Android-Based Media for Enhancing Critical Thinking in Elementary Science: A Systematic Review

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Abstract: The rapid advancement of information technology has accelerated innovation in learning media, particularly in elementary science education where developing higher-order thinking is critical. This PRISMA-guided systematic literature review examines the effectiveness of Android-based learning media in enhancing elementary students' critical thinking. Twenty-five peer-reviewed articles published between 2020 and 2025 were selected from Google Scholar, SINTA, and Scopus. Included studies comprised quantitative, qualitative, and mixed methods designs and were appraised for quality. Findings show that Android-based media, including educational games, interactive multimedia, augmented reality applications, and e-modules generally improve engagement and learning outcomes. However, only about one third of the studies explicitly measured critical thinking indicators such as analysis, evaluation, and problem solving, revealing a persistent gap between technological innovation and cognitive assessment. The review highlights pedagogical integration, offline access, and teacher readiness as key factors. Overall, Android-based media present a flexible, accessible option for 21st-century elementary science education with implications for instructional design, policy, and future research.

Abstrak: Perkembangan teknologi informasi yang pesat mendorong inovasi media pembelajaran, khususnya pada pembelajaran IPA di sekolah dasar. Studi tinjauan pustaka sistematis ini bertujuan menganalisis efektivitas media pembelajaran berbasis Android dalam meningkatkan keterampilan berpikir kritis peserta didik. Sebanyak 25 artikel nasional dan internasional yang diterbitkan pada periode 2020–2025 ditelaah, dengan sumber dari Google Scholar, SINTA, dan Scopus. Kajian ini mengikuti prosedur Systematic Literature Review (SLR) berbasis PRISMA untuk mengidentifikasi, mengevaluasi, dan mensintesis bukti empiris yang relevan. Hasil kajian menunjukkan bahwa media berbasis Android seperti permainan edukatif, video interaktif, dan e-modul secara konsisten berkontribusi terhadap peningkatan keterampilan berpikir kritis. Sekitar sepertiga artikel secara eksplisit mengukur indikator berpikir kritis seperti analisis, evaluasi, dan pemecahan masalah. Media ini juga meningkatkan keterlibatan belajar serta menyediakan lingkungan belajar yang fleksibel dan mudah diakses. Secara keseluruhan, media berbasis Android merupakan alternatif yang efektif dan relevan untuk pembelajaran IPA abad ke-21 di sekolah dasar serta memberikan implikasi praktis bagi pengembangan inovasi pendidikan ke depan.

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A. Introduction

21st-century education requires a paradigm shift from the mastery of factual knowledge to the development of higher-order thinking and essential life skills. In the global educational context, competencies such as critical thinking, creativity, communication, and collaboration (4C) are recognized as foundational skills that enable students to navigate increasingly complex scientific, technological, and social environments. Among these competencies, critical thinking has become a central focus because it equips learners to analyse information, make evidence-based judgments, and solve authentic problems encountered in daily life.

However, empirical findings indicate that elementary students' critical thinking skills remain low. Recent national and international studies (Kurniawati & Mawardi, 2021) report that science learning remains dominated by teacher-centred instruction, textbook dependence, and memorization-oriented assessments. These practices limit students' opportunities to explore, reason, and apply scientific concepts through inquiry. In classroom practice, many students struggle to interpret data, evaluate claims, or relate scientific ideas to real-world contexts. This problem highlights an urgent need for more interactive, student-centred learning approaches supported by innovative digital media.

Android-based learning media have emerged as a promising solution. The widespread availability of smartphones and the flexibility of mobile applications enable the integration of text, visuals, audio, animation, and interactive simulations on a single platform. Recent studies highlight their potential to support inquiry-based learning by enhancing engagement, visualization, and conceptual understanding (Cheng, 2023). In Indonesian elementary schools, research by Muttaqin et al (2021) and Hasanah et al (2022) has demonstrated that Android-based applications can enhance learning motivation. Furthermore, studies by Herlianus & Gunadi (2022), Isrokatun et al (2023), Permatasari & Hasanah (2025) confirm that these media significantly improve students' mastery of science concepts and facilitate flexible learning environments.

