



Integrating Socio-Scientific Issues into Mobile Learning to Foster Critical Thinking in Elementary Science: A Systematic Review

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Abstract: This study systematically analyzes the implementation of socio-scientific issues-oriented mobile learning to foster elementary students' critical thinking in science. A Systematic Literature Review following the PRISMA protocol with qualitative synthesis examined ten peer-reviewed articles (2021–2025) meeting strict inclusion criteria. Selected studies integrated mobile learning with socio-scientific issues in elementary science and explicitly measured critical thinking. Findings show consistent moderate-to-high improvement, with N-Gain scores ranging from 0.59 to 0.80. Implementations were mainly associated with problem-based learning combined with guided inquiry. Effective designs integrated interactive multimedia, augmented reality, and Android-based platforms to enable flexible, ubiquitous learning. Frequently addressed issues included environmental pollution, food waste management, and local ecosystem conservation, providing authentic contexts for multi-perspective analysis. Overall, the review confirms that socio-scientific issues-oriented mobile learning is a promising pedagogical approach for promoting higher-order thinking in elementary science, while highlighting the need for adequate technological infrastructure and strong teacher digital competence to ensure effective implementation.

Abstract: Penelitian ini bertujuan menganalisis secara sistematis penerapan pembelajaran bergerak berorientasi isu sosiosaintifik sebagai media pembelajaran sains untuk meningkatkan keterampilan berpikir kritis peserta didik sekolah dasar. Metode tinjauan pustaka sistematis dengan protokol PRISMA dan pendekatan sintesis kualitatif digunakan untuk mengidentifikasi, menyeleksi, serta menganalisis sepuluh artikel terakreditasi yang diterbitkan pada periode 2021–2025. Kriteria inklusi meliputi integrasi mobile learning dan isu sosiosaintifik, konteks pembelajaran sains sekolah dasar, serta pengukuran keterampilan berpikir kritis yang dinyatakan secara eksplisit. Hasil sintesis menunjukkan bahwa pembelajaran bergerak berorientasi isu sosiosaintifik cenderung meningkatkan keterampilan berpikir kritis dengan tingkat efektivitas sedang hingga tinggi, ditunjukkan oleh nilai N-Gain antara 0,59–0,80. Implementasi pembelajaran didominasi oleh model problem-based learning yang dipadukan dengan pendekatan inkuiri terbimbing. Rancangan pembelajaran yang efektif mengintegrasikan multimedia interaktif, teknologi augmented reality, serta platform berbasis Android yang mendukung akses belajar fleksibel. Isu yang banyak digunakan meliputi pencemaran lingkungan, pengelolaan limbah pangan, dan pelestarian ekosistem lokal sebagai konteks autentik pembelajaran. Kajian ini menegaskan potensi mobile learning berorientasi isu sosiosaintifik sebagai strategi pedagogis inovatif dalam pembelajaran sains sekolah dasar.

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A. Introduction

Digital transformation in the 21st-century education ecosystem demands learning innovations that integrate technology with contextual pedagogical approaches to develop students' high-level cognitive competencies. In the era of Society 5.0, education is expected not only to transmit scientific knowledge but also to prepare learners to respond critically and adaptively to complex real-life problems. One of the most essential competencies in this context is critical thinking, which should be cultivated from the elementary education level as a foundation for lifelong learning and informed decision-making. Critical thinking enables learners to analyze information, evaluate evidence, and synthesize ideas when facing multidimensional challenges in their personal and social lives.

Natural Science learning at the elementary school level plays a strategic role in fostering critical thinking skills by exploring scientific phenomena encountered in the surrounding environment. Science learning provides opportunities for students to observe, question, investigate, and reason logically, which are fundamental processes in developing analytical and evaluative thinking. However, in practice, science learning in elementary schools is still predominantly characterized by conventional instructional approaches that emphasize knowledge transmission and teacher-centered Instruction. Such approaches tend to position students as passive recipients of information, limiting their opportunities to actively construct understanding and engage in reflective Inquiry. As highlighted by [Erümit \(2024\)](#), teacher-centered learning practices are less effective in training students to build conceptual understanding independently and develop a critical-reflective mindset. This condition is further exacerbated by the limited availability of learning media that are adaptive to the characteristics of digital-native learners, who require flexibility, interactivity, and immediate access to information via mobile devices.

