14 (3) (2025) 437-449

Unnes Science Education Journal
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Trends and Mapping of STEAM-based Interactive Media: A Systematic and Bibliometric Review

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DOI: http://dx.doi.org/10.15294/usej.v13i1.34411

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Article Info

Submitted 2025-09-29
Revised 2025-11-07
Accepted 2025-12-15

Keywords

Interactive digital media; Interactive learning media; STEAM-based media

Abstract

Integrating interactive digital media with the STEAM approach is considered a potential solution to increase student engagement, creativity, and critical thinking. This study aims to systematically review the development and implementation of STEAM-based interactive learning media for education during 2016-2025. The method used was a systematic literature review by analyzing national and international publications relevant to STEAM integration, interactive media design, and learning outcomes in science education. In addition, this study also used a bibliographic analysis method. From 409 initial articles, 66 articles were selected for full review, and 16 articles met the inclusion criteria. Content analysis was conducted to examine the types of media, pedagogical approaches, education levels, and reported learning outcomes. All studies reported that interactive media have high validity and practicality, and are effective in improving concept understanding, learning independence, and student engagement. The findings show that STEAM-based interactive media significantly improves students' conceptual understanding, critical thinking, and creativity, as well as fostering motivation and reducing misconceptions. Furthermore, research trends highlight the increased adoption of web-based platforms, gamification, and contextual visualization to create meaningful learning experiences.

How to Cite

Munif, D. H., & Subali, B. (2025). Trends and Mapping of STEAM-based Interactive Media: A Systematic and Bibliometric Review. *Unnes Science Education Journal*, 14(3), 437-449.

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p-ISSN 2252-6617
e-ISSN 2502-6232

INTRODUCTION

The development of science and technology is driving significant transformation in education, especially in the use of digital-based interactive learning media. Interactive media allows users to be actively involved in their use which provides two-way communication and real-time feedback (Tene et al., 2024; Booyoesen, 2023; Hossain, 2023; Prytyka, 2023). Interactive media can provide a more immersive experience and facilitate users in understanding complex material concepts that have been difficult to explain using conventional approaches (Mayer, 2017). Interactive learning media has the characteristics of being interactive and participatory which involves its users through features such as practice questions, quizzes, simulations, and direct feedback. Media combines animation, audio, video, text, and images to enhance the appeal and clarify the material (Daryanes et al., 2023; Putri et al., 2021).

Today's learning has shifted by emphasizing student activeness in interdisciplinary learning that focuses on critical thinking, creativity, and collaboration (the demands of 21st century learning). Science, technology, engineering, arts, and mathematics (STEAM) learning emerged as a learning approach that bridges the practice of technology and artistic creativity with scientific content to provide great opportunities in the development of contextual, interactive learning media that are more relevant to students' lives. The integration of STEAM approaches in learning can develop 21st century skills (Xu, 2025; Li, 2024; Zayyinah et al., 2022; Quigley et al., 2017). 21st century education emphasizes the mastery of Critical thinking, Creativity, Collaboration, and Communication (4C) competencies (Puspa et al., 2023; Wijaya et al., 2016). Previous research has shown that the application of the STEAM approach in science learning is able to improve conceptual understanding, problem-solving skills, and creativity (Ridwan et al., 2022; Smith, 2015). The integration of STEAM approaches in interactive media makes media an authentic task ecosystem that blends scientific inquiry, simple simulation, simple engineering, and science communication. The use of integrated STEAM-based interactive media implemented in an interdisciplinary and integrated manner in learning provides promising benefits in meeting the challenges of the 21st century (Deák & Kumar, 2024).

