MAPPING THE LANDSCAPE OF STEAM EDUCATION (2021–2025): A BIBLIOMETRIC ANALYSIS OF MEDIA, LEARNING OUTCOMES, AND ASSESSMENT PRACTICES

Muhammad Sholihul Huda[1], Barokah Isdaryanti[2], Ellianawati Ellianawati [3], Fahrur Rozi[4]
[1]Post Graduate School, Primary Education Study Program, Universitas Negeri Semarang, Central Java, Indonesia
[2]Elementary School Teacher Education, Faculty of Education and Psychology, Universitas Negeri Semarang, Central Java, Indonesia
[3]Physics Education, Faculty of Mathematics and Natural Science, Universitas Negeri Semarang, Central Java, Indonesia
[4]Economic Education, Faculty of Economics and Business, Universitas Negeri Semarang, Central Java, Indonesia
[1]muhammadshuda17@students.unnes.ac.id

ABSTRACT

This study maps the state of science, technology, engineering, arts, and mathematics education from 1 January 2021 to 16 October 2025 by synthesizing research on instructional media, learning outcomes, and assessment practices. The objective is to identify dominant trends, gaps, and implications to guide classroom innovation and evaluation. Articles were located in Scopus, Google Scholar, and Crossref and screened using a process modeled on PRISMA. From 1,375 records, 168 met the inclusion criteria after duplicate removal, relevance screening, and full-text checks focused on classroom practice, media integration, and outcome measurement. Methods combined a systematic review with bibliometric mapping of annual output, venues, co-authorship, keyword co-occurrence, and methodological features. Results show steady growth, peaking in 2024, and five clusters: primary education, media development and validation, learning-outcome testing, analytical approaches, and digital engagement. Quantitative achievement testing remains prevalent, while formative and performance-based assessments and measures of digital literacy and higher-order thinking gain momentum. The review concludes that enhanced technology, student-centered designs are reshaping practice and recommends media-rich tasks, clear rubrics, and longitudinal, comparable assessment frameworks.

Keywords: assessment practices, bibliometric analysis, instructional media, learning outcomes, primary education, steam education

A. INTRODUCTION

Science, Technology, Engineering, Arts, and Mathematics (STEAM) has rapidly evolved into a prominent pedagogical framework for cultivating twenty-first-century competencies in

primary schooling; yet, the field remains fragmented in how studies conceptualize and operationalize instructional media, how they define and measure learning outcomes, and how assessments are designed to evidence those outcomes (Perignat & Katz-Buonincontro, 2019; Marín-Marín et al., 2021). Since 2021, the proliferation of digital and innovative media—ranging from e-books and digital worksheets to augmented reality and online platforms—has further diversified classroom practices, but has also produced heterogeneous approaches to evaluating impact (Leavy et al., 2023; Deák & Kumar, 2024; Jiang et al., 2025; Ruiz Vicente et al., 2020). This heterogeneity complicates efforts to compare findings across contexts and to identify the most generative directions for curriculum, assessment, and teacher professional learning (Gao et al., 2020). Against this backdrop, a synthesis that simultaneously maps media use, links it to reported outcomes, and examines the assessment practices used to substantiate those outcomes is timely and necessary.

Recent studies document steady growth in STEAM publications and an expansion from conceptual advocacy to classroom implementation, particularly at the primary level (Abdi et al., 2024; Cai et al., 2023; Chiu, 2025; Phuong et al., 2023). Parallel to this growth, research has clustered around (a) the development and validation of learning media, (b) testing and outcome measurement, (c) analytical and methodological advances, and (d) the affective and digital dimensions of learning (Tene et al., 2025; Rodrigues-Silva & Alsina, 2023). While these strands have matured, they have largely progressed in parallel, resulting in limited cross-talk between media design choices and the assessment tools used to capture creativity, collaboration, digital literacy, and higher-order thinking (Sanz-Camarero et al., 2023; Silva-Hormazábal & Alsina, 2023). Moreover, the persistence of short-term, pre-/post-test designs and the uneven use of validated instruments constrain the field's ability to draw cumulative inferences about what works, for whom, and under what conditions (Gao et al., 2020). A focused, period-bounded synthesis can therefore surface convergences

and reveal where evidence is thin or methodologically inconsistent.

