

TRENDS IN THE DEVELOPMENT OF INTEGRATED STEAM DIGITAL LEARNING MEDIA IN PRIMARY SCHOOLS FROM 2020 TO 2025

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Abstract

The rapid advancement of digital technology requires the education sector to continually innovate in designing interactive, contextual, and relevant learning that aligns with 21st-century demands. One approach that has received increasing attention is STEAM-integrated digital learning, which combines Science, Technology, Engineering, Arts, and Mathematics. This approach is believed to enhance higher-order thinking skills, particularly critical thinking, while also strengthening creativity, collaboration, and communication (4C) among primary school students. This study aims to systematically review research trends on the development and implementation of STEAM-integrated digital learning media in primary schools from 2020 to 2025. Employing a Systematic Literature Review guided by PRISMA 2020, data were collected from five major databases: Google Scholar, Scopus, ERIC, ScienceDirect, and DOAJ. Through a structured selection process, 20 relevant journal articles published within the specified period were analyzed using basic bibliometric and thematic analysis techniques. The findings reveal a notable increase in publications in 2022. Dominant keywords include STEAM, Augmented Reality, Critical Thinking, and Elementary School. The most frequently examined learning media were Augmented Reality and interactive or mobile learning applications, commonly implemented through Project-Based Learning and Problem-Based Learning models. Most studies (85%) primarily focused on critical thinking, with creativity and cognitive learning outcomes also receiving considerable attention. Research and Development (60%) and quasi-experimental methods (30%) were the most commonly employed research designs. Overall, the integration of digital technology in STEAM learning demonstrates positive effects on the development of primary school students' 4C competencies; however, this review contributes novel insights by systematically mapping the limited exploration of collaboration and communication skills within STEAM-based digital learning research at the primary education level.

Keywords: STEAM learning; Digital Technology; Augmented Reality; 4C Skills; Primary School

Abstrak

Perkembangan teknologi digital menuntut dunia pendidikan untuk terus berinovasi dalam menciptakan pembelajaran yang interaktif, kontekstual, dan relevan dengan tuntutan abad ke-21. Salah satu pendekatan yang semakin mendapat perhatian adalah pembelajaran digital yang diintegrasikan dengan Science, Technology, Engineering, Arts, and Mathematics. Pendekatan ini diyakini tidak hanya mampu mengembangkan kemampuan berpikir tingkat tinggi seperti berpikir kritis, tetapi juga keterampilan penting lainnya seperti kreativitas, kolaborasi, dan komunikasi (4C) pada siswa sekolah dasar. Penelitian ini bertujuan untuk meninjau secara sistematis berbagai studi mengenai tren pengembangan dan penerapan media pembelajaran digital terintegrasi STEAM di sekolah dasar dalam rentang waktu 2020–2025. Metode penelitian yang digunakan adalah *Systematic Literature Review* dengan panduan PRISMA 2020. Data diperoleh dari lima basis data utama, yaitu Google Scholar, Scopus, ERIC, ScienceDirect, dan DOAJ. Berdasarkan proses seleksi sistematis, 20 artikel jurnal relevan yang diterbitkan antara 2020–2025 dianalisis secara bibliometrik dasar dan tematik. Hasil analisis menunjukkan tren peningkatan publikasi pada tahun 2022. Kata kunci dominan meliputi STEAM, Augmented Reality, Critical Thinking, dan Elementary School. Jenis media yang paling banyak diteliti adalah Augmented Reality dan aplikasi interaktif/mobile learning, yang sering diterapkan melalui model Project-Based Learning atau Problem-Based Learning. Mayoritas studi (85%) berfokus pada pengukuran kemampuan berpikir kritis, dengan kreativitas dan hasil belajar kognitif juga menjadi fokus yang signifikan. Metode *Research and Development* (60%) dan kuasi-eksperimen (30%) merupakan desain penelitian yang paling umum digunakan. Secara umum, penggunaan teknologi digital dalam pembelajaran STEAM terbukti berkontribusi positif terhadap pengembangan kompetensi 4C siswa sekolah dasar, dan penelitian ini secara khusus memberikan kontribusi baru melalui pemetaan celah riset pada aspek kolaborasi dan komunikasi yang masih minim dieksplorasi dalam pengembangan media STEAM digital di sekolah dasar.