Despite these positive indications, a significant research gap remains. Most existing studies focus on general learning outcomes, such as motivation, conceptual understanding, or learning achievement while systematic examination of the effects of Android-based media on *critical thinking* is limited. Few studies explicitly analyze how digital mobile platforms support cognitive processes such as reasoning, inference, evaluation, and problem-solving. Moreover, prior reviews tend to discuss digital learning tools broadly, without specifically synthesizing empirical evidence on Android-based media in elementary science education.

To address this gap, the present study conducts a Systematic Literature Review (SLR) guided by PRISMA to analyze empirical findings from 25 peer-reviewed journal articles published between 2020 and 2025. This review examines how Android-based learning media are designed, implemented, and evaluated in relation to students' critical thinking skills.

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The novelty of this study lies in providing the first systematic, PRISMA-guided synthesis focused explicitly on the impact of Android-based learning media on the critical thinking skills of elementary science students. Unlike previous reviews that emphasize general digital learning or academic achievement, this review focuses on higher-order thinking processes. It maps the strengths, limitations, and research trends over the last five years.

The research question guiding this review asks whether Android-based learning media effectively enhance elementary students' critical thinking skills, which types of Android media are commonly used and how their design and features support critical thinking dimensions such as analysis, evaluation, inference, and problem solving, and to what extent Android-based implementations outperform conventional instructional approaches in elementary science classrooms. The general objective of the study is to systematically analyze the influence of Android-based learning media on the development of critical thinking in elementary science education. Operationally, the study aims to map the types and key characteristics of Android-based media deployed in primary science lessons, examine which critical thinking indicators are defined and measured and the validity of the instruments used, assess effectiveness relative to traditional methods using available metrics such as N-Gain and effect sizes, identify enabling and constraining factors including pedagogical integration, teacher readiness, infrastructure, and offline accessibility, and derive evidence-based recommendations for instructional design and policy to support the deliberate development of higher-order thinking through Android-based educational tools.

B. Method

This study employed a Systematic Literature Review (SLR) research design to identify, evaluate, and synthesise empirical findings on the effectiveness of Android-based learning media in enhancing critical thinking skills in elementary science education. The SLR approach was selected because it provides a structured, transparent, and replicable procedure for summarising existing evidence. The review protocol followed the PRISMA 2020 guidelines and was preregistered on the Open Science Framework (OSF) to ensure methodological rigour. The central research question guiding this review was: *"How effective are Android-based learning media in improving students' critical thinking skills in elementary science education?"* This central question was further elaborated into three sub-questions: the types of Android-based media used, their influence on critical thinking dimensions such as analysis, evaluation, and inference, and their effectiveness compared with conventional instructional approaches. In an SLR, the "participants" refer not to individuals but to the set of empirical studies included in the review. A total of 25 articles met the eligibility criteria, including studies involving elementary school students (grades 1–6), science learning content, Android-based learning media as the primary intervention, and outcomes related to critical or higher-order thinking skills. The studies were published between 2020 and 2025

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in peer-reviewed national (SINTA) and international (Scopus/DOAJ) journals, written in English or Indonesian, and available in full text.

The review applied both inclusion and exclusion criteria to ensure the relevance and quality of the selected studies. The inclusion criteria consisted of empirical studies using quantitative, qualitative, or mixed-methods designs; research involving Android-based learning media in elementary science education; and studies that measured critical thinking or science performance outcomes. Exclusion criteria included non-empirical articles (e.g., reviews or editorials), studies not involving Android media, research with participants outside the elementary school level, and articles with inaccessible full texts. The literature search was conducted from February to March 2025 across Scopus, DOAJ, SINTA, Google Scholar, and ResearchGate using Boolean search strings related to Android-based learning media, science education, critical thinking, and elementary schooling. Search syntax was adapted to each database, and only peer-reviewed journal articles from Google Scholar and ResearchGate were retained. Study selection followed the four PRISMA stages identification, screening, eligibility, and inclusion, performed independently by two reviewers. Interrater reliability was assessed using Cohen's Kappa, and disagreements were resolved through discussion or consultation with a third reviewer.