In response to these challenges, mobile learning has emerged as a promising learning medium that can increase student engagement and provide ubiquitous access to learning materials. Mobile learning enables students to access learning resources anytime, anywhere, supporting personalized, self-paced learning experiences. In the context of science education, integrating mobile learning enables students to explore content interactively, collaboratively, and contextually, in line with individual learning rhythms ([Crompton et al., 2021](#)). Mobile learning environments can incorporate multimedia elements such as videos, animations, simulations, and interactive quizzes, which support diverse learning styles and facilitate deeper cognitive processing. These characteristics make mobile learning particularly relevant for elementary school students, who benefit from visual, interactive, and experiential learning opportunities.

Nevertheless, technological integration alone is insufficient to ensure meaningful learning outcomes. The pedagogical approach embedded within mobile learning design plays a crucial role in determining its effectiveness. One pedagogical approach that has gained increasing attention in science education is the integration of socio-scientific issues (SSI). Socio-scientific issues are complex, controversial, and socially relevant problems grounded in scientific concepts while involving moral, ethical, and socio-economic

considerations. Integrating SSI into science learning provides a meaningful context that connects scientific knowledge with real-world challenges. Kinskey & Zeidler (2021) emphasize that embedding socio-scientific issues in learning activities enables students to engage with science content while simultaneously considering ethical dilemmas and societal impacts.

The socio-scientific issues approach has been shown to be effective in stimulating complex cognitive processes because it exposes learners to dilemmatic situations that require scientific evidence-based argumentation, multi-perspective evaluation, and rational decision-making (Sadler, 2011). This finding is further corroborated by a systematic review conducted by Hernández-Ramos et al (2021), which confirmed that the integration of socioscientific issues with technology-enhanced problem-based learning significantly promotes students' critical thinking skills, scientific argumentation, and informed decision-making across various educational levels. Through SSI-based learning, students are encouraged to analyze multiple viewpoints, justify their reasoning with scientific evidence, and make informed decisions, all of which are core components of critical thinking. When integrated into mobile learning environments, SSI provides authentic, contextual learning experiences closely connected to students' daily lives. This integration promotes active engagement and meaningful learning, as students not only learn scientific concepts but also apply them to socially relevant issues (Kustantia et al., 2023).

Despite the growing interest in mobile learning and socio-scientific issues, existing research reveals several significant limitations that warrant further investigation. Research gaps are evident in three main areas. First, previous studies have tended to examine mobile learning and socio-scientific issues as separate instructional approaches, without systematically analyzing their integration within a unified pedagogical framework. As noted by Lin et al (2024), research on technology-enhanced learning often focuses on technological effectiveness. In contrast, studies on SSI emphasize pedagogical and ethical dimensions, resulting in fragmented insights that fail to capture the synergistic potential of combining the two approaches. Second, most existing studies have focused on secondary and tertiary education contexts, where learners are assumed to possess more advanced cognitive and self-regulatory abilities. Consequently, the unique characteristics of elementary school students—such as the need for structured scaffolding, guided Inquiry, and differentiated instructional support—have not received sufficient attention in prior research (Tsai et al., 2020). Third, there remains a lack of comprehensive synthesis studies that systematically analyze instructional design patterns, types of socio-scientific issues, pedagogical strategies, and learning effectiveness specifically within the context of elementary science education. This absence of focused synthesis limits the availability of evidence-based guidance for educators seeking to implement SSI-oriented mobile learning at the primary education level.

Addressing these gaps, the present study offers a novel contribution by conducting a Systematic Literature Review that explicitly integrates mobile learning and socio-scientific issues in the context of elementary science education. The novelty of this research lies in its

systematic synthesis of empirical studies that examine not only learning effectiveness but also instructional design characteristics, pedagogical models, and content themes relevant to the cognitive development of elementary school students. Unlike previous studies that either focus on a single approach or target higher education levels, this review provides a holistic and developmentally sensitive analysis of SSI-oriented mobile learning practices tailored to primary learners with distinct scaffolding needs.