Kata Kunci: Pembelajaran STEAM; Teknologi Digital; Augmented Reality; Keterampilan 4C; Sekolah Dasar

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Introduction

Entering the era of digitalisation, the education sector is required to adapt continuously to rapid technological development and changing societal demands (Ramadhanti, 2024). The transformation of digital technology has altered how students access information and how learning outcomes are defined in modern education. Primary education plays a critical role in developing foundational competencies, yet many classrooms still rely on conventional instructional practices that limit active learning (Kamila et al., 2025). This condition creates a gap between educational practice and the demands of twenty-first-century skills. As a result, students often lack sufficient opportunities to develop critical thinking, creativity, collaboration, and communication skills (Stenbom & Geijer, 2025). Therefore, meaningful integration of digital technology into learning processes has become an urgent educational need. Without such integration, schools risk failing to prepare students for complex real-world challenges.

To address these challenges, the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach has emerged as a relevant interdisciplinary learning framework (Mulyana, 2023). STEAM emphasises the integration of multiple disciplines to solve real-world problems rather than teaching subjects in isolation. The inclusion of Arts highlights the importance of creativity and design thinking in supporting innovation and problem-solving (Rizki et al., 2024). This approach is particularly suitable for primary school students, who benefit from contextual and experiential learning. Through STEAM, students are encouraged to explore, experiment, and create, supporting both cognitive and affective development (Asila, 2025). Consequently, STEAM aligns strongly with the goals of twenty-first-century education (Nugraheny et al., 2025). Its implementation is expected to foster balanced development of knowledge, skills, and attitudes from an early age.

The implementation of STEAM learning can be strengthened through the use of digital learning media. Digital technologies enable the visualisation of abstract concepts and support interactive learning experiences that are difficult to achieve through traditional methods (Rantanen et al., 2025). Media such as web-based platforms, mobile applications, and augmented reality provide opportunities for immersive and engaging learning (Duong et al., 2024). These technologies allow students to actively participate in simulations, virtual experiments, and project-based activities. Digital learning media also support flexible and student-centred learning environments (Kasmawati et al., 2023). In addition, technology-assisted learning can increase students' motivation and engagement during classroom activities. Therefore, the integration of digital media is considered a key factor in optimising STEAM learning in primary education (Yang et al., 2024).

Although numerous studies have reported positive outcomes of STEAM-integrated digital learning, existing research shows several limitations (Syah et al., 2023). Most studies focus primarily on cognitive outcomes, particularly critical thinking skills. Creativity is sometimes examined, but collaboration and communication skills are often mentioned only conceptually and rarely measured explicitly (Fearn & Hook, 2023). In addition, previous studies tend to be fragmented and lack systematic synthesis within a specific time frame. This condition makes it

difficult to identify dominant research trends, methodological patterns, and underexplored areas (Maroungkas et al., 2023). As a result, a comprehensive understanding of the development of all 4C competencies in STEAM digital learning remains limited. This gap highlights the need for a structured review that captures both strengths and shortcomings of existing studies (Neldarisasmita et al., 2025).

In response to these gaps, this study aims to conduct a Systematic Literature Review of STEAM-integrated digital learning media in primary schools published between 2020 and 2025 (Kimmons, 2020). This review seeks to map research trends related to media types, instructional models, targeted skills, and research designs. By adopting the PRISMA 2020 guidelines, this study ensures a transparent and systematic review process (Muñoz Padilla et al., 2024). The findings are expected to provide a comprehensive overview of current research developments. More importantly, this study contributes by explicitly identifying the limited attention given to collaboration and communication skills in existing STEAM digital learning research (Yulianti et al., 2024). Thus, the results offer valuable insights for future research, instructional development, and evidence-based decision making in primary education.

