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LITERATURE REVIEW: STEAM-BASED E-LKPD FOR ENHANCING STUDENTS' CRITICAL THINKING SKILLS

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Abstract

Students' low critical thinking ability remains a major challenge in school learning and is often driven by the dominance of conventional, teacher-centered instruction, which provides limited opportunities for learners to practice analyzing problems, constructing logical reasoning, drawing conclusions, and reviewing their answers. This situation highlights the need for innovative digital learning materials that promote active, contextual learning aligned with 21st-century skills. This study aims to analyze the impact of STEAM-based E-LKPD on improving students' critical thinking skills. The study employed a literature review method by analyzing 10 articles retrieved from the Scopus and Google Scholar databases. The synthesis indicates that STEM/STEAM-based E-LKPD is consistently considered feasible and effective in enhancing critical thinking, as reflected in moderate-to-high gains and/or clear performance differences between experimental and control groups. The strongest effects occur when E-LKPD is integrated with problem- or project-based activities and supported by media such as animated videos or interactive applications (e.g., Canva) that facilitate concept visualization, document learning processes, and strengthen students' reasoning in designing solutions and evaluating findings.

Keywords:Critical thinking skills ; STEAM-based E-LKPD

1. INTRODUCTION

The 2022 PISA findings confirm that Indonesia's mathematics literacy achievement still requires substantial strengthening. Although Indonesia reportedly improved its ranking compared with PISA 2018, its mathematics literacy score actually declined by 13 points over the same period (Ministry of Education, Culture, Research, and Technology [1]. This indicates that an improved rank does not automatically reflect better mathematical reasoning quality. PISA defines mathematics literacy as the capacity to use mathematics to reason and solve problems in real-world contexts, including selecting strategies, evaluating solutions, and communicating reasoning logically features that directly overlap with critical thinking skills [2]

This low performance is more appropriately interpreted as an issue of the learning process rather than merely an outcome of test scores. In mathematics learning, critical thinking does not develop when students are trained only to follow routine procedures and focus on obtaining final answers. When instruction is dominated by conventional methods and mechanical practice, students tend to memorize steps without understanding the underlying conceptual rationale; as a result, they often struggle when confronted with modified questions, unfamiliar contexts, or non-routine problems that require analysis, strategy evaluation, and justification [3], [4].

Evidence from previous studies supports the use of STEAM-oriented instructional approaches particularly through E-LKPD to foster students' critical thinking skills. Research in elementary education has reported that STEM-based learning can improve students' critical thinking more effectively than conventional instruction, and STEAM-based approaches have also been associated with higher learning outcomes in experimental groups compared with control groups [5], [6]

In addition, development studies indicate that STEM-based E-LKPD supported by digital media (e.g., animated videos) is generally rated as valid, practical, and effective for enhancing critical thinking, and STEM-based LKPD can produce moderate to high learning gains when tasks are designed to require analysis and evidence-based reasoning[7], [8], [9], [10] Similar findings have been reported for STEAM-based LKPD, which has been considered feasible and practical as an innovative learning resource [6], [11], [12], [13]) Moreover, integrating problem- or project-based learning models into LKPD/E-LKPD can further strengthen reasoning and evaluation processes, although project-based implementation often faces practical constraints such as time management and student engagement [9], [14], [15], [16] Overall, these findings suggest that worksheet development should not focus solely on visual appeal and usability, but must prioritize task designs that explicitly cultivate analysis, strategy selection, justification, and solution evaluation skills aligned with mathematical literacy and critical thinking[17], [18].

At the level of instructional materials, student worksheets (LKPD) have the potential to shape learning activities and determine the quality of students' thinking processes. Numerous digital LKPD developments and STEM-based implementations have been conducted to make learning more varied, including the use of design platforms such as Canva. However, these efforts often emphasize practicality and visual appeal, while task designs that intentionally guide students through critical thinking stages such as analyzing information, selecting strategies, evaluating steps, and constructing logical justifications have not consistently become the primary focus. In addition, STEM integration in mathematics worksheets typically highlights the science–technology–engineering components, whereas the "Arts" element has not been consistently operationalized as a

pedagogical strategy to strengthen visual representation, mathematical communication, and cognitive engagement[19], [20].