Based on the identified research gaps and the proposed novelty, this study is guided by the following research questions: 1) How are socio-scientific issues-oriented mobile learning approaches implemented in elementary science education as reported in previous studies?, 2) What instructional design features, pedagogical models, and technological characteristics are most commonly employed in SSI-oriented mobile learning for developing elementary students' critical thinking skills?, 3) What patterns of learning effectiveness are reported regarding the impact of SSI-oriented mobile learning on elementary students' critical thinking skills?, and 4) What types of socio-scientific issues are most frequently used in elementary science learning contexts, and how do they support critical thinking development?

Accordingly, the purpose of this study is to systematically analyze and synthesize existing empirical research on the implementation of socio-scientific issues-oriented mobile learning in elementary science education. Specifically, this study aims to identify dominant implementation patterns, examine instructional design and pedagogical strategies, evaluate reported learning effectiveness in terms of critical thinking development, and map the types of socio-scientific issues used as learning contexts.

The contributions of this research are both theoretical and practical. Theoretically, this study contributes to the development of an integrative pedagogical framework that combines mobile learning with socio-scientific issues in elementary science education, extending the existing literature, which has predominantly focused on higher education contexts. In practice, the findings provide evidence-based recommendations for educators, instructional designers, and curriculum developers on designing mobile learning environments that support higher-order thinking skills at the elementary education level. By offering a systematic synthesis of best practices, this study supports the development of technology-enhanced science learning that is pedagogically sound and developmentally appropriate (Afikah et al., 2022; Nasution et al., 2023).

B. Method

This study uses the Systematic Literature Review (SLR) method to analyze the implementation of socio-scientific issues-oriented mobile learning in elementary school science learning. The SLR stage follows the PRISMA protocol, which comprises identification, screening, and inclusion of scientific articles (Page et al., 2021). Literature searches were conducted on the Scopus, Google Scholar, and ERIC databases using the keywords "mobile learning", "socio-scientific issues", "critical thinking", and "elementary education" with a publication range of 2021-2025. Inclusion criteria include: (1) peer-

reviewed articles that discuss mobile learning based on socio-scientific issues, (2) focus on science learning at the elementary school level, (3) measuring critical thinking skills as an outcome variable, and (4) available in full text in English or Indonesian. Exclusion criteria include: (1) non-empirical articles such as editorials and opinion papers, (2) research at the secondary or higher education level, and (3) studies that do not explicitly measure critical thinking skills.

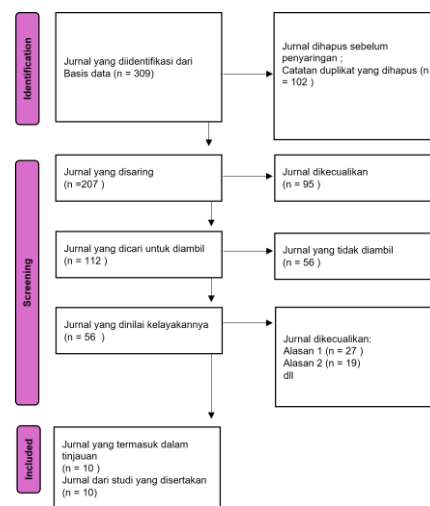


Figure 1. PRISMA Flowchart

The identification process resulted in 309 articles from the database which was then eliminated from duplication so that 207 articles remained. Screening based on the relevance of the title and abstract left 112 articles to be reviewed. The full-text feasibility assessment identified 56 articles that met the inclusion criteria; after a methodological quality evaluation using the Critical Appraisal Skills Programme (CASP) adaptation instrument, 10 articles met the standards of scientific rigor and were selected for in-depth analysis. Data extraction includes study characteristics, mobile learning design, types of socio-scientific issues, critical thinking measurement instruments, and key research findings.

C. Result

Study Selection Results

A *Systematic Literature Review* following the PRISMA 2020 protocol identified 309 publications across three databases: Scopus (156 articles), Google Scholar (98 articles), and ERIC (55 articles). The elimination of duplication identified 102 duplicate articles, leaving 207 publications for screening. An evaluation of the relevance of the title and abstract identified 112 articles that met the topic criteria. Full-text assessments identified 56 articles that met the inclusion criteria, but the methodological quality evaluation using the *Critical Appraisal Skills Programme* identified 10 articles that met high scientific rigor standards. Exclusion criteria included educational level mismatch (32 articles), lack of explicit critical thinking (18 articles), and low methodological quality (6 articles).