The prospect of interactive media development is in line with multimedia learning theory (presenting images in a coordinated manner applying the principles of signaling, segmenting, modality, and coherence) as well as in line with cognitive load theory that emphasizes intrinsic management and extraneous cognitive load reduction in the context of optimal essential processing optimal (Abdoune et al., 2024; Lee et al., 2024; Anmarkrud et al., 2019). In recent years, the number of research and publications related to the development of STEAM-based interactive media has shown significant increase. However, the growth of literature has not been accompanied by comprehensive mapping efforts to understand the research landscape in this field. This gap leads to a lack of a comprehensive picture of current research focus, dominant methodologies, and knowledge gaps that can be directed for future research. Although the volume of publications related to STEAM interactive media has increased, the existing literature is still fragmented into specific subtopics such as educational games, physics simulations, or digital art applications. There has been no effort to map the overall intellectual landscape and the evolution of these topics over time. The absence of bibliometric mapping makes it difficult for researchers to understand the mainstream in this field of research.

This study uses a methodological approach that integrates quantitative bibliometric analysis with systematic qualitative review in a synergistic manner to provide in-depth insights. This study provides a previously unavailable visual mapping that can be used to navigate the field of interactive media research. This study was conducted not only to reflect the current state of the field, but also to formulate future targeted and evidence-based research so that researchers can prioritize potential topics.

This research must be conducted because the 21st century demands the ability to produce a generation that is literate and competent in facing the 4.0 industrial revolution and 5.0 society. The use of the STEAM approach is believed to foster critical, collaborative, and creative skills that require effective interactive media. In response to this request, this study was conducted to systematically review and bibliometrically analyze the literature related to STEAM-based interactive media. The purpose of this study is specifically to map the publication trends of STEAM-based media research publications, analyze the characteristics of the research, identify collaboration networks between researchers, and reveal research gaps and the development of STEAM-based interactive media for further research.

METHOD

This study used systematic review design combined with bibliometric analysis. This combination of methods was chosen to not only synthesize findings qualitatively but also map the quantitative research landscape and visually map (Donthu et al., 2021). Reviews are designed and reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines to ensure data transparency (Page et al., 2021). The research was conducted to evaluate trends and map STEAM-based interactive media. A systematic review approach was chosen to ensure that all of the selected literature could be screened, identified, and analyzed transparently and consistently. Bibliometric mapping is performed for quantitative analysis of publication metadata aimed at identifying trends, themes or clusters, and collaborative networks using tools such as VOSviewer. Bibliometric analysis was chosen because this study aims to map the distribution of publications, research trends in the last 10 years, and map author collaboration.

The research questions were formulated using a modified or adjusted PICO framework with a systematic and bibliometric review. Description of the PICO framework in Table 1.

Table 1. PICO Framework

PICO Framework	Information
Population	Research that develops or evaluates interactive media based on Science, Technology, Engineering, Arts, and Mathematics (STEAM).
Intervention	STEAM-based interactive media (media type, development design, integration of steam aspects) including their methodology and application trends.
Context	Formal education with a publication period between 2016 – 2025.
Outcomes	Mapping of research characteristics, publication trends, dominant keywords, author collaboration networks, research gaps, and future research recommendations.

Based on Table 1. The main question of this study is how to map research and trends in the development and implementation of STEAM-based interactive media in the world of Education based on the latest literature?

The source of this review data was obtained from various journal articles that the researcher collected using Harzing's Publish or Perish by selecting the main data source from Google Scholar. The researcher limited the publication period of the article to the range of 2016 – 2025. This research is not carried out directly by involving humans as research subjects, so the target population is all scientific articles that meet the inclusion criteria. The search was carried out by following the PRISMA guidelines, namely through four main stages. The stages of the prism groove are depicted in Figure 1.