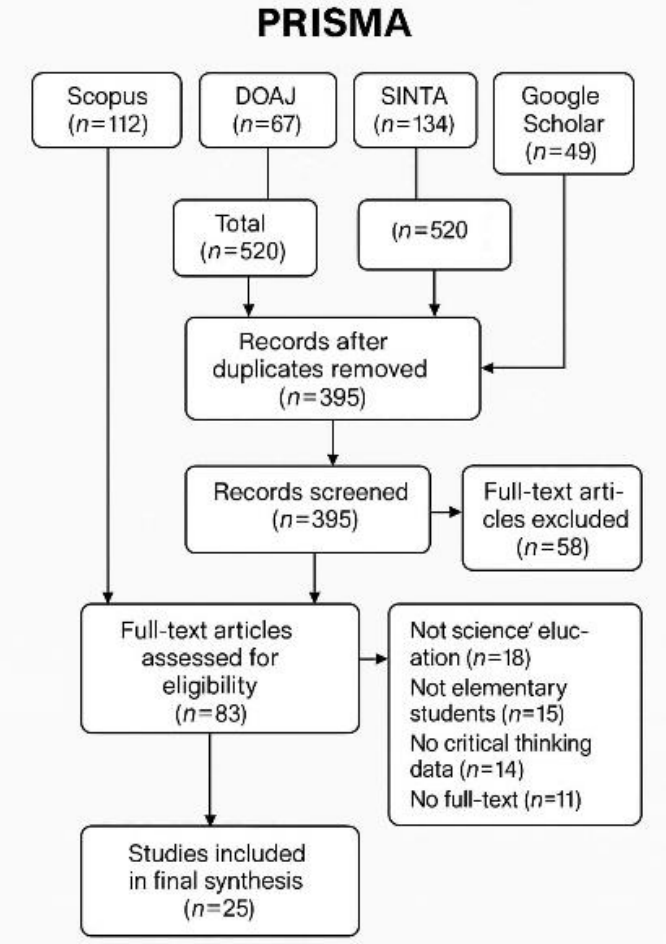

Figure 1. PRISMA 2020 Flow Diagram of the Study Selection Process

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Quality appraisal was conducted using the Mixed Methods Appraisal Tool (MMAT) 2018, and only studies scoring at least 60% were included to ensure adequate methodological robustness. Data extraction captured information such as authors, publication year, research objectives, study design, sample characteristics, types of Android-based media, critical thinking indicators, learning outcomes, and effectiveness results. Qualitative data were analysed thematically using the six-phase framework of Braun & Clarke (2006), which includes familiarisation, coding, theme development, theme review, theme definition, and reporting. Quantitative findings were analysed using Hake's N-Gain formula, and effect sizes (e.g., Cohen's d)

The values were calculated when the data allowed cross-study comparability. For example, a study reporting a pretest score of 45, a post-test score of 80, and a maximum score of 100 yields an N-Gain of 0.64, categorised as a high level of improvement. To ensure validity and reliability, the study employed reviewer triangulation, maintained an audit trail to document all analytical decisions, used both narrative and tabular data displays, and incorporated peer debriefing sessions to enhance interpretive accuracy. Potential publication bias was acknowledged due to the reliance on peer-reviewed journal articles.

C. Result

A systematic review of 25 journals published between 2020 and 2025 indicates that the use of Android-based learning media in elementary school science education is becoming increasingly widespread. Various forms of media, including interactive applications, e-modules, educational games, and Augmented Reality-based multimedia, have been utilised in the reviewed studies. The following are the main findings from the analysis of the reviewed journals:

1. Media Development Model: 72% of the learning media used in this study were developed using the ADDIE model. The rest used the ASSURE, Borg & Gall, or other modified models.