This study addresses that gap by conducting a systematic, bibliometric analysis of STEAM education research published from 2021 to 2025 with explicit attention to three interlocking facets: instructional media, learning outcomes, and assessment practices. By integrating systematic reviewing (to ensure transparent study selection and appraisal) with bibliometric mapping (to visualize thematic structures, author and venue networks, and keyword co-occurrences), the study provides a field-level "map" of dominant trends and emergent niches. Theoretically, the work clarifies how media modalities align with targeted competencies and which assessment approaches are most frequently mobilized to evidence those competencies. Practically, it offers teachers and school leaders an evidence-informed basis for selecting or designing media alongside appropriate assessments, and it highlights promising directions for curriculum designers and policymakers seeking coherence between instruction and evaluation.

Accordingly, this research pursues the following questions as an integrated inquiry rather than as isolated aims: (1) What dominant research trends characterize STEAM education during 2021–2025, particularly in primary schools; (2) how are digital and innovative learning media (e.g., e-books, AR/VR, digital worksheets, and online platforms) integrated to support teaching and enhance student learning outcomes; and (3) which assessment approaches are most frequently employed, and how are they linked to the measurement of student outcomes? The answers to these questions are expected to yield implications for theory building in STEAM (by articulating construct-measurement alignments), for practice (by informing media-assessment pairing in lesson design), and for future research agendas (by identifying under-examined outcomes and advocating more robust, comparable assessment frameworks).

B. METHOD

This study employed a systematic literature review coupled with a bibliometric science-mapping approach to describe and explain the landscape of STEAM education during

2021–2025 with specific attention to instructional media, learning outcomes, and assessment practices. Guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), the review defined the population as peer-reviewed journal publications on STEAM education from 1 January 2021 to 16 October 2025. The unit of analysis was each eligible article; variables for coding comprised (a) media type or modality used in instruction, (b) learning outcomes targeted and measured, and (c) assessment approaches employed. These variables were operationalized from article titles, abstracts, keywords, and methods sections and recorded in a structured extraction sheet.

The identification stage consisted of comprehensive searches in Scopus, Google Scholar, and Crossref using combinations of controlled and free-text terms related to “STEAM” (including “STEM to STEAM” and “arts integration”), “education/school/classroom,” “learning outcomes,” “assessment,” and “instructional media.” Searches were run and exported with Publish or Perish to unify metadata fields (authors, title, year, source, keywords, abstract, citations). Records from the three sources were merged and de-duplicated programmatically and manually. Screening was performed on titles and abstracts to remove clearly irrelevant items; eligibility was then established through full-text assessment against inclusion criteria: publication type (article or review), focus on STEAM in educational contexts, alignment with at least one focal dimension (media, outcomes, or assessment), English language, and accessible full text. At the end of eligibility checks, 268 articles met criteria; the inclusion stage retained 168 articles of sufficient methodological quality and relevance for analysis.

Data collection used a standardized coding protocol applied to the included articles. For bibliometric indicators, we extracted publication year, source/journal, author affiliations, keywords, and citation counts. For the review synthesis, we coded media categories (e.g., e-books, digital worksheets, AR/VR, online platforms), outcome domains (e.g., conceptual understanding, creativity, critical thinking, digital literacy), and assessment approaches (e.g.,

objective tests, performance tasks with rubrics, formative assessment strategies). To enhance consistency, synonymous keywords were normalized (e.g., “augmented reality” and “AR” treated as one term), and ambiguous labels were resolved through discussion using explicit decision rules.

Instrument quality and trustworthiness were addressed by piloting the coding sheet on a subset of articles to refine category definitions and by applying transparent inclusion/exclusion rules throughout PRISMA stages. Content validity of the coding categories was supported by grounding definitions in contemporary STEAM education literature and aligning outcome and assessment codes with commonly accepted constructs in primary and secondary education research. Any disagreements in coding were reconciled through deliberation to reach consensus.

Data analysis proceeded on two tracks. First, bibliometric analysis described annual publication trends, core sources, prolific authors, and co-occurrence structures of author keywords. Keyword co-occurrence networks were generated and visualized in VOSviewer to identify thematic clusters and their interrelations. Second, the qualitative synthesis mapped how instructional media are paired with particular outcome targets and which assessment practices are used to evidence those outcomes, yielding narrative integrations of patterns and gaps. The combined approach provides both a macroscopic overview of the field and a fine-grained understanding of how media, outcomes, and assessment practices intersect within STEAM education during the 2021–2025 window as shown in Figure 1.