Figure 1. Stage of the PRISMA Model

The prism grooves carried out in this study are as follows: (1) literature identification: an article search was conducted through Harzing's Publish or Perish (Pop) with the Google Scholar search bar using keywords in two languages, namely Indonesian and English. Search in Indonesian using the keywords "development," "interactive media," "media," "learning media," and "STEAM-based"; Produced 314 articles. Meanwhile, searches in English used the keywords "development," "interactive media," "media," "learning media," and "STEAM-based"; produced 95 articles; (2) screening: duplicate articles, non-journal publication articles (books, theses, dissertations, opinion articles, editorials, reviews, conference reviews) and titles and abstracts are reviewed to assess the relevance of the topic. Irrelevant articles are eliminated. Produced 342 excluding articles; (3) eligibility: a complete ar-

ticle review is carried out to evaluate its suitability with the research objectives, namely the development of STEAM-based interactive media and the existence of research methodologies and research results. Articles that do not meet the criteria are eliminated and the reason is recorded. Produced 33 excluded articles; (4) data extraction (Included): article selection is carried out based on specific quality criteria, such as publication in journals or conferences, year of publication (2016-2025), accessibility of the full text, including validation results, and relevance to interactive media or STEAM-based learning media.

Furthermore, bibliometric analysis was also carried out using VOSviewer software to map the authors' collaboration networks, publication trends, and distribution of their research by country or institution. After that, it is included in the stage of synthesis of results, namely grouping systematic analysis of learning media based on its type, STEAM integration, and reported outputs. The results are used to identify key trends and research gaps. The inclusion and exclusion criteria are clearly established before the selection process. The inclusion and exclusion criteria are outlined in more detail in Table 2.

Table 2. Inclusion and Exclusion Criteria

Criteria Type	Inclusion	Exclusion
Article Type	Peer-reviewed journal articles and conferences.	Opinions, editorials, textbooks, reviews, conference reviews, non-scientific articles, theses, dissertations.
Topic	STEAM-based interactive learning media.	It does not relate to interactive media or STEAM approaches.
Article Content	Development of STEAM-based interactive learning media.	Irrelevant to STEAM or interactive media.
Year of Publication	2016 – 2025.	Before 2016 and after 2025 or not yet available for the year of publication.
Language	Indonesian or English.	Other than Indonesian or English.
Educational Context	Formal Education.	Non-formal or general with no educational focus.
Method	Accompanied by validation results or results.	There are no validation tests or weak methodologies or unclear methodologies.
Source	Google Scholar	Grey domains or repositories (campus repositories, ResearchGate, Academia, Semantic Scholar, Google Books).
Accessibility	Full text (open access or official database) is available.	No full-text or limited access available.

The types of data collected include components: 1) year of publication, 2) author's name, 3) article title, 4) journal source, 5) abstract, and 6) output. In addition, the data is also extracted by containing components: 1) interactive media type, 2) STEAM integration, and 3) output metrics. Literature data collection is carried out using the main tools, namely online databases as the primary source, Mendeley to organize articles, and Microsoft Excel to extract and manage bibliometric data.

The research data were analyzed qualitatively, descriptively, and bibliometric analysis. This technical analysis is carried out in the following stages: (1) descriptive qualitative analysis: is carried out by describing the basic characteristics of the literature including those related to publication trends per year, its geographical distribution, the most productive journals, and the most influential authors; (2) bibliometric analysis: is carried out by analyzing co-occurrence (the co-occurrence of keywords to map the main concepts and to-

pics in the research), citation analysis (identifying the most influential articles), collaboration analysis (mapping the network of cooperation between researchers and institutions), and bibliographic coupling (grouping articles according to the similarity of the cited references).

This study employed a systematic literature review (SLR) method to identify, evaluate, and synthesize research on the development and implementation of STEAM-based interactive learning media, particularly Circulation Adventure, in circulatory system education for junior high school students during 2020–2025. The SLR approach was selected because it enables comprehensive mapping of research trends, evaluation of methodological quality, and extraction of findings across multiple studies in a structured and transparent manner (Widodo et al., 2024; Liberati et al., 2009). This method was adapted from established guidelines in educational research and modified to focus on STEAM integration and interactive media in science education contexts.