Research Methods

This study employed a Systematic Literature Review (SLR) to synthesise empirical research related to the development and implementation of STEAM-integrated digital learning media in primary schools (Höfrová et al., 2024). The SLR method was selected because it allows researchers to systematically identify, evaluate, and synthesise findings from multiple primary studies in a transparent and replicable manner. Compared to traditional narrative reviews, SLR provides a more structured approach that helps minimise researcher bias and enhances the reliability of the review outcomes. This method is particularly suitable for examining research trends and patterns across a growing body of literature. In the context of this study, SLR was used to map developments in digital learning media integrated with STEAM education at the primary school level. The review process was conducted following the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure consistency and methodological rigour. The use of PRISMA also supports clarity in reporting the stages of literature selection and synthesis.

1. RQ1: What are the trends in publications (number per year, publication sources) regarding integrated STEAM digital learning media in primary schools for the period 2020-2025?
2. RQ2: What are the most dominant keywords in research in this field based on basic bibliometric analysis?
3. RQ3: What types of digital learning media are most often developed or implemented in the context of STEAM in primary schools?
4. RQ4: What learning models or approaches are often associated with the use of STEAM digital media?
5. RQ5: What 4C skills (critical thinking, creativity, collaboration, communication) or other learning outcomes are the focus of measuring the impact of STEAM digital learning media?
6. RQ6: What research methods (e.g., R&D, experiments, qualitative) were predominantly used in these studies?

The literature search strategy was conducted systematically in October 2025 to ensure a comprehensive and up-to-date retrieval of relevant studies. The main data sources consisted of reputable international and national academic databases, including Google Scholar, Scopus, ERIC (Education Resources Information Centre), ScienceDirect, and DOAJ (Directory of Open Access Journals). These databases were selected because they provide extensive coverage

of peer-reviewed research in the fields of education, educational technology, and interdisciplinary learning. Using multiple databases was intended to minimise publication bias and increase the likelihood of capturing diverse research perspectives. To support the search process and facilitate initial metadata management, Publish or Perish (PoP) software was utilised. Search keywords were developed based on the research questions and were structured using Boolean operators to broaden and refine the search results. The keyword combinations focused on terms related to STEAM education, digital learning media, and primary education. To maintain relevance and consistency with the research objectives, the search was limited to journal articles published between 2020 and October 2025.

The study selection process was conducted following the PRISMA 2020 flow, which consists of four main stages: identification, screening, eligibility, and inclusion (Nuragnia et al., 2021). This process is illustrated in the PRISMA Flow Diagram (Figure 1).