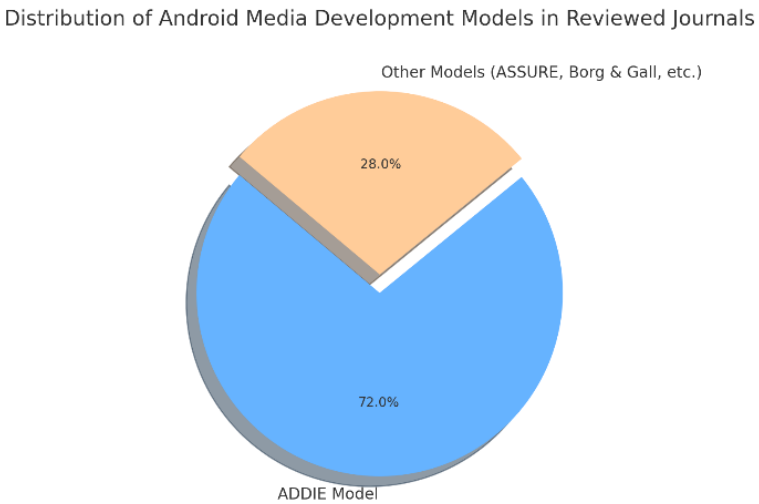

Figure 2. Distribution of Android Media Development Models in Reviewed Journals (Source: Analysis of 25 Journals Published between 2020-2025)

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2. Measurement of Learning Outcomes and Critical Thinking Skills: 60% of articles explicitly reported improvements in student learning outcomes after using Android-based media. However, only 36% of articles directly measured or discussed students' critical thinking skills.

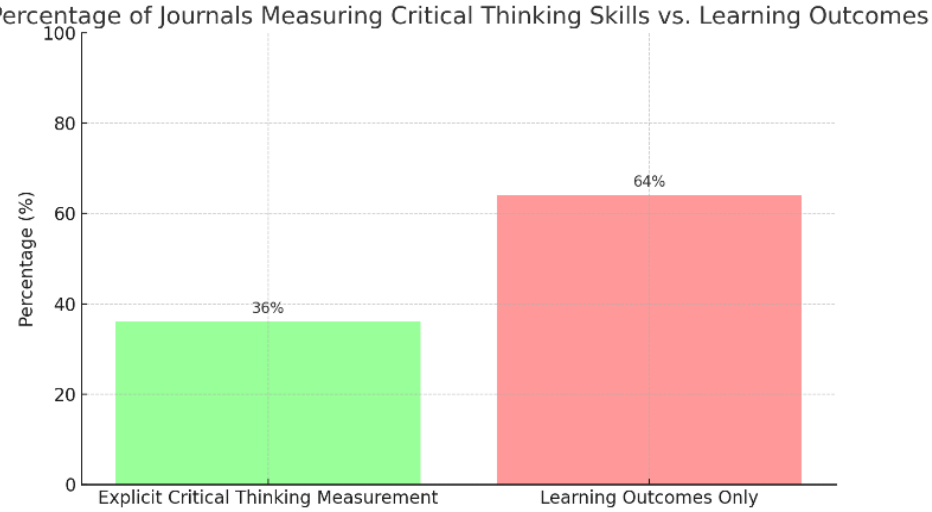

Figure 3. Percentage of Journals Measuring Critical Thinking Skills vs Learning Outcome (Source: Analysis of 25 Journals Published between 2020-2025)

3. Type of Media Used: Media that emphasise high interactivity and visualisation, such as Augmented Reality (AR) and educational games, are more effective at stimulating students' reflection, exploration, and problem-solving skills.
4. Research on Improving Critical Thinking: Some studies, such as those by Elisabeth & Mawardi (2021), Yulianti & Herpratiwi (2022), and Yayat & Febriyani (2024), demonstrate significant improvements in students' critical thinking skills through the use of Android-based media.
5. Commonly Used Aspects of Critical Thinking: The most commonly used aspects of critical thinking in these studies include focus, supporting reasons, organisation, and the evaluation of arguments, which are usually based on the Zubaidah et al (2015) framework or its adaptations.
6. Teacher's Role as Mediator: Most journals emphasise the teacher's important role as a mediator in the use of learning media. The effectiveness of the media is greatly influenced by interface design, offline accessibility, and ease of use in the context of classroom learning.