RESULT AND DISCUSSION

The results of this study obtained a collection of article data obtained from the search process using Harzing's Publish or Perish (PoP) with the Google Scholar search bar using Indonesian keywords and English keywords. The data generated from the search was 409 articles. Articles were extracted and analyzed resulting in 16 articles that met inclusion criteria for further analysis. The articles are processed and analyzed using Microsoft Excel based on their characteristics.

The results of the study summary report some of the main findings and their implications for the research or development of STEAM-based learning media. The distribution of the study by year of publication shows that the concentrations in this last two-year period are 2024 and 2025. These results indicate that current research attention is increasing towards the development of STEAM-based interactive media. The increase in publications in this period can be indicated because of the acceleration of technology adoption after the Covid-19 pandemic and the encouragement to conduct integrated research. Educational institutions and educators are competing to find innovative solutions for learning to remain effective (Haas et al., 2023; Chen et al., 2019). Rapid progress in the development of digital technologies and the demands of 2st century curriculum and skills can also be a rapid driver of research related to this topic. Technological advances such as virtual classrooms, Augmented Reality, and e-learning platforms encourage the development of innovative and accessible interactive media. In addition, it is also to encourage success in learning through the role of interactive media that can increase motivation, creativity, and understanding of concepts so that students can develop their critical thinking skills, science literacy, and creativity (Çelik & Dutta, 2025; Hsiao et al., 2025; Rosidah et al., 2025; Nindiasari et al., 2024; Setiawan & Shobri, 2024; Hasibuan et al., 2022; Rukayah et al., 2022; Twiningsih & Elisanti, 2021; Jesionkowska et al., 2020).

The results of the review report that different types of interactive media have been developed with augmented reality, apps, interactive webs, e-modules, or flipbooks. These media are the most popular type of media. Studies on the application of STEAM aspects in the study show that most studies integrate at least three aspects of STEAM with the Technology and Science aspects which are the most consistently applied aspects. The full and balanced integration of STEAM aspects of these five aspects is still limited, as evidenced by some studies that still highlight certain aspects according to the context of the subject being studied. Several articles from the 16 included articles discuss the results of measuring media effectiveness. All measurement results show a positive impact, namely reporting an improvement in students' skills or learning outcomes. Statistically, significant improvements were reported in critical thinking skills, problem-solving skills, collaboration, learning motivation, and cognitive learning outcomes. The results of the effectiveness of several studies included in the included article are described in Table 3.

Table 3. Results of the Effectiveness of STEAM-based Media

No	Researchers	Outcome Variables	Key Results
1	Fitriasih et al. (2025)	Problem solving and student collaboration skills.	The use of media has been shown to be effective in improving problem-solving and collaboration. Significant improvement (MANCOVA).
2	Mahendra et al. (2025)	Learning motivation	The effectiveness of the media (the results of the student response questionnaire), the effectiveness value is 90.4% (very effective category).

No	Researchers	Outcome Variables	Key Results
3	Sinaga & Amdayani (2025)	Acid-base material learning outcomes	Increase in average test score (pretest 22.90 (posttest 67.03). The paired sample t-test showed a significant difference ($p < 0.05$) indicating that the media was effective in improving students' understanding and learning outcomes.
4	Niati et al. (2025)	Science process skills and learning outcomes	The results of the science process skills questionnaire were 86% (high) and the student learning outcomes (test) were 89%.
5	Rohimah et al. (2025)	Critical thinking skills	N-gain score g =g 0.7115 (high category), the average score of pretest (57.61) and posttest (86.89) increased.
6	Afiyah et al. (2024)	Material understanding compositional functions	N-gain score g = 0.76 (high), effective media in improving student understanding.
7	Mayanti & Widiyatmoko (2025)	Creative thinking and collaboration	The N-gain score of the experimental class was higher than that of the control class. The results of the experimental t-Test were 48.2 > the control was 36.29.
8	Aini et al. (2025)	Critical thinking	The average pretest (64.2) < the average post-test (85.1). N-gain score g = 0.61 (moderate – high effect).
9	Layn et al. (2025)	Collaboration and Communication, Critical Thinking	All indicators of collaboration and communication reached 100% (excellent). N-Gain score g = 0.5926 (moderate). Significant improvement in pretest and posttest scores.