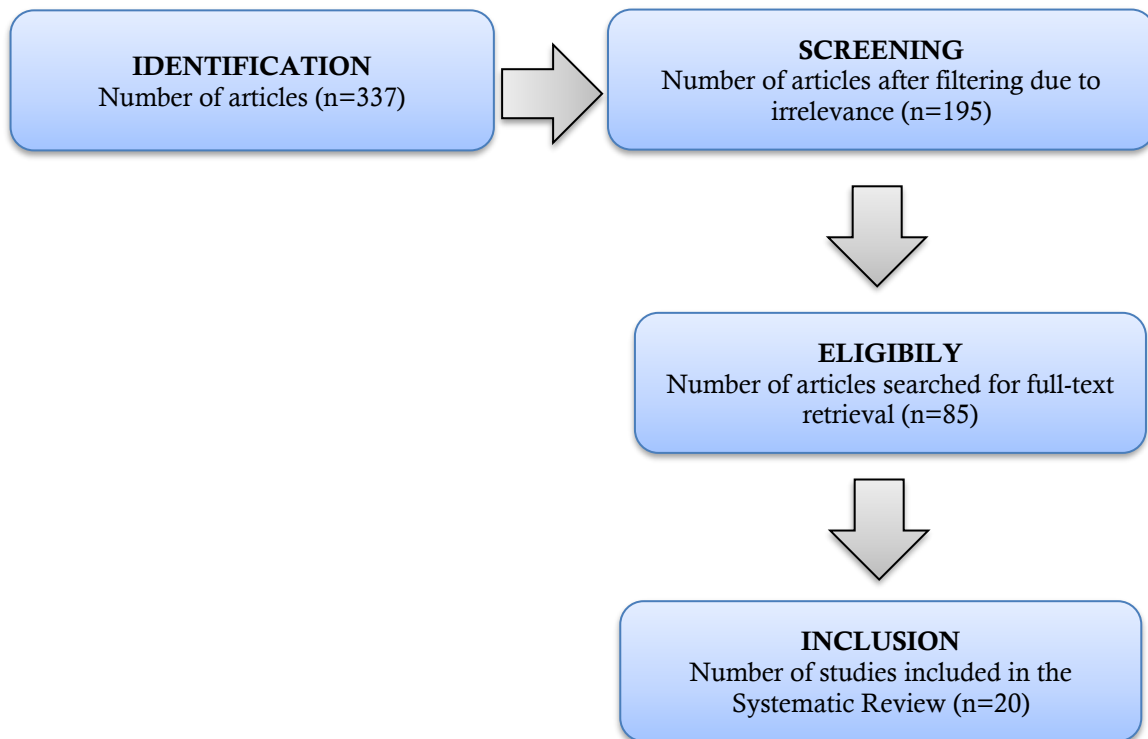


Figure 1. PRISMA Flow Chart

Based on Figure 1, the study selection process followed four main stages, namely identification, screening, eligibility, and inclusion, in accordance with the PRISMA 2020 guidelines. At each stage, articles were reviewed systematically to ensure their relevance to the research objectives and their overall methodological quality (Fitria & Nuroh, 2025). During the screening stage, titles and abstracts were examined to remove duplicate records and studies that were clearly unrelated to the research focus. Subsequently, full-text articles were assessed at the eligibility stage to determine their suitability based on predefined inclusion and exclusion criteria. To ensure objectivity and reduce potential selection bias, the screening of titles, abstracts, and full texts was conducted independently by two researchers. Any disagreements arising during the selection process were resolved through discussion, and when consensus could not be reached, a third researcher was involved. The inclusion and exclusion criteria

guiding this process are presented in Table 1 and were developed systematically to ensure that only relevant, high-quality studies aligned with the research focus were included in the final review.

Table 1. Article Inclusion and Exclusion Criteria

Aspect	Kriteria Inklusi	Kriteria Eksklusi
Year of Publication	2020–2025 (until October)	< 2020 or > October 2025
Language	Indonesian or English	Languages other than Indonesian or English
Types of Documents	Articles published in reputable scientific journals (peer-reviewed journal article)	Conference proceedings, books, book chapters, dissertations, theses, technical reports, editorials, letters, opinion pieces, book reviews
Focus of Study	Development or implementation of Digital Technology-Based Learning Media integrated with STEAM	Non-STEAM studies, STEAM studies without digital technology aspects, focusing only on one component of STEAM without integration
Educational Context	Primary school (SD) or equivalent (e.g., primary school, elementary school, grades 1-6)	Pre-school, junior high school, senior high school, university, non-formal education
Variable/Outcome	Explicitly discusses or measures the impact on at least one of the 4C Skills or other student learning outcomes (e.g., conceptual understanding, motivation, cognitive learning outcomes).	Does not discuss or measure the impact on students (e.g. only focuses on teacher perceptions, expert validation without student trials)
Type of Study	Empirical studies (quantitative, qualitative, mixed), development studies (R&D) involving student evaluation	Pure theoretical studies, other literature reviews, position papers

Although PRISMA 2020 does not mandate a formal quality assessment for all types of systematic reviews, this step remains important to ensure the reliability and trustworthiness of the evidence synthesised in this study. Therefore, all articles that passed the eligibility stage were assessed for their methodological quality. Considering the diversity of study designs included in this review, such as Research and Development, quasi-experimental, and qualitative descriptive studies, the quality assessment was conducted in a descriptive manner (Purba & Saragih, 2023). The assessment focused on fundamental methodological aspects, including the clarity of research objectives, the adequacy of data collection or research procedures, and the transparency of result reporting. This process aimed to identify potential methodological limitations that could influence the interpretation of findings. To maintain objectivity, the quality assessment was conducted independently by two researchers. The results of this assessment were used to contextualise and interpret the findings rather than serving as additional exclusion criteria, unless a study was deemed methodologically uninformative (Heryani et al., 2022).

