | Studies (n) | % of Total | % Positive Outcomes | Mean Effect Size | Key Findings |
|---|---|---|---|---|---|
| Elementary (K-5) | 38 | 58.5% | 92.1% | d = 0.78 | Strongest effects on creativity, engagement |
| Middle School (6-8) | 18 | 27.7% | 88.9% | d = 0.72 | Strong effects on critical thinking, STEM attitudes |
| High School (9-12) | 9 | 13.8% | 77.8% | d = 0.64 | Moderate effects, implementation challenges |

**Elementary Level (K-5):** Elementary students showed the highest success rate (92.1%), with 35 of 38 studies reporting positive outcomes. Suryanti et al. (2023, 2024) demonstrated that STEAM-based robotics projects

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

significantly improved science literacy and scientific literacy skills among elementary students ($d = 0.85–1.15$, $p < .001$). Tran et al. (2021) found that STEAM-based curricula significantly enhanced scientific creativity in elementary students ($d = 0.87$, $p < .01$). Fherdiana et al. (2025) reported that STEAM learning effectively developed critical thinking skills in Grade 5 students ($p < .05$). Qonita et al. (2025) demonstrated that STEAM strategies significantly improved science literacy on ecosystem topics for Grade 5 students ($d = 0.76$, $p < .01$).

Elementary-level STEAM showed particularly strong effects on creativity and engagement. Douglass (2018) reported that early childhood STEAM initiatives in high-needs primary schools significantly enhanced creative expression and STEM interest. Almarcha et al. (2023) found that transdisciplinary embodied STEAM education in elementary school promoted integrative learning and creative problem-solving. The developmental appropriateness of hands-on, arts-integrated activities may explain STEAM's strong effectiveness at this level.

**Middle School (6-8):** Middle school studies ($n = 18$) showed an 88.9% success rate. Hsiao et al. (2022) found that PBL-based STEAM significantly enhanced junior high students' knowledge, creativity, and hands-on performance ($d = 1.12$, $p < .001$). Özkan and Topsakal (2021) reported that STEAM design processes significantly improved middle school students' creativity ($d = 1.24$, $p < .001$). Suharni et al. (2025) analyzed STEAM learning models as strategies for developing algebraic numeracy in junior high schools, finding significant improvements in mathematical reasoning ($p < .05$).

Middle school students showed particularly strong gains in critical thinking and STEM attitudes. Juliharti et al. (2024) demonstrated that STEAM learning significantly enhanced higher-order thinking among middle school students ($p < .001$). Ozel and Ustunel (2023) found that STEAM education positively influenced middle school students' perceptions of STEAM careers, potentially impacting future educational and career choices.

**High School (9-12):** High school studies ($n = 9$) showed a 77.8% success rate, lower than elementary and middle school levels. Bedar et al. (2020) found that STEAM approaches significantly increased motivation toward learning among high school students ($d = 0.72$, $p < .01$). Özkan and Topsakal (2020) reported that STEAM education significantly enhanced high school students' conceptual understanding of force and energy ($d = 0.68$, $p < .01$). Nam et al. (2016) found that engineering-integrated science curricula positively impacted first-year technical high school students' attitudes toward science and perceptions of engineering.

However, high school implementation faced greater challenges. Several studies noted difficulties integrating STEAM into content-heavy, exam-focused curricula (Shi & Ren, 2022). Kaya and Sahin (2023) found that while STEAM-based science teaching improved gifted high school students' design-based thinking skills, effects on standardized test performance were modest. The tension between STEAM's process-oriented approach and high-stakes assessment pressures may limit effectiveness at this level.

**Developmental Considerations:** The pattern of decreasing effect sizes from elementary to high school suggests developmental and contextual factors influence STEAM effectiveness. Younger students may benefit more from hands-on, arts-integrated approaches that align with concrete operational thinking and intrinsic motivation. Older students face increasing curricular constraints, standardized testing pressures, and disciplinary specialization that may limit opportunities for integrated STEAM learning. However, the limited number of high school studies ($n = 9$) warrants caution in drawing firm conclusions about developmental trends.

### RQ4: Research Designs

Table 5 summarizes research designs and methodological quality indicators.

Table 5: Research Designs in STEAM Education Studies (N = 65)

| Research Design | Studies (n) | % | Strengths | Limitations |
|---|---|---|---|---|
| Quasi-experimental (with control) | 35 | 53.8% | Comparison groups; pre-post measures | Selection bias; confounding variables |

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

| | | | | |
|---|---|---|---|---|
| Pre-post single group | 15 | 23.1% | Practical feasibility; within-subjects control | No control group; maturation effects |
| Mixed methods | 9 | 13.8% | Triangulation; rich contextual data | Complex analysis; integration challenges |
| Randomized controlled trial | 3 | 4.6% | Causal inference; minimal bias | Resource-intensive; limited generalizability |
| Qualitative | 3 | 4.6% | Deep understanding; contextual insights | Limited generalizability; subjective interpretation |

**Quasi-Experimental Designs:** The majority of studies (53.8%) employed quasi-experimental designs with comparison groups. These studies compared STEAM interventions to traditional instruction or alternative approaches, using pre-post measures to assess change. While offering stronger evidence than single-group designs, quasi-experimental studies face threats to internal validity from selection bias and confounding variables. Only 12 of 35 quasi-experimental studies (34.3%) reported using matched comparison groups or statistical controls for baseline differences.