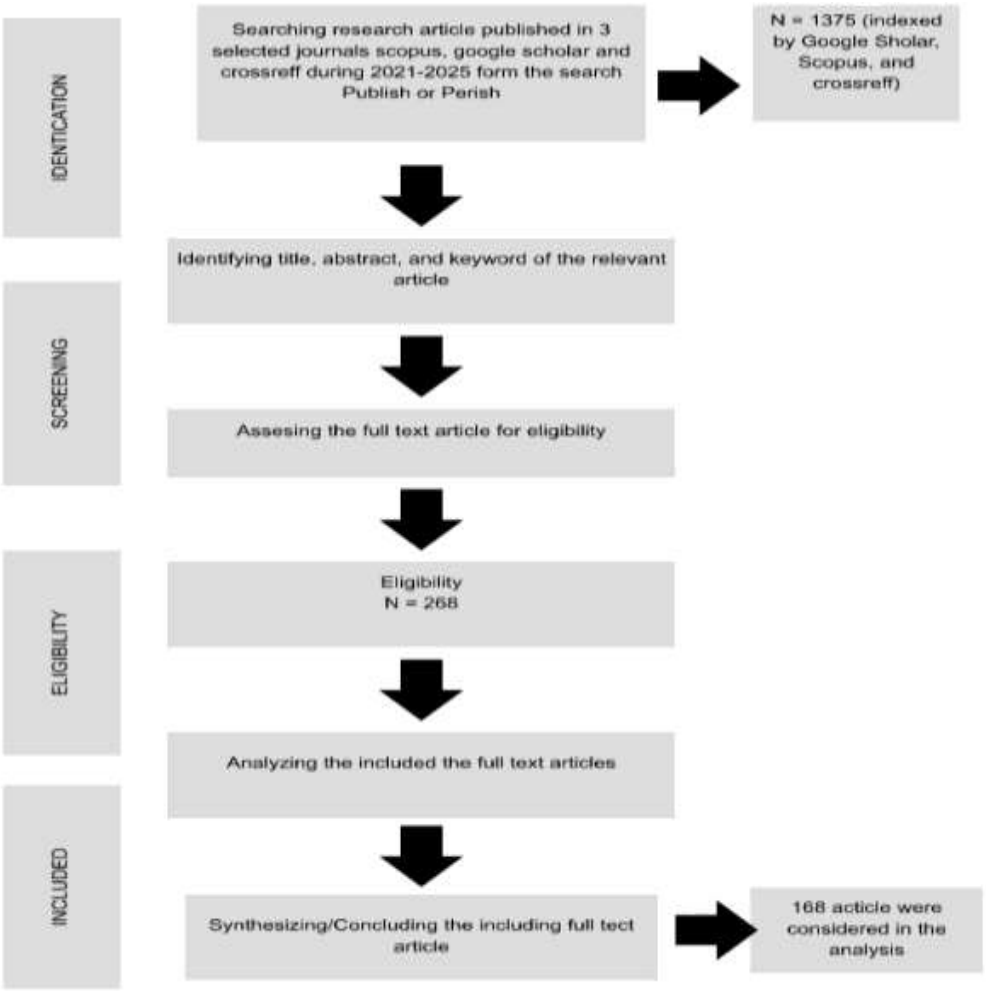

Figure 1. PRISMA Flow Diagram

C. FINDINGS AND DISCUSSION

This section presents the principal findings from the final corpus *(n = 168)* and discusses them in relation to recent STEAM education literature (2021–2025). We organize the narrative around the three research questions (trends/themes; media integration; assessment and learning outcomes), then synthesize cross-cutting implications. Tables are explained before they appear, and figure captions are provided for easy insertion into the manuscript.

Based on the systematic review, research on STEAM education in science learning from 2021 to 2025 can be classified into several analytical dimensions, including publication distribution by year, country of origin, research methodologies, educational levels,

and thematic developments identified through keyword mapping using VOSviewer. This classification aims to provide a holistic understanding of how STEAM principles have been integrated into science education across different learning contexts, particularly in promoting creativity, problem-solving, and interdisciplinary skills among students as shown in table 1.