Data extraction was carried out using a structured extraction form developed in accordance with the research questions of this review. The extracted data included bibliographic information, research context, types of STEAM-integrated digital learning media, instructional models, targeted 4C skills or other learning outcomes, research designs, and key findings (Jamil & Murniati, 2025). Data extraction was initially performed by one researcher and subsequently

verified by a second researcher to ensure accuracy and completeness. The extracted data were then synthesised using two complementary approaches. First, basic bibliometric analysis was conducted to identify publication trends and dominant keywords across the selected studies. Second, thematic content analysis was employed to examine patterns related to media types, learning models, research methods, and learning outcomes. The synthesis process involved grouping findings according to themes relevant to the research questions and identifying similarities and differences among studies. Due to the heterogeneity of research designs and outcome measures, a quantitative meta-analysis was not conducted in this review.

Results and Discussion

The distribution of publications per year based on the 20 selected articles is presented in Table 2. The number of publications varied across the 2020–2024 period, with seven articles published in 2022. In other years, the number of publications ranged between two and four articles. Regarding publication sources, 11 articles (55%) were published in international journals, while 9 articles (45%) appeared in nationally accredited journals. Table 2 summarises the annual distribution of publications included in this review.

Table 2. Distribution of Articles Based on Year of Publication (N=20)

Year of Publication	Number of Articles
2020	3
2021	4
2022	7
2023	4
2024	2
Total	20

The frequency of author keywords extracted from the 20 selected articles is summarised in Table 3. The most frequently occurring keywords were “STEAM/STEM,” “Elementary School/Primary,” and “Critical Thinking.” Other commonly used terms included “Digital Media,” “Augmented Reality,” and “Project-Based Learning/Problem-Based Learning.” In addition, a manual co-occurrence analysis identified recurring combinations of keywords appearing across multiple articles. These combinations involved terms related to STEAM or STEM, learning models, and learning outcome variables.

Table 3. Most Frequently Used Keywords/Key Terms (N=20)

Key Words / Key Terms	Frequency (Article)
STEAM / STEM	19
Elementary School / Primary	20
Critical Thinking	17
Augmented Reality (AR)	10
Digital Media / E-Module / Mobile Learning / Interactive	15
Project-Based Learning (PjBL) / Problem-Based Learning (PBL)	12
Creativity / Creative Thinking	9
Science Learning / IPA	16

Analysis of titles and abstracts identified several recurring themes across the reviewed studies, as presented in Table 4. Frequently identified themes included digital learning media development, integration of the STEAM approach, application of active learning models, and

measurement of learning outcomes. References to student motivation, engagement, and primary school learning contexts were also identified in several abstracts. Table 4 presents the frequency of occurrence of these themes.

Table 4. Main Themes from Abstract Analysis (N=20)

Main Theme	Frequency of Occurrence (Articles)
Digital Media Development (AR, Apps, Web)	19
Integration of the STEAM/STEM Approach	19
Implementation of PjBL/PBL/Inquiry	14
Critical Thinking Assessment	17
Measuring Creativity	9
Measurement of Cognitive Learning Outcomes	11
Primary School Context / Science Learning	20
Student Motivation / Engagement	9
Collaboration / Communication	6