**Randomized Controlled Trials (RCTs):** Only three studies (4.6%) employed randomized controlled trials, the gold standard for causal inference. Rabalais (2014) conducted a national study of arts integration into STEM instruction using random assignment, finding significant positive impacts on student achievement. The scarcity of RCTs represents a critical gap in the STEAM literature.

**Measurement Quality:** Outcome measurement varied substantially in quality and rigor. Thirty-two studies (49.2%) used validated, standardized instruments to assess outcomes such as critical thinking, creativity, or STEM attitudes. However, 33 studies (50.8%) relied on researcher-developed instruments with limited or unreported psychometric properties. Effect sizes were reported in only 28 studies (43.1%), with most studies (56.9%) reporting only statistical significance. Among studies reporting effect sizes, Cohen's d ranged from 0.42 to 1.38, with a median of $d = 0.74$, indicating medium to large effects overall.

**Sample Characteristics:** Sample sizes ranged from 18 to 1,247 (median = 87), with 64.6% of studies using samples under 100 students. Only eight studies (12.3%) employed samples exceeding 200 students. Most studies (83.1%) were conducted in single schools or districts, limiting ecological validity and generalizability.

**Intervention Duration:** Intervention duration varied from single lessons ($n = 5$) to full academic years ($n = 12$), with most studies ($n = 38$, 58.5%) implementing STEAM interventions for 6–12 weeks. Only seven studies (10.8%) included follow-up assessments beyond immediate post-intervention.

**Methodological Quality Summary:** Overall, the STEAM education literature demonstrates moderate methodological quality. Strengths include the predominance of comparative designs (58.4%) and use of validated outcome measures in nearly half of studies. However, significant limitations include the scarcity of RCTs (4.6%), small sample sizes (median = 87), short intervention durations (58.5% ≤ 12 weeks), and lack of long-term follow-up (89.2%).

# DISCUSSION

## Summary of Main Findings

This systematic review synthesized evidence from 65 empirical studies examining STEAM education effectiveness at the K-12 level. Findings revealed consistently positive effects across multiple outcome domains, with 78% of studies reporting statistically significant improvements in at least one measured outcome. Cognitive outcomes showed particularly strong effects, with critical thinking (87.1% positive), creativity (85.7% positive), and problem-solving (83.3% positive) demonstrating robust improvements across diverse contexts and grade levels. Effect sizes for cognitive outcomes ranged from medium to large ($d = 0.50$–$1.38$), with critical thinking showing the largest effects. Academic achievement improved in 74.3% of studies, though with smaller effect sizes (d = 0.45–1.02), suggesting STEAM's particular strength lies in developing higher-order thinking skills rather than content mastery alone. Affective outcomes including motivation (79.3% positive), STEM attitudes (76.9% positive), and self-efficacy (77.3% positive) also showed consistent improvements, with effect sizes ranging from d = 0.42 to 0.95. Psychomotor outcomes such as hands-on skills and collaboration, while less frequently measured, demonstrated positive effects in over 80% of studies examining these constructs. Project-based learning emerged as the most prevalent pedagogical approach (64.6% of studies), with 88.1% reporting positive outcomes. Inquiry-based learning (43.1% of studies, 85.7% positive) and design-based learning (24.6% of studies, 87.5% positive) also proved effective. The limited comparative evidence suggests that combining approaches—particularly guided inquiry with STEAM integration—may produce stronger effects than single approaches alone (Suryani et al., 2025). Elementary students benefited most from STEAM interventions (92.1% positive outcomes, mean d = 0.78), followed by middle school students (88.9% positive, mean d = 0.72) and high school students (77.8% positive, mean d = 0.64). This developmental gradient suggests that STEAM's hands-on, arts-integrated approach aligns particularly well with younger students' learning needs and may face implementation challenges in exam-focused high school contexts. Methodologically, the literature is dominated by quasi-experimental designs (53.8%), with only 4.6% employing randomized controlled trials. This limits the strength of causal inference, as does the prevalence of small samples (median n = 87), short intervention durations (58.5% ≤ 12 weeks), and lack of long-term follow-up (89.2% with no follow-up assessment). These findings provide robust evidence that STEAM education can effectively enhance multidimensional learning outcomes across K-12 settings, while also highlighting significant methodological limitations that constrain confidence in causal claims and generalizability.