Table 1. Ranking of the Most Cited Authors in STEAM Education and Science Learning (2021–2025)

Title	Authors	Citations
Fostering AI Literacy in Elementary Science, Technology, Engineering, Art, and Mathematics (STEAM) Education in the Age of Generative AI	Stefanus Christian Relmasira et al.	60
Emotions in the doing of science: Exploring epistemic affect in elementary teachers' science research experiences	Shannon G. et al.	52
Investigating the effectiveness of STEAM education on students conceptual understanding of force and energy topics	Gulbin Ozkan et al.	50
Elementary Preservice Teachers Challenges in Designing and Implementing Socioscientific Issues-Based Lessons	Melanie Kinskey et al.	42
STEAM Designed and Enacted: Understanding the Process of Design and Implementation of STEAM Curriculum in an Elementary School	Cassie F. Quigley et al.	41

Child-Robot Theater: Engaging Elementary Students in Informal STEAM Education Using Robots	Jaclyn Barnes et al.	39
ICT tools for remote teaching and learning mathematics: A proposal for autonomy and engagements	Niroj Dahal et al.	36
Sources of engineering teaching self efficacy in a STEAM methods course for elementary preservice teachers	Donna L. Webb et al.	35
Influence of the Sources of Science Teaching Self-Efficacy in Preservice Elementary Teachers Identity Development	Deepika Menon	33
STEAM education- metacognition Specific Learning Disabilities	Niki Lytra et al.	28

Trends and thematic structures in 2021–2025. The bibliometric mapping indicates sustained growth of STEAM publications across 2021–2025, with the literature consolidating around several interconnected themes. The keyword co-occurrence network reveals clusters centered on: *(a)* development of instructional media and resources; *(b)* assessment and testing of learning outcomes; *(c)* analytical and methodological approaches (e.g., design-based research, quasi-experimental designs); and *(d)* affective/digital engagement (motivation, collaboration, digital literacy). These clusters point to a field moving beyond generic advocacy toward implementation studies particularly in primary school contexts yet still characterized by heterogeneous constructs and measures. This pattern aligns with recent reports that STEAM scholarship is diversifying in methods and outcomes while seeking stronger construct–measurement coherence as shown in Table 2 and Figure 2.

Table 2. Trends in STEAM Education Publications (2021–2025)

Year	Number of Articles
2021	150
2022	152
2023	210
2024	265
2025	175

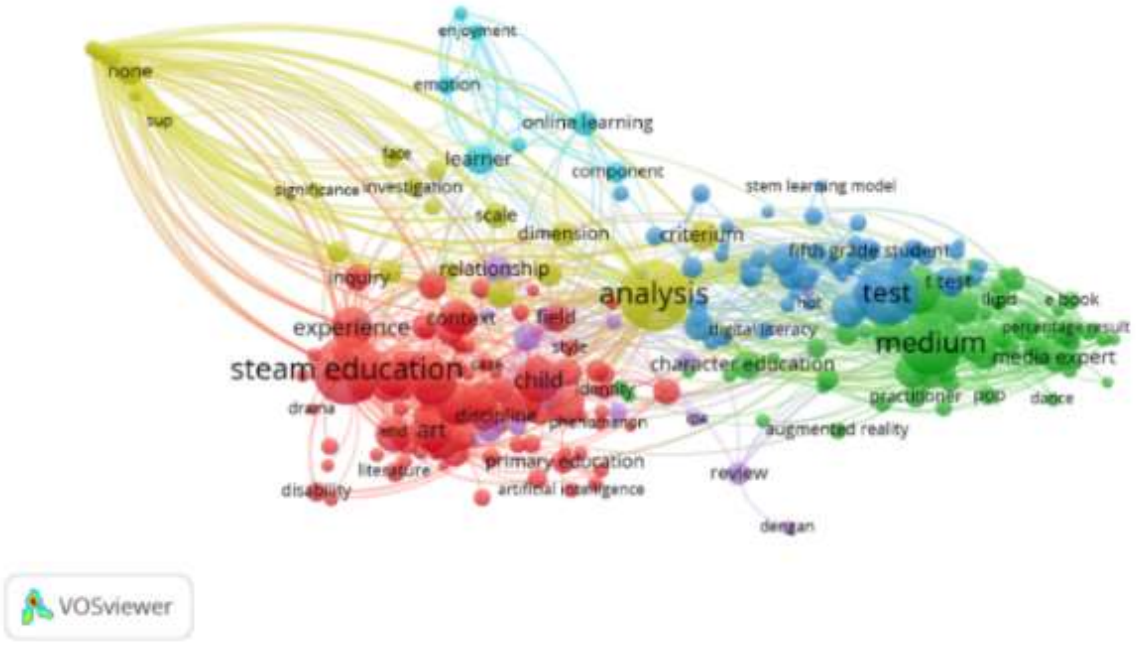

Figure 2. Keyword Co-Occurrence Network of STEAM Education Research (2021–2025) Visualized Using VOSviewer

Integration of digital and innovative media. Across the corpus, studies most frequently report the use of e-books, digital worksheets/LKPD, AR/VR and virtual labs, online learning platforms, and gamified tools. Media are commonly positioned to scaffold inquiry, visualization, and hands-on problem solving in integrated tasks that connect science, technology, engineering, arts, and mathematics. In primary settings, LKPD and e-books are often employed to sequence investigation steps and embed

simulations, while AR/VR and virtual labs are leveraged to visualize abstract concepts (e.g., forces, organs, energy flow) in 3D; platforms and gamified tools are used to promote collaboration, creativity, and literative feedback as shown in Table 3.