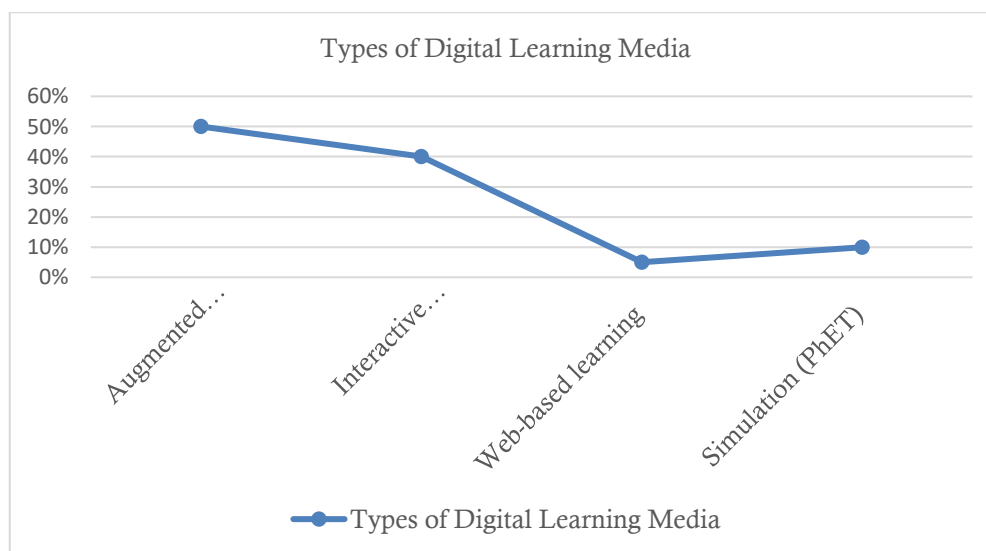


Figure 2. Distribution of Types of STEAM Digital Learning Media (N=20)

The distribution of digital learning media types reported in the selected studies is shown in Figure 2. Augmented Reality (AR) was reported in 10 articles. Interactive applications, mobile learning tools, and digital modules were identified in 8 articles. Web-based learning media and simulation-based tools were reported less frequently. Figure 2 summarises the types of digital media examined in the reviewed studies.

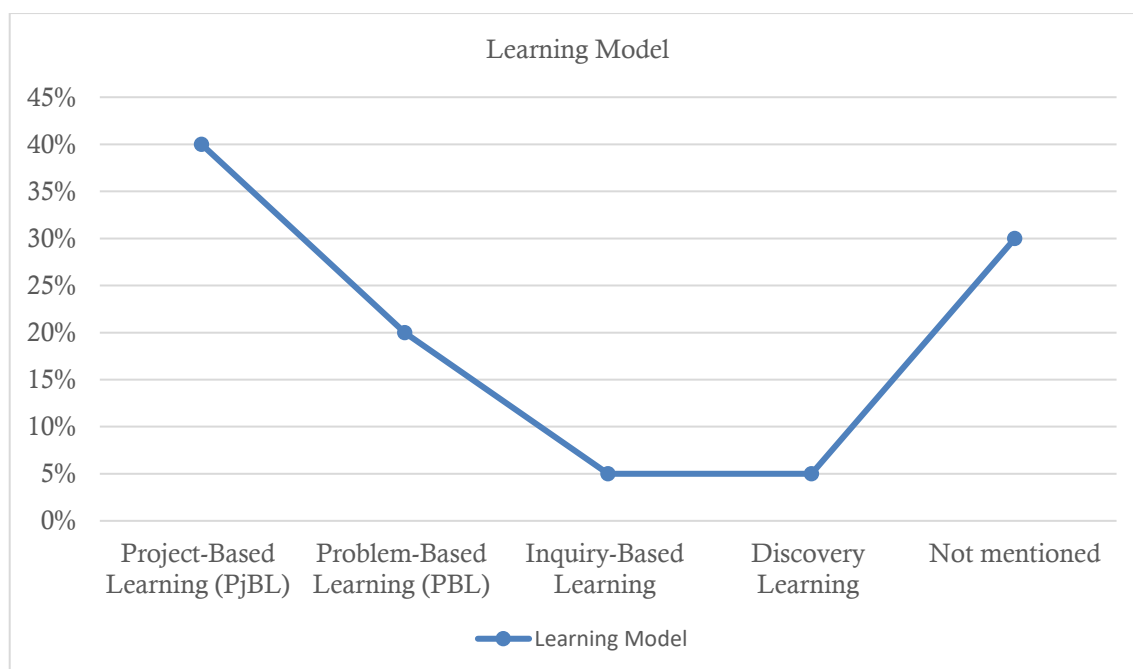


Figure 3. Frequency of Learning Models Used (N=20)

Figure 3 presents the frequency of learning models reported in the selected articles. Project-Based Learning was reported in 8 articles, while Problem-Based Learning appeared in 4 articles. Inquiry-Based Learning and Discovery Learning were each identified in one article. Several studies did not specify a particular instructional model but described the use of student-centred or active learning approaches.