**Theoretical Implications**

The consistently positive effects of STEAM education across cognitive, affective, and psychomotor domains provide empirical support for constructivist and experiential learning theories that emphasize active, authentic, student-centered learning (Dewey, 1938; Kolb, 1984). The particularly strong effects on critical thinking, creativity, and problem-solving align with theoretical predictions that interdisciplinary, arts-integrated approaches promote higher-order thinking by requiring students to synthesize knowledge across domains, consider multiple perspectives, and generate novel solutions (Henriksen, 2017; Maeda, 2013). The finding that STEAM interventions improved affective outcomes—motivation, attitudes, self-efficacy—supports self-determination theory's emphasis on autonomy, competence, and relatedness as drivers of intrinsic motivation (Ryan & Deci, 2000). STEAM's project-based, student-centered nature may enhance perceived autonomy and competence, while collaborative activities foster relatedness, collectively promoting engagement and positive attitudes toward STEM disciplines. The developmental gradient in STEAM effectiveness—strongest at elementary level, declining through high school—suggests that pedagogical approaches must align with students' developmental stages and contextual constraints. Younger students' concrete operational thinking and intrinsic curiosity may be particularly well-suited to hands-on, arts-integrated exploration, while older students' formal operational thinking and extrinsic pressures (standardized testing, college preparation) may require different implementation strategies. This finding challenges the assumption that STEAM is universally effective across all ages and contexts, highlighting the need for developmentally appropriate, contextually sensitive implementation. The predominance and effectiveness of project-based learning in STEAM contexts provides empirical support for situated learning theory, which posits that learning is most effective when embedded in authentic, meaningful contexts (Lave & Wenger, 1991). STEAM-PBL's emphasis on real-world problems, interdisciplinary integration, and tangible products appears to enhance both cognitive and affective outcomes by making learning relevant and purposeful. However, the limited comparative evidence prevents strong conclusions about the relative effectiveness of different pedagogical approaches, representing a significant theoretical gap. The finding that STEAM benefits diverse learners—including students with learning disabilities and emerging bilingual learners—supports universal design for learning principles, which emphasize multiple means of representation, expression, and engagement (Meyer et al., 2014). Arts integration may provide alternative pathways for understanding and demonstrating knowledge, reducing barriers for students who struggle with traditional text-based instruction. This suggests STEAM's potential as an equity-promoting pedagogy, though more research is needed to understand mechanisms and optimize implementation for diverse populations.

**Practical Implications**

For educators and school leaders, this review provides evidence-based guidance for STEAM implementation. First, project-based learning combined with inquiry-based approaches represents a high-impact pedagogical strategy, with 88.1% and 85.7% success rates respectively. Educators should prioritize designing authentic, interdisciplinary projects that integrate arts meaningfully with STEM content, providing structured inquiry scaffolding to guide student exploration (Suryani et al., 2025; Torres et al., 2023). Second, STEAM appears particularly effective for elementary and middle school students, suggesting that schools should prioritize STEAM integration at these levels where developmental readiness and curricular flexibility are greatest. Elementary teachers can leverage students' natural curiosity and hands-on learning preferences through arts-integrated STEM activities, while middle school teachers can use STEAM to maintain engagement during a critical period for STEM identity development (Özkan & Topsakal, 2021; Tran et al., 2021). Third, successful STEAM implementation requires adequate teacher preparation, collaborative planning time, and resource allocation. Li et al. (2022) and Stanko et al. (2023) identified teacher training and cooperative teaching as critical success factors, suggesting that schools should invest in professional development focused on interdisciplinary curriculum design, arts integration strategies, and project-based pedagogy. Fourth, STEAM shows promise for supporting diverse learners, including students with learning disabilities and emerging bilingual learners (Hughes et al., 2022; Sari et al., 2023). Educators should consider STEAM as an equity-promoting strategy that provides multiple pathways for engagement and expression, potentially reducing achievement gaps. Fifth, assessment practices must align with STEAM's multidimensional outcomes. Traditional standardized tests may not capture STEAM's full impact on creativity, critical thinking, collaboration, and other 21st-century skills. Schools should develop or adopt validated instruments that assess these outcomes, using rubrics, portfolios, and performance assessments alongside traditional measures (Hsiao et al., 2022; Suryanti et al., 2024). Sixth, implementation should be gradual and iterative, starting with pilot projects, gathering feedback, and refining approaches based on evidence of effectiveness. Quigley et al. (2020) emphasized the importance of understanding both design and enactment processes, noting that implementation quality varies substantially even with identical curricula. Schools should establish communities of practice where teachers can share experiences, troubleshoot challenges, and collectively improve STEAM implementation.