In response to these needs, a STEAM-based e-LKPD supported by Canva is positioned as an instructional tool that is not only digital and engaging but also systematically structured to train critical thinking through problem-based tasks that demand analysis, evaluation, and justification. STEAM enables cross-disciplinary contextual integration while leveraging the Arts component to strengthen representations, communicate ideas, and foster creativity that remains oriented toward problem solving; meanwhile, Canva serves as a visual design medium that helps present tasks in a systematic and accessible manner. Thus, the focus of the study goes beyond product feasibility alone to examine how the e-LKPD guides students' critical thinking processes as they solve mathematical problems.

2. METHODS

The research method used in this study is a descriptive literature review (library research)[21], [22]. The research procedure is presented in

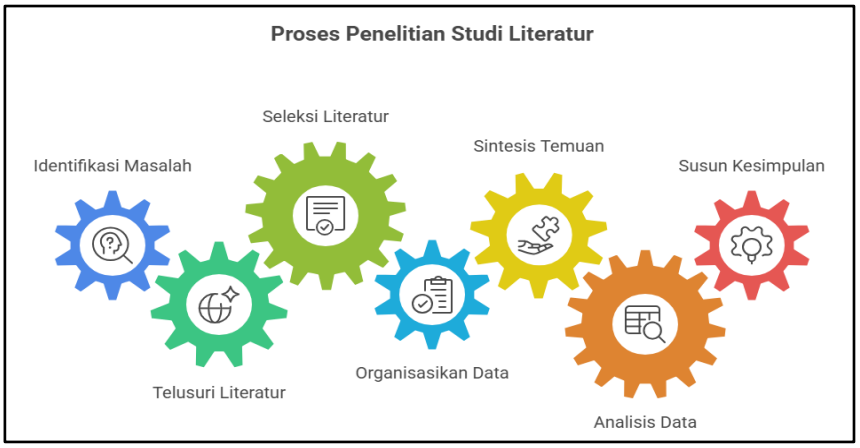


Figure 1. Research Procedure

This study employed a literature review method by collecting, reviewing, and synthesizing theories, concepts, and findings from previous research on the use of STEAM-based E-LKPD (Science, Technology, Engineering, Arts, and Mathematics) and its relationship with students' critical thinking skills. The unit of analysis consisted of scientific documents, namely 10 articles obtained through Google Scholar and Scopus. The selected articles specifically focused on STEAM-based E-LKPD and critical thinking, presented clear theoretical discussions or empirical data, and were preferably published within the last 5–10 years.

The research instrument was a document analysis sheet developed by the researcher to standardize the extraction of information from each article. It recorded source details (authors, year, title, journal/publisher), research objectives, educational context, research design/method, characteristics of the STEAM-based E-LKPD (STEAM components, types of activities, media/platform), the critical thinking indicators used, and the main findings regarding the impact of E-LKPD on critical thinking skills. The research procedure followed these stages: identifying the problem and defining the review focus; searching for articles in Google Scholar using relevant keywords; collecting and organizing key data into the analysis sheet; and synthesizing the findings into themes to obtain a systematic and comprehensive overview. Data were analyzed qualitatively using content analysis, including reducing irrelevant data, grouping findings, and comparing results and arguments across articles (both consistent and divergent). The synthesized results were then used to draw comprehensive conclusions, while also highlighting the review's limitations and outlining directions for further research[21], [22], [23].

3. RESULT AND DISSCUSSION

Based on publication data collected from Scopus and Google Scholar, research on STEAM-based E-LKPD shows a clear upward trend in recent years, with the number of publications increasing notably during the 2023–2025 period, as illustrated in Figure 2