The review identified several effective media formats contributing to these results. Educational games (Anggraeni et al., 2023; Damarjati & Miatun, 2021) and interactive multimedia (Fahruji et al., 2022; Manggala et al., 2023; Nursalimah & Sutisna, 2024; Renggani et al., 2023) have shown positive impacts on student engagement. Furthermore, the implementation of e-modules and e-magazines (Dermawan et al., 2025; Febriyana et al., 2022; Rohmah et al., 2020), as well as augmented reality technologies (Rosyid & Setyasto, 2024; Syawaludin et al., 2019), has been consistently associated with the enhancement of

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critical thinking abilities (Roslina et al., 2024; Susanto & Hapudin, 2024; Zuryanty et al., 2023).

Table 1. Summary of Findings from 25 Journals

No.	Research Title (Focus)	Media/Application (Platform)	Subjects (Grade/Count)	Key Findings
1	Development of Interactive Learning Media	Smart Apps Creator (SAC)	4th Grade (n=32)	Valid, practical, effective.
2	Android-Based Earth Change Learning Media	Android-based app	5th Grade (n=62)	Valid, improved critical thinking.
3	Android-Based WUZARU Media for Science Learning	WUZARU app	4th Grade	Significant improvement (90.36 avg. post-test).
4	Android-Based Dilan E-Module (Didroid)	Dilan E-Module	Elementary Students	Valid, practical, media score 100%.
5	Android-Based AR Learning Media on the Respiratory System	AR app	5th Grade (n=27)	Very feasible, improved outcomes (N-Gain 0.73).
6	Android-Based Learning Media for Musculoskeletal Systems	Kodular app	5th Grade	Increased enthusiasm and comprehension.
7	Interactive IPAS Learning Media	Smart Apps Creator	4th Grade (n=32)	Valid, practical, effective.
8	Improving Critical Thinking Through the ABSA Water Cycle App	Water Cycle App (ABSA)	5th Grade (n=34)	Improved critical thinking (Cycle 2: 76%).
9	Appy Pie Interactive Learning Media for Ecosystem Balance	Appy Pie Mobile Learning	5th Grade (n=6)	Very feasible, effective (N-Gain 0.701).
10	Android-Based Interactive Learning Media for Animal Reproduction	Android media	6th Grade	Valid, practical.
11	iSpring Suite 9 Android Media for Science Learning	iSpring Suite 9	5th Grade	Valid, very practical.
12	Android-Based Learning on the Water Cycle	Android media	5th Grade	Excellent, expert review 95.59%.
13	SETS-Based Learning Module to Foster Critical Thinking	SETS module	Elementary Students	Valid, increased critical thinking.
14	AR-Based Interactive Multimedia for Critical Thinking	AR Multimedia	Teacher Ed. Students	Improved critical thinking.

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No.	Research Title (Focus)	Media/Application (Platform)	Subjects (Grade/Count)	Key Findings
15	Online Media for Critical Thinking in Primary Schools	Online Media	Primary School Students (n=98)	Improved critical thinking.
16	Android-Based Learning Media for Critical Thinking	Android media	Elementary students	Enhanced interactivity and independent learning.
17	Android Mobile App for Critical Thinking Practice	Android App	3rd Grade	Includes analysis and questioning steps.
18	"Perjalanan Si Maya" Educational Game for Critical Thinking	"Perjalanan Si Maya" game	Elementary Students	Improves critical thinking and interest.
19	Wismaya Inquiry-Based Android Game for Critical Thinking	Wismaya inquiry game	4th Grade	Valid, 94% mastery, N-Gain 59.34%.
20	Android-Based "Klanimal" Media for Animal Classification	Klanimal media	5th & 6th Grade	High suitability, N-Gain 0.70.
21	Android-Based Science Learning Media for Critical Thinking (COVID-19)	Android scientific media	Primary school children	Effective for improving critical thinking during the pandemic.
22	Android-Based Educational Game for Critical Thinking	Educational game	Elementary students	Valid, improves critical thinking.
23	Improving Critical Thinking with Interactive E-Modules	Interactive E-modules	Elementary students	Enhanced critical thinking ability.
24	Android-Based E-Magazine for 5th Grade Learning	Android-based e-magazine	5th Grade	Media validity 95%, material 100%.
25	Android-Based Learning Media for Critical Thinking	Android learning media	Prospective teachers	Valid, necessary for learning complex materials.