Table 5. Frequency of Measured Learning Outcome Variables (N=20)

Learning Outcome Variables	Number of Studies	Percentage (%)
Critical Thinking	17	85%
Creativity / Creative Thinking	9	45%
Cognitive Learning Outcomes	11	55%
Student Motivation / Engagement	9	45%
Collaboration	2	10%
Communication	1	5%
Science Literacy	2	10%
Problem Solving	1	5%

(Note: One study may measure more than one variable)

The distribution of learning outcome variables measured across the reviewed studies is presented in Table 5. Critical thinking was reported in 17 articles. Creativity and cognitive learning outcomes were reported in 9 and 11 articles, respectively. Student motivation and engagement were reported in 9 articles. Collaboration and communication were reported in a limited number of studies. Some studies measured more than one learning outcome variable.

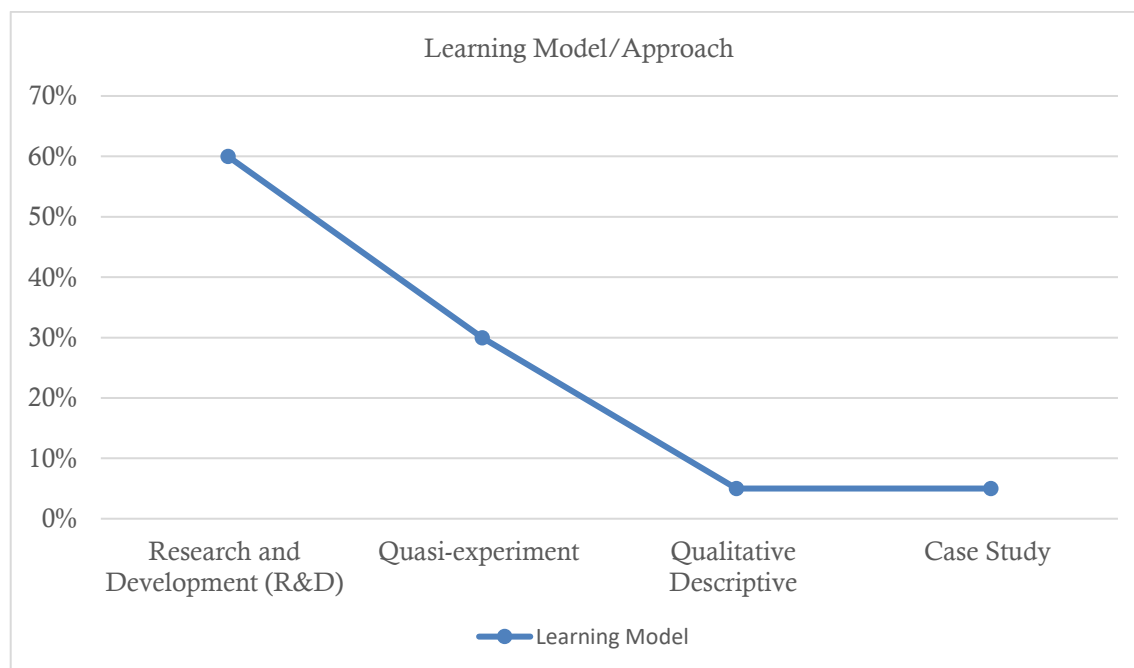


Figure 4. Distribution of Research Methods Used (N=20)

Figure 4 shows the distribution of research methods used in the selected articles. Research and Development designs were reported in 12 articles, while quasi-experimental approaches appeared in 6 articles. Qualitative descriptive methods and case studies were reported in one article each. Figure 4 summarises the methodological approaches employed in the reviewed studies.

The prominence of keywords such as *STEAM*, *Augmented Reality*, *Critical Thinking*, and *Elementary School* reflects the dominant focus of recent research on the integration of interdisciplinary learning approaches with digital technology in primary education (Li et al., 2022). This pattern suggests that STEAM-based digital learning has become a central theme within contemporary educational research. The considerable contribution of Indonesian-based studies within the selected sample also indicates strong local engagement with global educational trends (Irwan et al., 2024). Nevertheless, this pattern should be interpreted cautiously, as the database selection and language criteria may have influenced the representation of national publications.