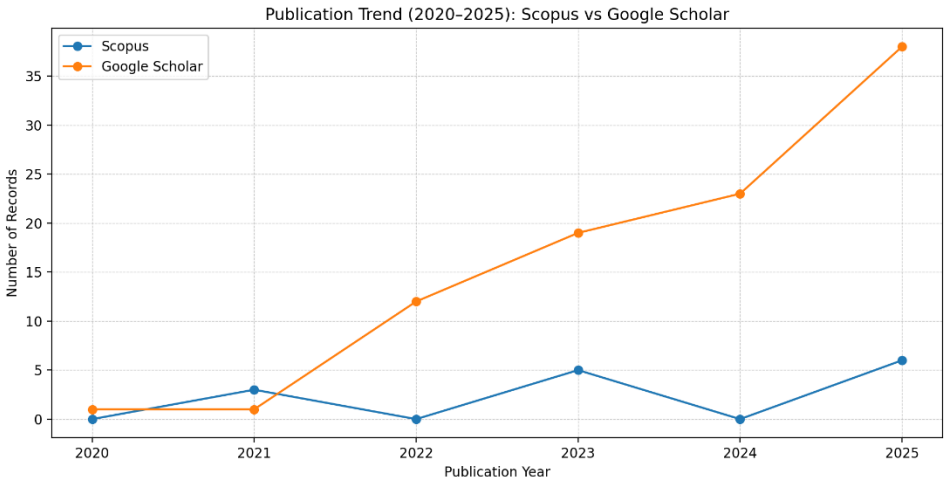


Figure 2. Trend Publication

These findings indicate that STEAM-based E-LKPD is gaining increasing attention as an innovative instructional resource to promote active learning and strengthen students' critical thinking skills.

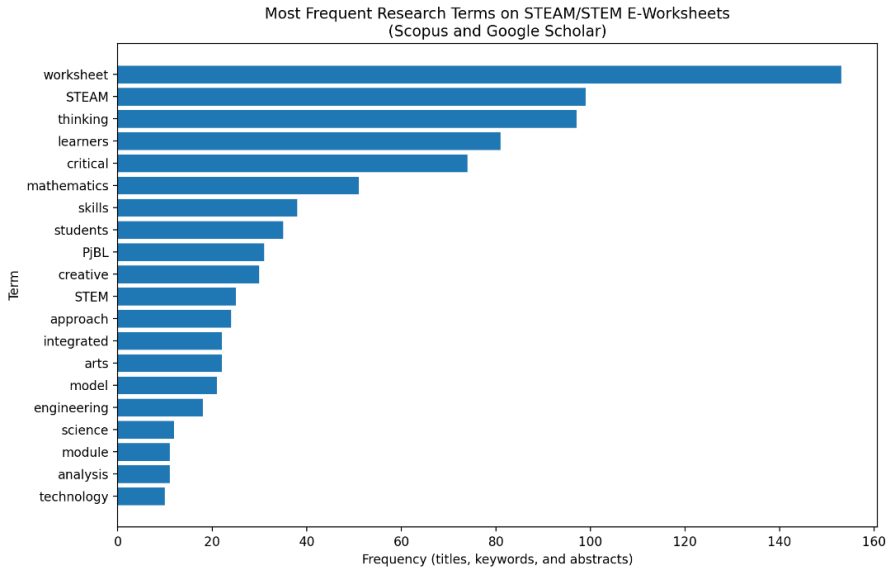


Figure 3. Most Frequent Research Term

The chart shows the terms that most frequently appear in the titles, keywords, and abstracts of studies on STEAM e-worksheets. The dominant terms indicate that the main research focus is on strengthening critical thinking, developing worksheets as instructional media, and implementing the STEAM approach, which is often combined with PBL/PjBL models. The presence of terms such as science, technology, engineering, arts, and mathematics highlights the integrative nature of STEAM, while terms such as problem, project, model, and approach suggest that many studies emphasize problem- and project-based learning as a mechanism to promote students' analysis and reasoning [24], [25], [26].

The use of STEAM-based E-LKPD to improve students' critical thinking skills was derived from the analysis of 10 journal articles. The results of the analysis of these articles are presented as follows:

Table 2. Article Analysis Related to STEAM

No.	Journal Title	Summary of Findings
1	Implementation of STEM (Science, Technology, Engineering, and Mathematics) Learning on Elementary Students' Critical Thinking Skills[5]	The study found that implementing STEM learning had a positive and significant effect on students' critical thinking skills. The N-Gain test confirmed that STEM was reasonably effective in improving critical thinking compared with conventional methods.
2	Development of a STEM-Based E-LKPD Supported by Animated Videos to Improve Senior High School Students' Critical Thinking Skills[7]	This study developed a STEM-based E-LKPD with animated videos to address low critical thinking in exponential topics at the senior high school level. The product was reported as highly valid, practical, and effective, with an N-Gain of 0.598 (moderate category).
3	Development of a STEM-Based LKPD to Improve Critical Thinking in Elementary School: Changes in the States of Matter[8]	The study developed a STEM-based LKPD using the Canva application for Grade 4 elementary students. The LKPD was valid, practical, and highly effective in improving critical thinking, with an N-Gain of 0.73 (high category).