Based on the data obtained during the review, it shows that the development of STEAM-based interactive media shows a positive and promising trend in the world of education in Indonesia. From the 16 articles that were analyzed in depth, it was found that media development is dominated by the ADDIE model. This shows its suitability to create learning products systematically and measurably. The clarity of stages in ADDIE allows researchers to analyze needs in depth, design products according to needs analysis, develop them through a validation process, implement them measurably, and always evaluate comprehensively. The ADDIE model is simple and systematic with evaluation and revision at each stage to produce valid media products (Nurhayati et al., 2021). R&D research methods also dominate, indicating that research in this area still focuses on product creation and validation of innovative products as solutions to address specific needs in learning practices. Studies of STEAM aspects show that while all claim to use this approach, the degree of balance and depth of integration of these five aspects varies. The science (S) and technology (T) aspects of the entire study are almost always well integrated. However, the other aspects, namely arts (A) and mathematics (M), are often integrated for the art aspect only at the visual aesthetic level and in the mathematical aspect is not explicit (only limited to the analysis of research data). These findings are in line with previous research by Jannah & Prodjosantoso (2024) which confirmed that teachers' literacy ability to STEAM content is still in the "moderate" category and has the potential to be a inhibiting factor. This condition demands the implementation of more operational guidelines and the need to conduct training for educators in designing STEAM-based activities.

Publication Trend (by Year)

The results of this study reveal a substantial growth in research publications, particularly between 2024 and 2025.

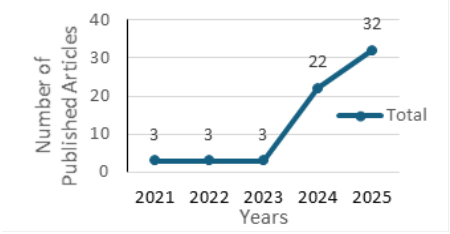

Figure 2. Publication Trend Graph

The increase in the number of publications is very significant from 2024 to 2025. This trend is not a random phenomenon, but a direct response

from the research world to the implementation of the Independent Curriculum in Indonesia. This curriculum emphasizes project-based learning (PjBL), differentiated learning, and strengthening the profile of Pancasila students. This is in line with the approach offered by STEAM. This year's surge in publications, namely 2025, indicates that researchers and practitioners are currently actively exploring and validating various interactive media models as a form of solution in realizing the curriculum vision. These findings are consistent with a study conducted by Li et al. (2020) which stated that innovations in education policy are often followed by waves of applied research to support their implementation. In addition, the 21st century Education paradigm emphasizes the development of higher-Level thinking skills such as skills in problem-solving, creativity, and collaboration that are in line with the basic philosophy of STEAM (Prahani et al., 2023).

Educational Level

The results by educational level demonstrate a dominant focus on elementary education, followed by junior and senior secondary levels, as shown in Figure 3.

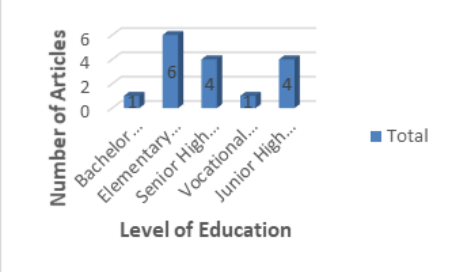

Figure 3. Educational Level Graph

The research that has been carried out is mostly focused on the elementary level followed by the junior high and high school levels. At the elementary level, STEAM integration is often implemented in integrated science subjects. The STEAM approach that is implemented in a fun manner is considered suitable for instilling the foundation of science and numeracy literacy from an early age (Azizah et al., 2020). Meanwhile, at the junior high and high school levels, the complexity of each subject such as science at junior high school level and physics, chemistry, or biology at the high school level often requires visualization and a concrete approach. STEAM media has the potential to bridge these needs (Pavlou et al., 2024).