D. Discussion

Generally, the use of Android-based learning media in elementary science education offers notable benefits, including increased student engagement, enhanced visualisation of abstract scientific concepts, and greater opportunities for independent learning. These results reinforce the theoretical perspectives of Jonassen (1999) and Mayer (2005), who argue that technology-supported environments enable meaningful, constructivist learning. However, this review also highlights several limitations and challenges that must be addressed to maximise the potential of Android-based media, particularly in enhancing students' critical thinking skills.

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The review of existing literature reveals several important insights regarding the integration of Android-based learning media and the development of critical thinking skills. First, the majority of studies demonstrate that Android-based media predominantly emphasise content delivery and conceptual explanation rather than systematically supporting higher-order thinking. Although many reported improvements in general learning outcomes, only 36% directly measured critical thinking, and an even smaller proportion embedded structured higher-order thinking tasks into their media design. This trend suggests that critical thinking is often treated as an indirect or secondary outcome. Furthermore, several studies, such as articles 1, 7, and 11 in Table 1, reported only moderate gains or no significant improvements in critical thinking, reinforcing the view that digital media alone cannot ensure the development of complex cognitive skills. These results are consistent with theoretical arguments asserting that critical thinking is shaped more by pedagogical approaches than by technology tools. Consequently, Android-based media should be intentionally designed to incorporate analytical questions, reflective prompts, problem-solving scenarios, and open-ended tasks that meaningfully scaffold students' higher-order thinking.

Second, the effectiveness of Android-based learning media is markedly enhanced when supported by strong pedagogical models. Studies by Mirfaka et al (2023) and Asani et al (2023) illustrate that media integration is vital. Additionally, Gianistika et al (2022) emphasize that when media are integrated into inquiry-oriented or real-world problem-solving contexts, students develop stronger analytical and evaluative thinking. In contrast, studies that employ Android media without robust pedagogical integration generally report limited improvements in critical thinking, suggesting that technology is not inherently transformative. This reinforces the argument that pedagogy rather than the device or software is the primary driver of higher-order cognitive development. Therefore, the design and application of Android-based media should be aligned with inquiry-driven, problem-based, or project-based learning frameworks to foster deeper cognitive engagement and promote meaningful learning.

Third, despite the promising potential of Android-based media, sustaining their practical implementation in actual classroom settings remains a significant challenge, especially within the Indonesian context. Several studies highlight persistent obstacles, including limited digital infrastructure, such as unstable internet connectivity, insufficient school-owned devices, and unequal access to student smartphones—along with issues related to teacher readiness, such as low digital literacy, limited ability to manage technology-rich learning environments, and uncertainty in aligning digital tools with curriculum expectations. Additionally, technical constraints, such as application bugs, the lack of offline functionality, and compatibility issues, further hinder the consistent use of Android-based media in schools. Collectively, these findings indicate that technological innovation must be accompanied by systemic support, adequate infrastructure, and sustained teacher professional development to ensure that Android-based learning media can genuinely contribute to the cultivation of students' critical thinking skills.

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Some reviewed studies reported minimal or inconsistent impacts due to these barriers, showing that the effectiveness of Android media is highly dependent on external factors. This finding is consistent with those from Indonesian educational technology research, which highlights the digital divide between urban and rural schools.

To improve sustainability, continuous professional development programs for teachers, investment in school infrastructure, and the development of lightweight, offline-friendly Android media are essential. Policies promoting equitable access to digital resources should also support the long-term integration of technology at the elementary level.

E. Implication

The findings of this study make significant contributions to the fields of science education and educational technology, particularly in the context of elementary school learning. This systematic review reinforces the understanding that Android-based learning media—when thoughtfully designed and pedagogically aligned can effectively enhance student engagement, foster comprehension of scientific concepts, and support the development of critical thinking skills.