Table 3. Examples of digital and innovative media integrated in STEAM education (2021–2025)

Media category	Typical instructional purpose in STEAM	Frequently reported learning outcomes	Common assessment approach
E-books; interactive modules	Structure inquiry steps; embed multimedia and simulations	Conceptual understanding; procedural fluency	Objective tests; short-answer items
Digital worksheets (LKPD)	Guide hands-on, cross-disciplinary tasks; evidence-collection	Problem solving; collaboration; creativity	Performance tasks with analytic rubrics
AR/VR; virtual labs	Visualize abstract phenomena; safe experimentation	Spatial reasoning; motivation/engagement	Observation checklists; scenario-based tasks
Online platforms/LMS	Orchestrate collaboration and feedback	Communication; digital literacy; self-regulation	Discussion analytics; reflective journals
Gamified tools	Sustain engagement; incentivize iteration	Persistence; creativity; computational thinking	In-game metrics; rubric-scored artifacts

Assessment approaches and their linkage to outcomes

Findings indicate that quantitative, achievement-oriented testing methods—such as pretest–posttest comparisons, t-tests, and quasi-experimental designs—remain the dominant mode of evaluating learning impact following media innovations or the adoption of new pedagogical models. This heavy reliance on quantitative outcomes

underscores an enduring preference for measurable cognitive gains over more complex dimensions of learning. Yet, two distinct shifts emerge within the broader trend. Approximately one-quarter of studies now emphasize outcomes related to digital literacy, higher-order thinking skills (HOTS), and creative problem solving, signaling growing interest in 21st-century competencies. Meanwhile, around one-fifth of the research corpus highlights formative and authentic assessment approaches, often integrated into project-based learning, performance tasks, or portfolio evaluations.

This gradual shift toward authenticity and formative assessment reflects an evolving understanding of learning as an active, process-oriented experience—valuing how learners think, design, and create, rather than merely what they recall or reproduce. Nonetheless, construct alignment remains inconsistent across studies: while creativity, collaboration, and problem-solving are frequently claimed as key outcomes, measurement practices often lag behind, relying on unvalidated rubrics or researcher-constructed instruments lacking comparability or reliability. As illustrated in Table 4.

Table 4. Outcome–assessment alignment observed in the 2021–2025 corpus

Outcome domain	Predominant assessment practice	Observed gaps/notes
Conceptual understanding; achievement	Pre/post objective tests; short-answer	Strong comparability, but limited attention to transfer and durability
Creativity; design thinking	Product/performance tasks with rubrics	Rubrics vary widely; inter-rater reliability rarely reported
Critical thinking/HOTS	Scenario-based tasks; mixed item sets	Definitions differ; few validated instruments reused across studies

D. CONCLUSION

This review answers the three research objectives by providing an integrated map of STEAM education scholarship from 2021–2025. First, the field exhibits sustained growth and consolidates around five interlinked themes primary STEAM implementation, media development and validation, assessment and testing, analytical/methodological advances, and affective digital engagement indicating a shift from advocacy to classroom enactment. Second, across contexts, e-books and digital worksheets (LKPD) structure inquiry and embed simulations; augmented reality/virtual labs make abstract concepts tangible; and online platforms and gamified tools orchestrate collaboration and build digital literacy—showing media integration that aligns with constructivist, student-centered learning. Third, while achievement-oriented pre/post testing remains predominant (55%), there is clear movement toward evaluating higher-order competencies (25%) and embedding authentic, formative assessment in projects and performances (20%). The principal contribution of this study is a field-level alignment between instructional media, targeted outcomes, and assessment practices, clarifying where evidence is robust and where measures are still emerging. By coupling systematic review with bibliometric mapping, the study offers a coherent structure that connects media choices to the competencies they aim to cultivate and to the instruments used to evidence those competencies, thereby advancing conceptual clarity and assessment literacy in STEAM education. These insights prioritize implications for educational practice and program evaluation: selecting or designing media should go hand in hand with transparent, construct-valid assessment so that reported gains reflect creativity, collaboration, problem solving, and digital literacy not merely short-term test performance.

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