Subject Distribution

An analysis of research outcomes across subject areas shows that science and mathematics account for the largest proportion of STEAM studies, as depicted in Figure 4.

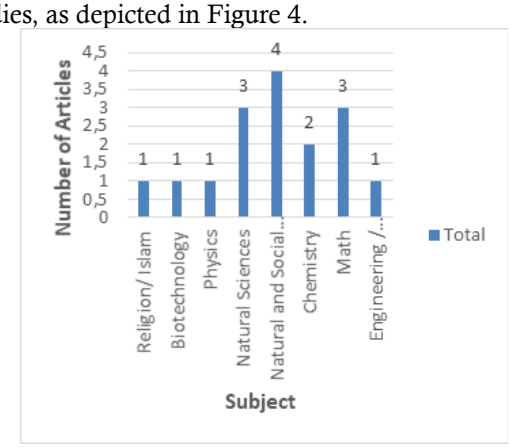

Figure 4. Subject Distribution Graph

The dominance of subjects is in science and mathematics subjects. This has become a globally consistent pattern in STEAM research (Portillo-Blanco et al., 2024). Dominance occurs because the acronym for STEAM contains aspects of science and mathematics so that integration feels more direct and natural. However, this condition also highlights that there are fundamental challenges to the integration of art that are often still limited to additional aesthetic elements rather than as an equivalent discipline that encourages creativity and design. The essence of this aspect of art in STEAM is to foster creativity and innovation that is at the heart of the engineering and discovery process (Herro et al., 2018; Quigley & Herro, 2016). The lack of representation of language and humanities learning reinforces the findings of Jannah & Prodjosantoso (2024) that teacher literacy in the implementation of interdisciplinary STEAM content integration is still being developed and needs to be developed.

Media Type

The research results based on media types indicate that Augmented Reality (AR) and e-modules or flipbooks are the most frequently developed learning media, as presented in Figure 5.

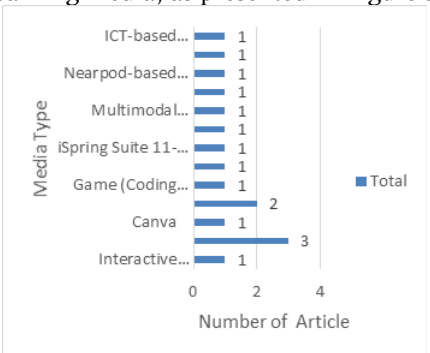

Figure 5. Media Type Graph

Graph 5 shows that Augmented Reality (AR) and e-modules or flipbooks are the most developed types of media. The popularity of AR is inseparable from its superior ability to visualize abstract concepts into real 3D models that can be interacted with directly (Ibáñez & Delgado-Kloos, 2018). In the context of STEAM, AR allows students to "see" chemical molecules, "assemble" electrical circuits, or "explore" biological systems capable of reducing cognitive load and improving their conceptual understanding (Mayer, 2024; Moreno & Mayer, 1999). Meanwhile, the emergence of android applications, Canva, and others shows that there is a need for media that is easy to access, use, and create. For example, Canva, with its intuitive template feature, can make it easier for teachers and students to make posters or project presentations without having to have high design skills.

Research Methodology

The results by development model demonstrate the dominance of the ADDIE framework in STEAM media development.