No.	Journal Title	Summary of Findings
4	Effectiveness of the STEAM Approach in Improving Elementary Students' Critical Thinking Skills[27]	STEAM-based learning was effective in improving Grade 5 students' critical thinking. There was a significant effect on critical thinking, and the experimental group's post-test mean (83.37) was much higher than the control group's (68.37). The approach created a supportive learning environment that encouraged active knowledge construction through hands-on activities and scientific literacy.
5	Critical Thinking in Solving Numeracy-Oriented Problems in Algebra Content[28]	Students with high numeracy met all critical thinking indicators (FRISCO: Focus, Reason, Inference, Situation, Clarity, Overview). Students with moderate numeracy met Focus, Reason, and Clarity but were less careful in checking answers (Overview). Students with low numeracy met only Focus and Clarity and struggled to provide logical reasons and draw accurate conclusions.
6	Development of a STEAM-Based LKPD for Grade VI in Science (IPA)[11]	The study developed a STEAM-based LKPD for Grade 6 elementary students and found it to be valid and practical. The LKPD was feasible and practical as an innovative teaching material to help students understand science content in an integrated way involving technology, engineering, arts, and mathematics.
7	Development of e-LKPD Based on Android-Assisted Problem-Based Learning to Improve Learners' Critical Thinking Ability[15]	The study showed that PBL-based LKPD supported by Android technology effectively improved students' critical thinking. Effectiveness testing indicated a significant improvement with an N-Gain of 0.56 (moderate category).
8	Augmented Reality Technology in Enhancing Learning Retention and Critical Thinking According to a STEAM Program[29]	AR-based e-content within a STEAM program improved students' critical thinking, especially among those with high mental capacity. The study also found that male students benefited more from AR-supported science learning than female students.
9	Student Worksheets Based on Problem-Based Learning to Improve Students' Critical Thinking Skills[30]	The study found that PBL-based worksheets improved student engagement and learning outcomes, although they did not significantly affect learning motivation.
10	The Integration of STEAM Project-Based Learning to Train	The main challenges in implementing STEAM-PjBL were time management and student engagement. It is important to

No.	Journal Title	Summary of Findings
	Students' Critical Thinking Skills in Science Learning Through an Electrical Bell Project[14]	develop project ideas aligned with instructional concepts and ensure active participation. STEAM-PjBL integration helped students connect ideas, make assumptions, and draw conceptual conclusions.

Based on the review of 10 articles, most studies indicate that STEAM-oriented approaches implemented through E-LKPD and combined with active learning strategies (e.g., PBL/PjBL) tend to improve learners' critical thinking skills across educational levels. In elementary school contexts, STEM implementation has been reported to have a positive and significant effect on students' critical thinking compared with conventional methods [5], [31] A similar pattern is also evident in STEAM-based learning at the elementary level, where the experimental group achieved a higher mean post-test score than the control group [27], [32].

In development-focused studies, a STEM-based E-LKPD supported by animated videos was reported to be highly valid, practical, and effective, producing a moderate improvement in critical thinking. The development of a STEM-based LKPD on changes in states of matter for elementary students was also reported as valid, practical, and highly effective, as reflected by a high N-Gain score[8] From the perspective of technology integration and instructional models, an Android-assisted PBL-based e-LKPD resulted in a moderate N-Gain improvement in critical thinking [9], [15] and PBL-based LKPDs were found to enhance student engagement and learning outcomes, although they did not consistently produce significant effects on learning motivation [30]

In addition, research that conceptualizes critical thinking as a learner profile shows variation influenced by students' baseline competencies. Students with high numeracy were able to meet all FRISCO indicators of critical thinking, whereas those with moderate and low numeracy showed limitations in reasoning and drawing conclusions [33]. In

immersive technology studies, STEAM programs utilizing augmented reality (AR) were reported to improve retention and critical thinking; however, the effects were influenced by learner characteristics (e.g., mental capacity), and outcomes differed across particular groups [29], [34], [35] Findings on STEAM-PjBL further confirm benefits for critical thinking training, although implementation faces challenges related to time management and student engagement [14]