Table 1. Synthesis of Systematic Literature on the Use of Mobile Learning Oriented to Socio-Scientific Issues

No	Name & Year	Research Title	Method	Subject	Discovery Results	Relevance to Research
1	(Fadilla & Baroka, 2025)	Development of Comic Books Based on Socio-Scientific Issues to Improve the Critical Thinking Skills of Grade V Elementary School Students	<i>Research and Development</i> ADDIE	Grade V Elementary School Students	SSI-based comic media was declared to be very valid (95-100%), the response of teachers and students was very appropriate (89.3-95%), and the <i>N-Gain</i> of 0.59 was medium in increasing critical thinking	Validating the effectiveness of SSI-based visual media in developing critical thinking skills through engaging authentic contexts
2	(Husniyyah et al., 2023)	<i>Scientific Literacy Improvement Using Socio-Scientific Issues Learning</i>	<i>Pre-experimental one-group pre-posttest</i>	29 Science Education Students	Science literacy increased from low to medium category, with an <i>N-gain</i> of 0.64; the implementation of SSI-PBL was carried out very well	Confirming SSI's approach with <i>problem-based learning</i> is effective in developing science literacy and higher-level thinking skills
3	(Pratiwi et al., 2021)	Development of Teaching Materials Based on Socio-Scientific Issues with Interactive Multimedia to Train Critical Thinking in Grade V Elementary School	<i>DDD-E</i> Development	Grade V students of SDN Sememi Surabaya	100% learning completeness with an average <i>post-test</i> of 91.2, <i>n-gain</i> of 0.8 in the high category, 92% positive student response to SSI interactive multimedia	Demonstrating SSI's integration with interactive multimedia resulted in a significant improvement in elementary school students' critical thinking skills
4	(Widyastuti et al., 2025)	<i>Exploration of Socio-</i>	<i>Qualitative descriptive</i>	71 grade VIII	49.3% of visual learner	Identify multimodal

No	Name & Year	Research Title	Method	Subject	Discovery Results	Relevance to Research
		<i>Scientific Issues Learning Media for Science Literacy through Hypercontent E-Module</i>		students and 2 teachers of SMP Negeri 11	students, 95.77% want interactive e-modules with videos and quizzes, positive response to SSI 97.18%	and collaborative needs in SSI-based digital media design to improve science literacy
5	(Masing & Aminatun, 2022)	<i>Developing an SSI-Based Learning Model of Android Module to Improve Critical Thinking Skills</i>	<i>Design and Development Research</i>	Grade X student of Giovanni Kupang High School	An SSI-based Android module is feasible to develop and effectively improve critical thinking skills on coastal ecosystem materials	Proving the Android platform effective as an SSI medium for the development of critical thinking in the context of local ecosystems
6	(Suryani et al., 2023)	<i>Development of Ethnoscience-Based Mobile Learning Web Media on Conductivity Materials</i>	<i>Development ADDIE</i>	28 students of class VII-A SMPN 2 Kamal	Media expert feasibility 89.18% (reliability 93.76%), subject matter expert 87.29% (reliability 95.41%), student response 88.19% is very good	Integrating local wisdom with mobile technology creates meaningful contextual learning
7	(Febriana et al., 2023)	<i>Development of Socio-Scientific Issues-Based E-Modules on the Theme of Food Loss and Food Waste to Train Critical Thinking</i>	<i>Research & Development 4D</i>	Junior High School Students	Very high validity, 93.35% of material experts, media, and practitioners to train critical thinking skills	Demonstrate contemporary issues of food waste effectiveness as a context for SSI to develop critical analysis skills
8	(Anwar et al., 2024)	<i>Development of Problem-Based Learning</i>	<i>4D Development</i>	Grade 8-A students of SMPN 3 Paron	Very high feasibility (media expert 96.8%, material	Confirming PBL-based mobile learning is