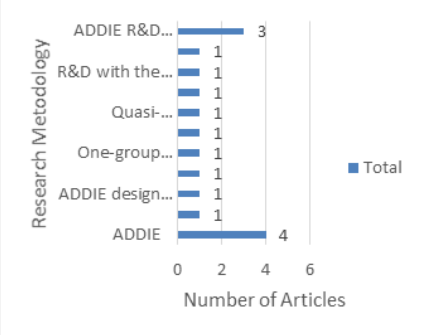

Figure 6. Research Methodology Graph

Graph in Figure 6. emphasized that the use of the ADDIE model in STEAM media development research dominates its use. This dominance occurs because the ADDIE model offers a systematic, iterative, and comprehensive framework (Branch, 2009). The linear and flexible nature of this model is suitable for use in research and development (R&D) in the world of education which requires a rigorous stage of expert validation and field trials before the medium is declared feasible and effective. Alternative models such as empathetic design thinking or process engineering design (EDP) are more reflective of the actual engineering process that can offer a more relevant approach to the spirit of inquiry in STEAM (Wan et al., 2023). The lack of use of qualitative approaches shows that in-depth exploration of the experience of students and teachers in using STEAM media is still research that has not been widely touched.

Pedagogical Approach

The results by pedagogical approach demonstrate the dominance of PjBL and STEAM in the analyzed studies.

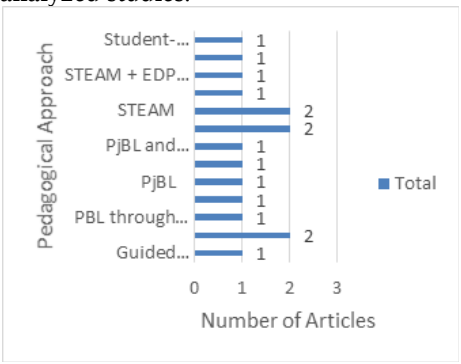

Figure 7. Pedagogical Approach Graph

The graph shows that PjBL and STEAM are the most dominant pedagogical approaches. Both dominate because of their philosophical alignment and basic principles. PjBL provides an ideal framework for meaningfully integrating all five aspects of STEAM. In line with a study conducted by Mayanti & Widiyatmoko (2025), Canva's PjBL-STEAM-assisted approach has been shown to be effective in improving students' creative thinking and collaboration skills. The purely STEAM approach dominates because it emphasizes the balanced integration of the five aspects of the discipline in the design of learning. However, interesting findings show that this STEAM approach is often combined with other pedagogical models to amplify its learning impact. The integration of STEAM with differentiated instruction as in the study of Murtyaningsih et al. (2025) shows its high effectiveness in improving letter memorization. The combination is done because it allows for the personalization of learning according to each student's learning style while still maintaining the STEAM framework. Likewise, Rosmita & Revita (2024) research that integrates STEAM with guided discovery and successfully facilitates mathematical problem-solving capabilities through structured discovery stages.

This study has several methodological and conceptual limitations despite providing valuable mapping. It exclusively uses Google Scholar as its main source through searches using Harzing's Publish or Perish. Although it produces extensive data, this database cannot comprehensively index all reputable journals when compared to paid databases such as Scopus and Web of Science or others. This resulted in several key publications from high-reputation international journals being overlooked. Furthermore, geographical and lin-

guistic biases were evident, as the inclusion criteria were limited to articles in Indonesian and English, and the final sample was dominated by the Indonesian educational context, meaning that the findings and trends mapped largely reflected the research landscape in Indonesia. Generalization into the global education context is still limited. Furthermore, although this study incorporates a systematic review, it focuses on the analysis of metadata and reported effectiveness. Research still needs to deepen its exploration of the quality of integration of each aspect of STEAM and critical analysis of the underlying pedagogical design. Most articles reviewed in this study are research and development (R&D), so this field is dominated by reviews of the feasibility and potential of media rather than evidence of large-scale implementation or long-term impact.