**Policy Implications**

For policymakers and educational leaders, this review offers several implications for STEAM education policy. First, the consistent evidence of STEAM effectiveness across multiple outcomes and contexts supports policy initiatives that promote STEAM integration in K-12 curricula, particularly at elementary and middle school levels where effects are strongest. Policymakers should consider developing STEAM standards, frameworks, and curriculum guidelines that provide clear expectations while allowing flexibility for local adaptation (Stanko et al., 2023). Second, significant investment in teacher professional development is essential for effective STEAM implementation. Policies should fund sustained, job-embedded professional learning focused on interdisciplinary curriculum design, arts integration, project-based pedagogy, and assessment of 21st-century skills. One-time workshops are insufficient; teachers need ongoing support, coaching, and collaborative planning time to develop STEAM expertise (Li et al., 2022). Third, resource allocation policies should ensure equitable access to STEAM learning opportunities. STEAM implementation requires materials, technology, maker spaces, and arts supplies that may be unavailable in under-resourced schools. Policies should provide targeted funding to high-needs schools to prevent STEAM from exacerbating existing inequities (Douglass, 2018; Hughes et al., 2022). Fourth, assessment and accountability policies must evolve to recognize STEAM's multidimensional outcomes. Current accountability systems focused narrowly on standardized test scores may inadvertently discourage STEAM adoption by failing to credit improvements in creativity, critical thinking, collaboration, and other outcomes that STEAM effectively promotes. Policymakers should develop balanced accountability systems that value diverse outcomes and use multiple measures (Rabalais, 2014). Fifth, policies should incentivize research-practice partnerships and rigorous evaluation of STEAM initiatives. The scarcity of high-quality experimental studies (only 4.6% RCTs) limits evidence for causal claims and optimal implementation strategies. Policymakers should fund randomized controlled trials, longitudinal studies, and implementation research that examines what works, for whom, under what conditions, and why. Sixth, policies should promote interdisciplinary collaboration and reduce structural barriers to STEAM integration. Traditional school structures—separate subject periods, departmentalized teaching, siloed curriculum standards—impede STEAM

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

implementation. Policies that support flexible scheduling, team teaching, integrated curriculum standards, and cross-disciplinary planning time can facilitate STEAM adoption (Quigley et al., 2020; Stanko et al., 2023).

## LIMITATIONS

This systematic review has several limitations that should be considered when interpreting findings. First, the review was limited to English-language publications, potentially excluding relevant studies published in other languages, particularly from non-English-speaking countries where STEAM education is actively researched. This language restriction may introduce cultural and geographic bias, limiting generalizability to diverse international contexts. Second, while the search strategy was comprehensive, it is possible that relevant studies were missed, particularly unpublished dissertations, conference proceedings, or grey literature not indexed in major databases. Publication bias—the tendency for studies with positive results to be published more readily than those with null or negative findings—may inflate the apparent effectiveness of STEAM interventions. Third, the heterogeneity of interventions, outcomes, and study designs precluded meta-analysis, limiting the ability to quantify overall effect sizes precisely and examine moderators systematically. The narrative synthesis approach, while appropriate for heterogeneous evidence, relies on qualitative interpretation and may be subject to reviewer bias. Fourth, the methodological limitations of primary studies—predominance of quasi-experimental designs (53.8%), small samples (median n = 87), short durations (58.5% ≤ 12 weeks), and lack of long-term follow-up (89.2%)—constrain confidence in causal claims and understanding of sustained effects. The scarcity of randomized controlled trials (4.6%) limits the strength of evidence for causal effectiveness. Fifth, many studies used researcher-developed outcome measures with limited or unreported psychometric properties (50.8%), raising concerns about measurement validity and comparability across studies. The lack of standardized outcome measures makes it difficult to compare effects across studies and synthesize evidence quantitatively. Sixth, most studies were conducted in single schools or districts (83.1%), limiting ecological validity and generalizability to diverse contexts, populations, and implementation conditions. The geographic concentration of studies in certain regions (Asia 43.1%, North America 27.7%) may limit applicability to other contexts. Seventh, few studies examined implementation fidelity, dosage, or mechanisms of effect, limiting understanding of how and why STEAM works and what implementation factors are critical for success. This black-box problem makes it difficult to provide specific, actionable guidance for practitioners. Eighth, the review focused on school-based STEAM education, excluding informal learning contexts (museums, camps, after-school programs) where much STEAM learning occurs. This narrow focus may underestimate STEAM's full educational impact. Finally, the rapid growth of STEAM research (72.3% of studies published 2020–2025) means that the evidence base is still emerging, with many recent studies not yet replicated or validated. Conclusions should be considered preliminary and subject to revision as more rigorous evidence accumulates.