No	Name & Year	Research Title	Method	Subject	Discovery Results	Relevance to Research
		Mobile Learning on Vibrations and Waves to Train Critical Thinking			93.8%), practicality 100%, effectiveness 95.8%, <i>t paired sig test</i> 0.00<0.05 had a significant effect	effective in training critical thinking skills with high accessibility
9	(Nubita & Istianah, 2024)	The Effect of Socio-Scientific Issues-Based Learning on the Critical Thinking Ability of Grade V Elementary School Students	Quasi-Experiment Non-Equivalent Control Group	Grade V Elementary School Students	Experimental class <i>N-Gain</i> 0.7017, high control 0.3785, medium category, <i>Independent Sample T-Test</i> 0.000<0.05 had a significant effect, student response 90.15%	Proving that SSI-based learning has a significant effect on improving the critical thinking skills of elementary school students
10	(Suardana et al., 2023)	Socio-Scientific Issues-Based Science Learning to Improve Critical Thinking Skills: A Systematic Literature Review	Systematic Literature Review PRISMA	26 Journal Articles and Proceedings	The most dominant PBL model (15.38%) was combined with SSI, 92.31% quantitative research, and critical thinking test instruments, with a combined indicator of 46.15%	Confirming that a variety of learning models can be combined with SSI to improve critical thinking skills.

Source: Research data processed, 2025

Ten articles show a diversity of methodological characteristics. The distribution of research design includes research and development (40%, n=4), quasi-experimental (20%, n=2), pre-experimental (10%, n=1), descriptive qualitative (10%, n=1), design and development (10%, n=1), and systematic literature review (10%, n=1). The subjects were dominated by elementary school students in grade V (50%, n=5), junior high school students in grade VIII (30%, n=3), and science education students (10%, n=1). The sample ranged from 28 to 71 participants. The geographical context is dominated by Indonesia (90%, n=9).

The publication period shows a peak in 2023 (40%, n=4), indicating the urgency of post-pandemic topics.

Table 2. Study Characteristics

Design	Frequency	%	Subject	Sample	Year
R&D	4	40%	Elementary School Class V	28-34	2021,2023,2025
Quasi-exp	2	20%	Elementary School Class V	60	2024
Pre-exp	1	10%	Students	29	2023
Descriptive	1	10%	Junior High School VIII	71	2025
Development	1	10%	High School X	32	2022
SLR	1	10%	Meta	26	2023

Source: Research data processed, 2025

The analysis identified three categories of instructional design. Interactive multimedia-based design (50%, n=5) integrates videos, animations, simulations, and formative quizzes in a single platform. Augmented reality-enhanced design (20%, n=2) uses AR technology to visualize complex phenomena. Collaborative mobile learning design (30%, n=3) emphasizes group discussions, argumentation forums, and collaborative decision-making. Android-based platforms dominated (70%, n=7), followed by web-based (20%, n=2) and hybrid (10%, n=1). Essential features include adaptive multimedia (100%), formative assessment (90%), gradual scaffolding (80%), and gamification (60%). The implementation duration is 4-8 weeks, with an intensity of 2-3 sessions per week.

The categorization identified five dominant themes. The most dominant environmental pollution (40%, n=4) includes water pollution, air pollution, and ecosystem degradation. Food waste management (20%, n=2) integrates the economic, socio-ecological, and ecological dimensions. Ecosystem conservation (20%, n=2) focuses on coastal and forest local ecosystems. Contextual physics phenomena (10%, n=1) and local ethnosience (10%, n=1) complete the distribution.

Table 3. SSI Type Distribution

Types of SSI	n	%	Example Topics
Environmental pollution	4	40%	Water, air, plastic
Food waste	2	20%	Loss, waste, sustainable food
Ecosystem conservation	2	20%	Coastal, local biodiversity
Contextual physics	1	10%	Vibration-waves
Ethnosience	1	10%	Local conductivity

Source: Synthesis of literature, 2025

Problem-Based learning was dominant (40%, n=4), with a structure of presentation of controversial issues, collaborative investigation, multi-perspective analysis, and evidence-based solutions. Guided Inquiry (30%, n=3) includes exploration, question formulation, data collection, analysis, and conclusion construction. Discovery Learning (20%, n=2) emphasizes self-exploration through inductive reasoning, with direct Instruction + SSI (10%, n=1) as an introductory model.