Further thematic analysis highlights distinct patterns in the types of digital media developed and implemented in STEAM learning contexts. Augmented Reality and interactive or mobile-based applications appear most frequently, suggesting a preference for media that support visualisation and interactivity (Huang et al., 2020). These media are often associated with the presentation of abstract concepts in science and mathematics, where visual and experiential elements are considered beneficial. Previous studies have noted that such technologies may facilitate contextual learning by connecting digital representations with real-world environments. However, the predominance of certain media types also indicates that other forms of digital technology remain relatively underexplored in primary-level STEAM research (Montero-Izquierdo et al., 2024).

The frequent association between STEAM digital learning media and Project-Based Learning or Problem-Based Learning models reflects a pedagogical alignment between technology use and active learning approaches (Epriliyani & Deta, 2024). These models emphasise inquiry, problem-solving, and student participation, which correspond with the

interdisciplinary nature of STEAM education. The use of digital media within these models appears to support learning activities that extend beyond information delivery. Rather than functioning solely as instructional tools, digital media are positioned as resources that facilitate exploration, collaboration, and knowledge construction (Amrianto et al., 2024). This trend suggests a shift toward learning designs that prioritise process-oriented learning experiences.

Analysis of learning outcomes measured across the reviewed studies reveals a strong emphasis on critical thinking and cognitive learning outcomes. This focus is consistent with broader educational objectives that prioritise higher-order thinking skills in the context of twenty-first-century education (Nofia Henita et al., 2023). Creativity and student motivation also receive notable attention, although to a lesser extent. In contrast, collaboration and communication skills are measured infrequently, despite their frequent inclusion in the conceptual framework of STEAM learning (Handayani et al., 2022). This discrepancy suggests that while collaborative learning is often assumed to occur, it is not consistently operationalised or assessed within empirical studies.

From a methodological perspective, the dominance of Research and Development designs reflects the strong orientation toward media development and product validation within this research field (Valentine et al., 2018). Quasi-experimental approaches are commonly employed to examine the effectiveness of developed media in comparison to conventional instruction. However, the limited use of qualitative or mixed-methods approaches suggests that fewer studies explore students' learning processes, interactions, and experiences in depth. This methodological pattern may constrain understanding of how and why certain learning outcomes emerge through STEAM-based digital learning (Au et al., 2025).

Overall, the findings of this review indicate that research on STEAM-integrated digital learning media in primary education has expanded considerably during the reviewed period. While existing studies demonstrate a strong focus on media development and cognitive outcomes, they also reveal clear opportunities for future research. Greater attention to collaboration and communication skills, as well as the adoption of more diverse methodological approaches, may contribute to a more comprehensive understanding of the educational impact of STEAM-based digital learning (Yim et al., 2025). Such directions are particularly relevant for advancing both theoretical insights and practical applications in primary education contexts.

Conclusion

Based on a Systematic Literature Review (SLR) analysis of 20 journal articles published between 2020 and 2025, it can be concluded that research on integrated STEAM digital learning media in primary schools shows a significant trend. First, there is a strong focus on the development and application of Augmented Reality (AR) media and Interactive/Mobile Learning Applications, which are often associated with active learning models such as Project-Based Learning (PjBL) and Problem-Based Learning (PBL). Second, these studies consistently report the positive impact of using STEAM digital media on student learning outcomes, particularly in improving critical thinking skills (the main focus of 85% of studies), conceptual understanding, and learning motivation and engagement. Third, the dominant research methods used were Research and Development (R&D) (60%) for media development and quasi-experiments (30%) to test its effectiveness.

However, this SLR also identifies areas that require further attention. Measurements of the impact on creativity skills (45%), collaboration (10%), and communication (5%) are still relatively limited compared to critical thinking and cognitive learning outcomes. Furthermore,

more diverse research designs are needed, particularly in-depth qualitative and mixed-methods studies, to gain a more comprehensive understanding of the processes and long-term impacts of learning with STEAM digital media. Future research is recommended to focus on the 4C aspects in a more balanced manner (especially collaboration and communication), explore new technologies, and use varied research methodologies in a broader geographical context.

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