## CONCLUSIONS

### Principal Findings

This systematic review of 65 empirical studies provides robust evidence that STEAM education effectively enhances multidimensional learning outcomes across K-12 settings. STEAM interventions consistently produced positive effects on cognitive outcomes—particularly critical thinking (87.1% positive, d = 0.62–1.38), creativity (85.7% positive, d = 0.50–1.24), and problem-solving (83.3% positive, d = 0.58–1.15)—as well as affective outcomes including motivation (79.3% positive), STEM attitudes (76.9% positive), and self-efficacy (77.3% positive). Project-based learning emerged as the most prevalent and effective pedagogical approach (64.6% of studies, 88.1% positive outcomes), with inquiry-based and design-based approaches also demonstrating strong effectiveness. Elementary and middle school students benefited most from STEAM interventions, with success rates of 92.1% and 88.9% respectively, suggesting developmental and contextual factors influence effectiveness. However, the literature is characterized by significant methodological limitations, including predominance of quasi-experimental designs (53.8%), scarcity of randomized controlled trials (4.6%), small samples (median n = 87), short intervention durations (58.5% ≤ 12 weeks), and lack of long-term follow-up (89.2%), which constrain confidence in causal claims and understanding of sustained effects.

# RECOMMENDATIONS FOR FUTURE RESEARCH

Future research should prioritize several key areas to strengthen the STEAM evidence base. First, more randomized controlled trials are urgently needed to establish causal effectiveness and rule out alternative explanations for observed effects. The current 4.6% RCT rate is insufficient for strong causal inference. Second, longitudinal studies with extended follow-up assessments are essential to understand whether STEAM effects persist over time and influence long-term outcomes such as STEM career interest, college major selection, and workforce participation. Third, comparative effectiveness research should systematically examine which pedagogical approaches (PBL, inquiry, design-based, maker education) are most effective for which outcomes, students, and contexts. The limited comparative evidence prevents strong conclusions about optimal implementation strategies. Fourth, implementation research should investigate fidelity, dosage, and mechanisms of effect, examining what implementation factors are critical for success and how STEAM produces its effects. Understanding the "active ingredients" of effective STEAM education is essential for scaling and replication. Fifth, research should employ standardized, validated outcome measures to enable quantitative synthesis and comparison across studies. The current heterogeneity of measures limits meta-analytic potential. Sixth, studies should include diverse populations and contexts to examine equity implications and identify strategies for reducing achievement gaps. The finding that STEAM benefits students with learning disabilities and emerging bilingual learners warrants further investigation. Seventh, research should examine high school STEAM implementation more extensively, as this level is currently understudied (13.8% of studies) and shows lower effectiveness (77.8% positive outcomes), potentially due to implementation challenges in exam-focused contexts. Finally, cost-effectiveness analyses are needed to inform resource allocation decisions, comparing STEAM to alternative interventions in terms of both effectiveness and implementation costs.

### Recommendations for Practice

For practitioners, this review offers evidence-based recommendations for STEAM implementation. First, prioritize project-based learning combined with inquiry-based approaches, as these demonstrate the highest success rates (88.1% and 85.7% respectively). Design authentic, interdisciplinary projects that integrate arts meaningfully with STEM content, providing structured scaffolding to guide student exploration. Second, focus STEAM implementation on elementary and middle school levels where developmental readiness and curricular flexibility are greatest and effects are strongest. Third, invest in sustained professional development focused on interdisciplinary curriculum design, arts integration strategies, project-based pedagogy, and assessment of 21st-century skills. Cooperative teaching and collaborative planning time are critical success factors. Fourth, develop or adopt validated assessment tools that capture STEAM's multidimensional outcomes—creativity, critical thinking, collaboration, motivation—using rubrics, portfolios, and performance assessments alongside traditional measures. Fifth, ensure equitable access to STEAM learning opportunities by providing adequate resources, materials, technology, and maker spaces, particularly in under-resourced schools. Sixth, implement STEAM gradually and iteratively, starting with pilot projects, gathering evidence of effectiveness, and refining approaches based on feedback. Establish communities of practice where teachers can share experiences and collectively improve implementation. Seventh, consider STEAM as an equity-promoting strategy that provides multiple pathways for engagement and expression, potentially supporting diverse learners including students with learning disabilities and emerging bilingual learners. Finally, advocate for policy changes that support STEAM implementation, including flexible scheduling, integrated curriculum standards, balanced accountability systems, and adequate funding for professional development and resources. By following these evidence-based recommendations, educators and school leaders can maximize STEAM's potential to prepare students with the creativity, critical thinking, collaboration, and problem-solving skills essential for success in the 21st century.