Table 4. Learning Model

Models	n	%	N-Gain	Categories
PBL	4	40%	0,64-0,80	Height
Guided Inquiry	3	30%	0,59-0,70	Medium-High
Discovery	2	20%	0,55-0,65	Medium
Direct+SSI	1	10%	0,59	Medium

Sources: *Suardana et al., 2023*; Research data processed, 2025

The combined indicator-based test (50%, n=5) included the dimensions of interpretation, analysis, evaluation, inference, explanation, and self-regulation, with Cronbach's alpha ranging from 0.78 to 0.89. The Ennis framework test (30%, n=3) focused on five indicators of critical thinking. The analytical rubric (20%, n=2) focuses on argumentation and decision-making. Instrument format: multiple-choice with rationale (40%), essay with rubric (30%), performance tasks (20%), and multimethod (10%). Content validity (CVI 0.82-0.96) and inter-rater reliability (Cohen's kappa 0.76-0.88) were in the excellent category. N-Gain analysis showed a high category (≥ 0.70) in 40% of articles (n=4), with a range of 0.70-0.80, and a medium category (0.30-0.69) in 60% of articles (n=6), with a range of 0.59-0.68. The quasi-experimental study showed an experimental N-Gain of 0.7017 versus a control of 0.3785 ($p=0.000<0.05$). Learning completeness reached 100% with an average post-test of 91.2. Media expert validation 89.18-96.8%, material expert 87.29-93.8%, student response 88.19-95%.

Table 5. Learning Effectiveness

Categories	n	%	Range	Significance
Height	4	40%	0,70-0,80	$p<0.05$
Medium	6	60%	0,59-0,68	$p<0.05$

Source: Research Results Synthesis Data, 2025

The comprehensive findings confirm that Mobile Learning-oriented socio-scientific issues consistently improve critical thinking skills with moderate-to-high effectiveness (N-Gain 0.59-0.80), indicating a substantial improvement empirically measured. Optimal instructional design integrates interactive multimedia, technology-augmented reality, and Android-based platforms, with Problem-Based Learning models dominating implementation (40%), followed by Guided Inquiry (30%), both proven to be effective in facilitating active knowledge construction. Relevant socio-scientific issues include environmental pollution (40%), Food Waste Management (20%), and ecosystem conservation (20%). They provide authentic contexts that stimulate deep cognitive engagement. Instruments Assessment demonstrates high validity and reliability with the most widely used combined indicators (50%) and covers the dimensions of interpretation, analysis, evaluation, inference, explanation, and Self-regulation. Models of Active Learning

resulted in a significantly greater increase than conventional learning ($p < 0.05$), confirming the superiority of the constructivist approach in developing higher-order thinking skills.

D. Discussion

This systematic review explicitly addresses how socio-scientific issues-oriented mobile learning has been implemented in elementary science education. It identifies the instructional design characteristics that support the development of students' critical thinking skills. The synthesis of 10 empirical studies indicates a consistent tendency toward moderate to substantial improvements in critical thinking, as reflected in Normalized Gain values ranging from 0.59 to 0.80. Notably, none of the reviewed studies reported low effectiveness outcomes ($N\text{-Gain} < 0.30$), suggesting that when mobile learning is appropriately integrated with socio-scientific issues, it has strong pedagogical potential to facilitate higher-level cognitive processes among elementary school students. These findings directly address the research focus on implementation patterns by showing that technology-enhanced learning environments grounded in authentic socio-scientific contexts can support the development of critical thinking skills from the basic education level.

The implementation patterns identified across the reviewed studies reveal the predominance of Problem-Based Learning as the main instructional model, followed by Guided Inquiry approaches. This tendency supports the theoretical proposition that elementary school students, when provided with developmentally appropriate scaffolding and exposed to authentic socio-scientific problems, are capable of developing analytical reasoning skills traditionally associated with higher education levels (Kinskey & Zeidler, 2021). Rather than reinforcing assumptions about cognitive limitations at the elementary level, these findings broaden the understanding of children's intellectual potential within optimally designed learning environments that combine Inquiry, collaboration, and technology support.

The observed learning effectiveness can be explained by the synergistic interaction of three pedagogical mechanisms. First, socio-scientific issues provide cognitively demanding contexts that require students to engage in multi-perspective analysis across scientific, social, economic, and ethical dimensions, thereby stimulating evaluation, synthesis, and critical assessment processes in line with social constructivist principles (Sadler, 2011). Second, mobile learning platforms facilitate ubiquitous access to multimodal learning resources, including interactive simulations, augmented reality visualizations, and collaborative discussion spaces, which accommodate diverse cognitive processing preferences while reducing extraneous cognitive load that may hinder learning (Crompton et al., 2021). Third, the application of Problem-Based Learning activates authentic problem-solving processes in which students collaboratively construct knowledge based on scientific evidence, enabling them to connect learning activities with real-life situations (Kinskey & Zeidler, 2021). The integration of these elements creates an authentic, interactive, and cognitively demanding learning ecosystem that optimizes germane cognitive load essential for the development of critical thinking skills.