Overall, the findings of this literature review suggest that STEAM-based E-LKPD/LKPD has the potential to enhance critical thinking because it positions learners to engage with authentic problems, construct arguments, and test solutions in a step-by-step manner. This is evident in implementation studies comparing treatment and control groups, where STEAM-oriented instruction produced stronger critical thinking outcomes than conventional learning [5], [36] Pedagogically, such designs encourage students to shift from passively receiving information to actively solving problems that require analysis and evaluation, which are central components of critical thinking[37], [38].

Within development-oriented studies, the effectiveness of E-LKPD is commonly supported by three key indicators: validity (content and design appropriateness), practicality (ease of use), and effectiveness (learning outcome improvement). A STEAM-oriented E-LKPD supported by animated videos was reported to improve critical thinking with moderate gains, indicating that visual support and structured tasks can help students build stronger reasoning when dealing with abstract content [39] Meanwhile, STEM-based LKPD in elementary settings with high N-Gain values suggests that when worksheets are designed to guide students through investigation and evidence-based reasoning, critical thinking gains can be stronger [16], [34], [40]. This is consistent with STEAM-based LKPD development that emphasizes interdisciplinary integration as an innovative learning resource for science instruction [9], [11]

However, it is important to emphasize that improvements in critical thinking are not determined solely by the instructional tool or approach; they are also shaped by students' prerequisite skills. Numeracy-focused findings indicate that learners with low numeracy tend to struggle with reasoning and inference, even when they can identify the general focus of the problem [41], [42] This implies that STEAM-based E-LKPD designed to train critical thinking should incorporate explicit scaffolding, such as reasoning prompts, step-by-step worked examples, and instructions for reviewing answers so that students do not remain at a purely procedural level [37], [38], [43].

From a technology perspective, findings on AR in STEAM support the view that technology can enrich learning experiences and facilitate critical thinking through more concrete and interactive representations, yet its effects are not uniform across all learners (Alkhabra et al., 2023). This aligns with evidence that Android-assisted e-LKPD can effectively improve critical thinking at a moderate level [15]. In other words, technology tends to be effective when it strengthens task design and argumentation processes rather than serving merely as a presentation medium. In project-based contexts, STEAM-PjBL helps students connect ideas and formulate conclusions, but persistent challenges in time management and engagement indicate that the quality of teacher implementation is a decisive factor for success [14] Therefore, the literature points to the conclusion that STEAM-based E-LKPD is most effective when accompanied by activity designs that demand reasoning and by strong implementation support.

4. CONCLUSION AND RECOMMENDATION

The implementation of STEAM-based digital E-LKPD/LKPD across educational levels tends to be effective in improving students' critical thinking skills because learning is designed to require learners to actively analyze problems, construct logical reasoning, draw

conclusions, and review their answers. This effectiveness is most evident when E-LKPD is integrated with problem- or project-based activities and supported by clear scaffolding, so students do not merely "complete tasks" but systematically engage in the full critical thinking process. Operationally, support from media such as animated videos and interactive applications (e.g., Canva) strengthens E-LKPD as a valid, practical, and effective learning tool by helping visualize concepts, structure work steps, and facilitate documentation of the problem-solving process. The STEAM framework naturally promotes contextual problem solving that demands both critical and creative thinking, while E-LKPD functions as a digital facilitator that organizes learning activities, reinforces engineering and mathematical components, and encourages original ideas as part of 21st-century skills. Nevertheless, this review is limited by the relatively small number of studies, heterogeneous research designs and measurement instruments, and the predominance of short-term evaluations; therefore, the findings should be generalized cautiously and do not yet fully capture retention or the transfer of critical thinking skills to other content areas. Accordingly, future research should strengthen the evidence base through more rigorous experimental designs and broader cross-context samples, examine moderating factors such as prior ability, numeracy, technology readiness, and the quality of teacher facilitation, and develop STEAM-based E-LKPD that more explicitly targets evidence-based argumentation and evaluation/overview processes, supported by longitudinal studies and large-scale implementation to map long-term impacts as well as practical challenges such as time management and student engagement.

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