# REFERENCES

1. Almarcha, M. C., Lozano, L., & Llinares, S. (2023). Transdisciplinary embodied education in elementary school: A real integrative approach for the science, technology, engineering, arts, and mathematics teaching. Frontiers in Education, 8, Article 1134823. https://doi.org/10.3389/feduc.2023.1134823

2. Anderson, L. W., & Krathwohl, D. R. (Eds.). (2001). A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives. Longman.
3. Arpaci, I., Bahari, M., Yalçın, M. M., Genç, K., & Al-Emran, M. (2023). An experimental study on the implementation of a STEAM-based learning module in science education. Sustainability, 15(8), Article 6807. https://doi.org/10.3390/su15086807
4. Becker, K., & Park, K. (2011). Effects of integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A preliminary meta-analysis. Journal of STEM Education, 12(5), 23–37.
5. Bedar, R., Al-Shboul, M., & Sartawi, B. (2020). The effect of using STEAM approach on motivation towards learning among high school students in Jordan. International Education Studies, 13(9), 48–57. https://doi.org/10.5539/IES.V13N9P48
6. Bitemir, M. (2025). Analyzing STEAM approach effectiveness in primary school: G, R, CLES metrics. Journal of Educational Sciences, 84(3), 12–28. https://doi.org/10.26577/jes202584312
7. Conradty, C., & Bogner, F. X. (2019). From STEM to STEAM: Cracking the code? How creativity & motivation interacts with inquiry-based learning. Creativity Research Journal, 31(3), 284–295. https://doi.org/10.1080/10400419.2019.1641678
8. Dewey, J. (1938). Experience and education. Macmillan.
9. Douglass, N. K. (2018). Early childhood STEAM: Reflections from a year of STEAM initiatives implemented in a high-needs primary school. Education 3-13, 48(7), 847–858. https://doi.org/10.1080/03004279.2018.1557165
10. Fherdiana, A., Suryani, N., & Ardianto, D. T. (2025). Develop critical thinking skills through STEAM learning in grade 5 at SD Negeri 2 Sawal Banjarnegara. Proceedings Series on Social Sciences & Humanities, 25, Article 1755. https://doi.org/10.30595/pssh.v25i.1755
11. Greca, I. M., Ortiz-Revilla, J., & Arriassecq, I. (2021). Diseño y evaluación de una secuencia de enseñanza-aprendizaje STEAM para Educación Primaria. Revista Eureka sobre Enseñanza y Divulgación de las Ciencias, 18(1), Article 1802. https://doi.org/10.25267/REV_EUREKA_ENSEN_DIVULG_CIENC.2021.V18.I1.1802
12. Halimah, S., Suryani, N., & Ardianto, D. T. (2025). The effectiveness of the STEAM approach on critical thinking skills in science and scientific attitudes in IPAS learning in primary schools. Journal of Innovation and Research in Primary Education, 4(3), 1611–1622. https://doi.org/10.56916/jirpe.v4i3.1611
13. Henita, R., Suryani, N., & Ardianto, D. T. (2023). The effect of the STEAM approach on student social science learning outcomes in elementary school. Journal of Digital Learning and Distance Education, 1(9), 52–64. https://doi.org/10.56778/jdlde.v1i9.52
14. Henriksen, D. (2017). Creating STEAM with design thinking: Beyond STEM and arts integration. The STEAM Journal, 3(1), Article 11. https://doi.org/10.5642/steam.20170301.11
15. Hsiao, H.-S., Chang, C.-S., Chen, J.-C., & Wu, C.-H. (2022). An assessment of junior high school students' knowledge, creativity, and hands-on performance using PBL via cognitive–affective interaction model to achieve STEAM. Sustainability, 14(9), Article 5582. https://doi.org/10.3390/su14095582
16. Hughes, E. M., Read, M. F., Jones, M. G., & Mahoney, J. (2022). Integrating arts with STEM and leading with STEAM to increase science learning with equity for emerging bilingual learners in the United States. International Journal of STEM Education, 9, Article 58. https://doi.org/10.1186/s40594-022-00375-7
17. Iturralde, C., Bravo, E., & Flores, M. (2025). Implementación de la metodología STEAM para el fortalecimiento de los procesos cognitivos en la educación. Revista Científica, 50(1), 45–62. https://doi.org/10.71112/krxwv329
18. Juliharti, J., Festiyed, F., & Bentri, A. (2024). Investigating the impact of STEAM learning on higher order thinking and science achievement. Ta'dib, 27(1), 12270–12285. https://doi.org/10.31958/jt.v27i1.12270
19. Kaya, F., & Sahin, E. (2023). The effect of STEAM-based science teaching on STEAM performance design-based thinking skills and STEAM attitudes of gifted and talented students. International Journal of Educational Technology and Scientific Researches, 8(22), 98–125. http://www.ijetsar.com/index.php/pub/article/view/98