The findings of this review are consistent with and extend previous research demonstrating the potential of mobile learning to support higher-order thinking skills in science education (Afikah et al., 2022). In particular, alignment with the study by Husniyyah et al (2023) confirms that socio-scientific issues-based Problem-Based Learning can elevate science literacy and critical thinking from low to medium-high levels, as indicated by an N-Gain of 0.64. In contrast to studies by Tsai et al (2020) and Lin et al. (2024), which predominantly examined secondary and tertiary education contexts, this systematic review highlights implementation patterns that are responsive to the unique scaffolding needs of elementary school students, thereby addressing an important gap in the literature. Furthermore, the consistent achievement of moderate to high N-Gain values (0.59–0.80) in studies employing interactive multimedia-based socio-scientific issues learning extends the findings of Pratiwi et al (2021) and Fadilla & Baroka (2025), suggesting a degree of generalizability across diverse learning settings.

In terms of instructional design characteristics, the dominance of Android-based platforms over web-based and hybrid systems reflects pragmatic considerations given the high penetration of Android smartphones in the Indonesian educational context, making them an accessible and feasible choice for elementary education settings (Suryani et al., 2023). Essential design features identified across studies include adaptive multimedia, formative assessment, gradual scaffolding, and gamification elements, all of which demonstrate responsiveness to the cognitive and motivational needs of elementary learners. Although augmented reality integration was reported in a smaller proportion of studies, its presence indicates a pedagogical shift toward more immersive and multisensory learning experiences, even as broader adoption remains constrained by technological infrastructure limitations.

The analysis of socio-scientific issue types further underscores the importance of contextual relevance in supporting the development of critical thinking. Issues with strong local relevance, such as environmental pollution, food waste management, and ecosystem conservation, were most frequently employed, confirming the proposition that authentic contexts closely connected to students' lived experiences foster deeper cognitive engagement and more meaningful learning (Febriana et al., 2023). The use of contemporary issues, such as food waste, in particular, illustrates the potential of socio-scientific issues-based learning to integrate scientific, economic, and ecological perspectives, thereby broadening students' understanding beyond isolated scientific concepts.

The diversity and quality of critical thinking assessment instruments used in the reviewed studies also strengthen the credibility of the synthesized findings. The predominance of combined indicator-based tests reflects the multidimensional nature of critical thinking, encompassing interpretation, analysis, evaluation, inference, explanation, and self-regulation. High levels of reliability, content validity, and inter-rater agreement reported across studies indicate that the measurement approaches employed possess sufficient psychometric quality to support valid conclusions regarding learning effectiveness.

Collectively, these findings extend constructivist learning frameworks by demonstrating that the pedagogical synergy between mobile learning and socio-scientific issues creates favorable conditions for fostering higher-order thinking skills from the elementary education level, challenging the traditional view that such skills are primarily developed in higher education. From a practical perspective, the results suggest that educators should prioritize the selection of accessible mobile platforms aligned with local technological contexts, the integration of authentic and locally relevant socio-scientific issues, and the implementation of Problem-Based Learning models supported by gradual scaffolding tailored to students' developmental needs (Masing & Aminatun, 2022; Anwar et al., 2024). In the Indonesian education context, effective and sustainable implementation further requires systematic investment in technological infrastructure and continuous enhancement of teachers' digital competencies to maximize the transformative potential of socio-scientific issues-oriented mobile learning (Nasution et al., 2023).

E. Implication

Theoretically, the findings of this systematic review extend constructivist learning frameworks by highlighting the pedagogical synergy between mobile learning and socio-scientific issues as a promising approach for facilitating higher-order thinking skills from the elementary education level. The integration of technology-enhanced learning environments with authentic, problem-oriented socio-scientific contexts supports active knowledge construction, multi-perspective reasoning, and reflective Inquiry, which are central principles of constructivist pedagogy. These findings challenge the traditional assumption that the development of complex cognitive skills is predominantly reserved for secondary or higher education and instead suggest that, with appropriate instructional design and scaffolding, elementary school students can engage in higher-level cognitive processes.