More specifically, this study underscores the importance of embedding higher-order thinking tasks within digital learning environments to promote analysis, evaluation, and reflection; integrating Android-based media with constructivist and inquiry-oriented teaching models such as Project-Based Learning (PjBL) and Inquiry-Based Learning to maximise cognitive engagement; and recognising the teacher's role as a central mediator whose pedagogical decisions determine the extent to which mobile learning tools support meaningful cognitive growth. In addition to these pedagogical implications, the findings also highlight several policy implications for educational authorities and school administrators. Given the persistent gaps in digital infrastructure and teacher readiness, particularly in many Indonesian elementary schools, this study recommends that local and national education offices (Dinas Pendidikan and Kemenag) invest in strengthening ICT infrastructure to ensure the consistent implementation of Android-based learning media across diverse school contexts; expand professional development programs to include continuous training on mobile learning integration, digital pedagogy, and the design of technology-enhanced activities that cultivate critical thinking; encourage collaboration between policymakers, universities, and educational developers to produce Android-based media that are equitable, offline-friendly, and aligned with curriculum standards; and establish quality standards or guidelines to ensure that digital learning products for elementary students incorporate explicit critical thinking components rather than merely offering interactive content. This study also identifies a notable gap in the existing literature: most Android-based learning media prioritise content delivery over the deliberate cultivation of critical thinking. Therefore, future research and development efforts should move beyond usability and interactivity toward creating digital learning tools that require deeper cognitive engagement. In summary, this review provides empirical evidence for the

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transformative potential of Android-based learning media in elementary science education, offering actionable insights for enhancing media design, classroom implementation, and educational policy. It also encourages future investigations into the long-term cognitive effects of Android-based media across diverse school settings and varied pedagogical frameworks.

F. Limitation and Suggestion for Further Research

This study has several limitations. First, the review includes only 25 articles published between 2020 and 2025, which may not fully represent the broader research landscape on Android-based learning media in science education. Second, the wide variation in research designs, sample sizes, and assessment methods reduces comparability across studies and limits the possibility of conducting a meta-analysis. Third, most studies examined short-term outcomes, providing limited insight into the long-term development of students' critical thinking skills. Finally, publication bias may be present, as studies with positive findings tend to be published more frequently than those reporting neutral or adverse effects.

To strengthen future research, several directions are recommended. First, studies should explicitly integrate clear indicators of critical thinking into the design of Android-based learning media and employ valid, reliable instruments to measure their impact. Interactive case studies, problem-based simulations, and information-evaluation tasks can be incorporated to support the development of these skills. Second, longitudinal research is needed to examine the sustained effects of Android-based media on students' critical thinking and science learning, including their progress across grade levels. Third, future studies should explore how different teacher-training models enhance educators' ability to effectively integrate Android-based learning media, particularly in promoting critical thinking during instruction. Fourth, broader research across diverse educational and cultural contexts is necessary to understand how infrastructure, curriculum conditions, teacher readiness, and student characteristics influence the effectiveness of Android-based learning media. By addressing these gaps, future studies can contribute to the more effective development and implementation of Android-based learning media that meaningfully support elementary students' critical thinking skills.

G. Conclusion

This systematic review of 25 journals highlights the significant potential of Android-based learning media in primary school science education, particularly in increasing student engagement, improving understanding of abstract concepts, and promoting self-directed learning. However, the analysis also reveals a critical gap, students' critical thinking skills have not been optimally developed. Although many studies report improved learning outcomes, most Android-based applications have not been designed to nurture analytical, evaluative, and reflective abilities systematically.

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The findings indicate that the most effective applications are those that incorporate interactive features, such as Augmented Reality, inquiry-driven quizzes, and game-based problem-solving elements that encourage deeper reasoning. Moreover, integrating these technologies into skill-oriented pedagogical models, such as STEM-integrated Project-Based Learning (PjBL-STEM), yields a greater impact in fostering students' critical thinking.

In conclusion, Android-based learning media present promising opportunities to advance science learning in elementary education. This study reinforces the urgency of integrating Android-based learning media into pedagogical frameworks that explicitly target the development of critical thinking, providing evidence-based direction for future research and design innovations in this field.

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