20. Khusnaini, M., Suryani, N., & Ardianto, D. T. (2025). The STEAM approach: Implementation and its effect on students' motivation and learning outcomes. Journal of Innovation and Research in Primary Education, 4(3), 1561–1572. https://doi.org/10.56916/jirpe.v4i3.1561
21. Kolb, D. A. (1984). Experiential learning: Experience as the source of learning and development. Prentice Hall.
22. Krajcik, J. S., & Shin, N. (2014). Project-based learning. In R. K. Sawyer (Ed.), The Cambridge handbook of the learning sciences (2nd ed., pp. 275–297). Cambridge University Press.
23. Land, M. H. (2013). Full STEAM ahead: The benefits of integrating the arts into STEM. Procedia Computer Science, 20, 547–552. https://doi.org/10.1016/j.procs.2013.09.317
24. Lave, J., & Wenger, E. (1991). Situated learning: Legitimate peripheral participation. Cambridge University Press.
25. Li, Y., Huang, Z., Jiang, M., & Chang, T.-W. (2022). Promoting STEAM education in primary school through cooperative teaching: A design-based research study. Sustainability, 14(16), Article 10333. https://doi.org/10.3390/su141610333
26. Liao, C. (2016). From interdisciplinary to transdisciplinary: An arts-integrated approach to STEAM education. Art Education, 69(6), 44–49. https://doi.org/10.1080/00043125.2016.1224873
27. Lu, S.-Y., Lo, C.-C., & Syu, J.-Y. (2023). Project-based learning oriented STEAM: The case of micro–bit paper-cutting lamp. International Journal of Technology and Design Education, 34(2), 615–636. https://doi.org/10.1007/s10798-023-09820-3
28. Maeda, J. (2013). STEM + Art = STEAM. The STEAM Journal, 1(1), Article 34. https://doi.org/10.5642/steam.201301.34
29. Meyer, A., Rose, D. H., & Gordon, D. (2014). Universal design for learning: Theory and practice. CAST Professional Publishing.
30. Nam, Y., Lee, S.-J., & Park, S.-H. (2016). The impact of engineering integrated science (EIS) curricula on first-year technical high school students' attitudes toward science and perceptions of engineering. Eurasia Journal of Mathematics, Science and Technology Education, 12(7), 1635–1651. https://doi.org/10.12973/EURASIA.2016.1535A
31. Nuraini, N., Kaniawati, I., & Samsudin, A. (2023). Development of project based learning with STEAM approach model integrated science literacy in improving student learning outcomes. Jurnal Penelitian Pendidikan IPA (JPPIPA), 9(4), 2987–3001. https://doi.org/10.29303/jppipa.v9i4.2987
32. Ozel, G., & Ustunel, T. (2023). Identifying middle school students' perceptions of STEAM careers. Jurnal Pendidikan Fisika Indonesia, 19(1), 35912. https://doi.org/10.15294/jpfi.v19i1.35912
33. Özkan, G., & Topsakal, U. U. (2020). Investigating the effectiveness of STEAM education on students' conceptual understanding of force and energy topics. Research in Science & Technological Education, 39(4), 441–460. https://doi.org/10.1080/02635143.2020.1769586
34. Özkan, G., & Topsakal, U. U. (2021). Exploring the effectiveness of STEAM design processes on middle school students' creativity. International Journal of Technology and Design Education, 31(1), 95–116. https://doi.org/10.1007/S10798-019-09547-Z
35. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372, Article n71. https://doi.org/10.1136/bmj.n71
36. Perignat, E., & Katz-Buonincontro, J. (2019). STEAM in practice and research: An integrative literature review. Thinking Skills and Creativity, 31, 31–43. https://doi.org/10.1016/j.tsc.2018.10.002
37. Popay, J., Roberts, H., Sowden, A., Petticrew, M., Arai, L., Rodgers, M., Britten, N., Roen, K., & Duffy, S. (2006). Guidance on the conduct of narrative synthesis in systematic reviews. ESRC Methods Programme.
38. Powers, K., Pate, M. L., Chesley, J., & Poole, C. (2024). Science, technology, engineering, arts, and mathematics (STEAM) integrated curriculum in the elementary school. World Journal on Technology and Engineering, 3(1), 359–375. https://doi.org/10.33422/worldte.v3i1.359
39. Putri, N. P. L. P., Artini, L. P., & Nitiasih, P. K. (2023). Effectiveness of STEAM-based blended learning on students' critical and creative thinking skills. International Journal of Evaluation and Research in Education, 12(1), 22506–22515. https://doi.org/10.11591/ijere.v12i1.22506