The main findings of this study are that out of 409 initial articles, 16 articles met the inclusion criteria for analysis (7 articles in 2024 and 9 articles in 2025). This sharp increase in publications occurred in 2024-2025. This reflects an active response in the research world to the implementation of the Merdeka curriculum in Indonesia. The impact of these findings is to validate that the curriculum has been used as a powerful catalyst for educational innovation, particularly in developing learning media that supports the differentiation process through the STEAM and PjBL approaches. The findings also show that the greatest focus of research is on the elementary school level, with science and mathematics as the dominant subjects. The impact of these findings is that they provide a clear roadmap for teachers, media developers, and policymakers to develop the most relevant interactive STEAM media at this level. Most publications are journal articles. The dominant types of media studied are Augmented Reality (AR) media, e-modules, flipbooks, Android applications, and interactive websites. The study found that the dominant research articles used R&D methodology with the ADDIE model, and some used quasi-experimental or pre-post control studies. The outcomes reported were consistently improved. The studies analyzed reported improvements in students' understanding of concepts/learning outcomes through significant pre-post results marked by an increase in the average or N-Gain score. Furthermore, studies related to the relationship with students' critical thinking skills recorded significant differences in several studies. The relationship between media and creativity, collaboration, and learning motivation reported an increase as seen from the questionnaire responses and 3C/4C indicators. Many developers reported that the validity of the developed media had high validity and practicality/feasibility.

The findings from this study have an impact on educational practices, namely that the consistent results of STEAM-based interactive media can improve conceptual understanding and 21st-century skills, thereby justifying the implementation of interactive STEAM media in classroom learning. The use of media can be the basis for schools or educators to adopt this solution, especially in PjBL-oriented curricula. The implementation of media can prioritize certain technologies, namely AR and web platforms (websites), which have been proven to be effective in visualizing abstract concepts. Through this prioritization, schools can develop tools or invest in tools that facilitate the visualization of material, especially for science and mathematics. The findings of this study also confirm that there is still a need for teacher training in designing balanced STEAM activities and utilizing interactive media pedagogically, not just technically. This study also shows the evaluation and standardization of assessment so that schools and researchers must adopt integrated rubric or measurement tools so that learning can be measured and compared effectively and efficiently.

Future research recommendations as a follow-up to this study include conducting studies with a stronger experimental design, such as using randomized controlled trials (RCTs) or at least using quasi-experimental designs with balanced control groups. Studies should report sample sizes, randomization procedures, and power analyses. Subsequent studies could also use larger samples to reduce bias and increase external validity so that the results can be generalized with accurate data. Subsequent studies could also expand the scope of bibliometrics by adding data collection from Scopus, Web of Science, or other journals to analyze citations and network mapping more comprehensively. It is also necessary to include relevant grey literature to avoid bias towards positive publications. If the research has enough studies with homogeneous metrics, researchers can perform a meta-analysis to calculate the aggregate effect size on key outcomes.

CONCLUSION

this study provides a comprehensive overview of current research trends in STEAM-based learning, revealing a significant growth in publications that reflects strong academic responses to contemporary curriculum reforms and 21st-century educational demands. The findings in-

dicate that STEAM research is predominantly concentrated at the elementary education level, with science and mathematics emerging as the most dominant subject areas. In terms of instructional media, Augmented Reality and digital learning resources such as e-modules and flipbooks are the most frequently developed, highlighting the growing need for visualization and accessible technology in STEAM learning. The ADDIE model remains the most widely adopted framework for media development, suggesting a preference for systematic and validated instructional design processes. Pedagogically, Project-Based Learning and STEAM-based approaches dominate due to their philosophical alignment and flexibility, often being integrated with other instructional models to enhance learning outcomes. Despite these advances, the limited integration of arts, humanities, qualitative approaches, and alternative development models indicates important research gaps. Therefore, future studies are encouraged to explore more interdisciplinary, student-centered, and experience-based approaches to fully realize the transformative potential of STEAM education.

ACKNOWLEDGMENT

We would like to express our gratitude for the support of Directorate of Research and Community Service Directorate General of Research and Development Ministry of Higher Education, Science and Technology In accordance with Contract Number: 089/C3/DT.05.00/PL/2025 dated May 28, 2025.

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