From a practical perspective, the results indicate that educators should prioritize the use of accessible mobile platforms, particularly Android-based applications, to ensure broad and equitable access to learning. The integration of authentic, locally relevant socio-scientific issues, such as environmental pollution and food waste management, is essential to creating meaningful learning contexts that resonate with students' lived experiences. In addition, the implementation of Problem-Based Learning models supported by gradual, developmentally appropriate scaffolding is recommended to accommodate the cognitive characteristics of elementary learners and effectively foster critical thinking skills within mobile learning environments.

In terms of policy implications, the findings underscore the urgency of strengthening technological infrastructure in elementary education settings to support sustainable implementation of mobile learning. Furthermore, systematic professional development programs focused on enhancing teachers' digital competencies are necessary to ensure effective pedagogical integration of technology and socio-scientific issues. At the curriculum level, these results suggest the need for policy initiatives that accommodate technology-

based, socio-scientific issues-oriented learning within national education frameworks, thereby supporting the systematic development of critical thinking skills from the early stages of formal education.

F. Limitation and Suggestion for Further Research

Despite the contributions of this systematic review, several methodological limitations should be acknowledged. First, the reviewed studies were predominantly conducted within the Indonesian educational context, accounting for approximately 90% of the analyzed literature. This geographical concentration may limit the generalizability of the findings to international or cross-cultural settings with different technological infrastructures, curricular frameworks, and socio-cultural characteristics. Second, a substantial proportion of the included studies employed Research and Development designs (approximately 40%), which, while valuable for exploring instructional feasibility and design effectiveness, provide limited causal evidence compared to experimental or randomized controlled research designs. As a result, the strength of causal inferences regarding the impact of socio-scientific issues-oriented mobile learning on critical thinking development remains constrained. Third, the publication time frame of 2021–2025, although relevant to post-pandemic educational transformations, may have excluded earlier foundational studies that could offer additional theoretical or methodological insights.

Based on these limitations, several directions for future research are recommended. Future studies should adopt experimental and longitudinal research designs to examine the long-term retention and transfer of critical thinking skills fostered through socio-scientific issues-oriented mobile learning. In addition, the development of comprehensive, authentic assessment instruments grounded in technology-enhanced assessment frameworks is needed to capture the multifaceted nature of critical thinking more accurately. Further research may also explore underlying cognitive mechanisms through methods such as think-aloud protocols and eye-tracking analysis to better understand students' reasoning processes during learning activities. Finally, investigating the moderating effects of demographic variables, including socio-economic status, digital literacy, and prior knowledge, would provide deeper insights into the conditions under which socio-scientific issues-oriented mobile learning is most effective, thereby supporting more inclusive and equitable instructional design.

G. Conclusion

This systematic literature review addresses fundamental questions regarding the implementation patterns and instructional design characteristics of socio-scientific issues-oriented mobile learning in elementary science education. The synthesis of 10 empirical studies demonstrates a consistent tendency: integrating mobile learning with socio-scientific issues supports the development of elementary school students' critical thinking skills with moderate to high effectiveness. These findings indicate that technology-enhanced learning environments, when grounded in authentic and socially relevant scientific issues, provide

meaningful opportunities for students to engage in higher-order cognitive processes from the early stages of formal education.

The review further reveals that effective implementation is closely associated with specific pedagogical and design characteristics. Problem-Based Learning and Guided Inquiry emerge as dominant instructional models, supported by gradual scaffolding that aligns with the cognitive development of elementary learners. In terms of technological design, the use of interactive multimedia, formative assessment features, and predominantly Android-based platforms facilitates flexible and accessible learning experiences. Socio-scientific issues with strong local relevance, such as environmental pollution, food waste management, and ecosystem conservation, serve as authentic learning contexts that stimulate multi-perspective analysis and evidence-based reasoning.

Theoretically, this study extends constructivist learning perspectives by demonstrating the pedagogical synergy between mobile learning and socio-scientific issues in fostering higher-order thinking skills at the elementary education level. In practice, the findings provide educators and instructional designers with evidence-based insights for developing pedagogically sound, developmentally appropriate mobile learning environments. Overall, this review underscores the potential of socio-scientific issues-oriented mobile learning as an innovative strategy for enhancing critical thinking in elementary science education and offers a foundation for future research and practice in technology-enhanced learning.

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