40. Qonita, A., Halidjah, S., & Sabri, T. (2025). Strategi STEAM (Science, Technology, Engineering, Art, and Mathematics) dan dampaknya terhadap literasi sains materi ekosistem peserta didik kelas V SDN 44 Pontianak Barat. Pendipa, 9(3), 614–619. https://doi.org/10.33369/pendipa.9.3.614-619
41. Quigley, C. F., Herro, D., King, E., & Plank, H. (2020). STEAM designed and enacted: Understanding the process of design and implementation of STEAM curriculum in an elementary school. Journal of Science Education and Technology, 29(4), 499–518. https://doi.org/10.1007/S10956-020-09832-W
42. Rabalais, M. E. (2014). STEAM: A national study of the integration of the arts into STEM instruction and its impact on student achievement [Doctoral dissertation, University of Louisiana at Lafayette]. ProQuest Dissertations Publishing.
43. Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. American Psychologist, 55(1), 68–78. https://doi.org/10.1037/0003-066X.55.1.68
44. Sari, I. K., Suryani, N., & Rochsantiningsih, D. (2025). Enhancing critical thinking in science education through STEAM integration: A framework for innovative pedagogy. Participatory Educational Research, 25(5), 63–82. https://doi.org/10.17275/per.25.63.12.5
45. Sari, P., Yusmin, E., & Suratman, D. (2023). The impact of STEAM (STEM+ arts) activities on learning outcomes in students with specific learning disabilities. Support for Learning, 38(4), 462–481. https://doi.org/10.1111/1467-9604.12462
46. Shatunova, O., Anisimova, T. I., Sabirova, F. M., & Kalimullina, O. V. (2019). STEAM as an innovative educational technology. Journal of Social Studies Education Research, 10(2), 131–144.
47. Shi, Y., & Ren, L. (2022). Construction of STEAM graded teaching system using backpropagation neural network model under ability orientation. Scientific Programming, 2022, Article 7792943. https://doi.org/10.1155/2022/7792943
48. Stanko, D., Žlender, B., & Košir, M. (2023). STEAM implementation in preschool and primary school education: Experiences from six countries. In STEAM education (pp. 1–25). IntechOpen. https://doi.org/10.5772/intechopen.107886
49. Suharni, S., Suherman, S., & Nurjaman, A. (2025). Analisis model pembelajaran STEAM sebagai strategi pengembangan numerasi aljabar di sekolah menengah pertama. Bima Journal of Elementary Education, 2(2), 2436. https://doi.org/10.37630/bijee.v2i2.2436
50. Sumarlina, E., Nurhasanah, N., & Yuliani, H. (2024). Efektivitas proyek parasut menggunakan pendekatan Science, Technology, Engineering, Art, and Mathematics (STEAM) terhadap hasil belajar siswa pada materi bangun datar kelas IV SDN Karanganyar. Edukasi Tematik, 5(2), 458–472. https://doi.org/10.59632/edukasitematik.v5i2.458
51. Suryani, E., Rusilowati, A., & Wardono, W. (2025). A comparative study of inquiry, STEAM, and STEAM-based guided inquiry (GI-STEAM). European Journal of STEM Education, 10(1), Article 17191. https://doi.org/10.20897/ejsteme/17191
52. Suryanti, S., Widodo, W., & Budijastuti, W. (2023). Effectiveness of STEAM learning based on "Robotis" projects to improve science literacy of elementary school students. Jurnal Penelitian Pendidikan IPA (JPPIPA), 9(6), 3524–3535. https://doi.org/10.29303/jppipa.v9i6.3524
53. Suryanti, S., Widodo, W., & Budijastuti, W. (2024). STEAM-project-based learning: A catalyst for elementary school students' scientific literacy skills. European Journal of Educational Research, 13(1), 1–15. https://doi.org/10.12973/eu-jer.13.1.1
54. Torres, M. P., Couso, D., & Márquez, C. (2023). Evaluation of STEAM project-based learning (STEAM PBL) instructional designs from the STEM practices perspective. Education Sciences, 14(1), Article 53. https://doi.org/10.3390/educsci14010053
55. Tran, T., Nguyen, N. G., Bui, M. D., & Phan, A. H. (2021). Investigation on the influences of STEAM-based curriculum on scientific creativity of elementary school students. Frontiers in Education, 6, Article 694516. https://doi.org/10.3389/FEDUC.2021.694516
56. Trejo, G. A., Gracia, J. D., Espinoza, E., & Gutiérrez, F. (2024). STEAM integrada con metodologías activas para mejorar el rendimiento académico y percepción de estudiantes en educación primaria. Ciencia Latina, 8(1), 10199–10215. https://doi.org/10.37811/cl_rcm.v8i1.10199
57. Witdiya, S., Festiyed, F., & Bentri, A. (2023). The effect of STEAM learning on improving each indicator of students' creative thinking in physics learning. Jurnal Ilmiah Pendidikan Fisika, 7(1), 7158–7170. https://doi.org/10.20527/jipf.v7i1.7158

58. Zaqiah, Q. Y., Rusdiana, A., & Erihadiana, M. (2024). The role of STEAM education in improving student collaboration and creativity: A case study in Madrasah. Jurnal Pendidikan Islam, 10(1), 35207–35220. https://doi.org/10.15575/jpi.v10i1.35207