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The Impact of Digital Literacy Integration on Critical Thinking Skills in Secondary School Students: A Quasi-Experimental Study

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ABSTRACT
The rapid digitalization of education demands the integration of digital literacy into instruction, yet empirical evidence on its effect on higher-order thinking in Indonesian secondary schools remains scarce. This quasi-experimental study examined the impact of systematic digital literacy integration on students' critical thinking skills. A total of 128 eleventh-grade students from two public senior high schools in West Sumatra participated, assigned to an experimental group (n=64) receiving technology-enhanced, inquiry-based learning with embedded digital literacy activities and a control group (n=64) following conventional instruction. Critical thinking was measured using an adapted Cornell Critical Thinking Test Level X before and after a 10-week intervention. Analysis of covariance, controlling for pretest scores and prior digital access, revealed a significant large effect of the intervention ($F(1,124)=127.84$, $p<.001$, partial $\eta^2=.508$). The experimental group's adjusted posttest mean ($M=63.28$, $SE=0.61$) substantially exceeded that of the control group ($M=52.14$, $SE=0.61$). The subscale analysis indicated significant improvements in induction, deduction, evaluation, and inference. Effect sizes ranged from Cohen's $d=1.42$ for the total score to $d=0.94$ for the evaluation. These findings demonstrate that deliberate integration of digital literacy can robustly enhance secondary students' critical thinking, offering a scalable, evidence-based model for 21st-century curriculum reform in Indonesia

Keywords: *Digital Literacy Integration, Critical Thinking, Quasi-Experimental*

I. INTRODUCTION
The twenty-first-century educational landscape has been profoundly reshaped by the ubiquity of digital technologies. In Indonesia, the national education system is undergoing a significant transformation through the implementation of the Kurikulum Merdeka (Emancipated Curriculum), which emphasizes competency-based learning, student-centered pedagogies, and the strengthening of the Pancasila Student Profile. Central to this profile is the dimension of critical thinking, articulated as the capacity to process information, evaluate ideas, and make reflective decisions. Concurrently, the Ministry of Education, Culture, Research, and Technology has accelerated the digitalization of schools, distributing ICT infrastructure and promoting the integration of technology across subjects. These dual imperatives create a pressing need to understand whether and how digital literacy the ability to access, manage, evaluate, and create information using digital tools can serve as a catalyst for developing critical thinking skills among secondary school students (Suryani and Sit 2025).

Despite policy-level enthusiasm, classroom practices in many Indonesian secondary schools remain dominated by teacher-centered, content-transmission approaches. A typical learning sequence begins with the teacher explaining concepts using PowerPoint slides or a whiteboard, followed by students completing worksheets that emphasize factual recall. Digital devices, if present, are often limited to projecting static materials or searching for information without structured pedagogical scaffolding. This surface-level technology use does not automatically translate into higher-order thinking. As Alfionita, et al. (2025) argue, the mere presence of technology does not guarantee the development of 21st-century competencies; rather, it is the deliberate design of learning activities that integrate technology in cognitively demanding ways that makes the difference. This gap between the availability of digital tools and their transformative pedagogical use constitutes a critical problem in Indonesian education, risking the squandering of substantial public investment in digital infrastructure (Alfionita, Apriani, and Reta 2025).

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Digital literacy, as conceptualized by Faizhal, et al. (2025), encompasses three interconnected dimensions: technical (operational skills), cognitive (critical evaluation and creation of information), and social-emotional (responsible online communication). When integrated meaningfully into instruction, digital literacy moves beyond teaching students how to use software and devices. It entails engaging learners in authentic tasks such as evaluating the credibility of online sources, synthesizing information from multiple digital modalities, constructing evidence-based digital arguments, and collaborating in virtual environments. These activities inherently demand the cognitive operations that define critical thinking: analysis, evaluation, inference, explanation, and self-regulation (Faizhal et al. 2025). Thus, there is a strong theoretical alignment between digital literacy integration and critical thinking development. However, empirical validation of this relationship in the Indonesian secondary school context is still in its infancy. Most existing studies are either correlational, small-scale qualitative inquiries, or conducted in Western higher education settings, limiting their generalizability to Indonesian adolescents.

The present study addresses this gap by posing the central research question: To what extent does the systematic integration of digital literacy into subject instruction affect the critical thinking skills of Indonesian secondary school students? A quasi-experimental design was employed, involving an experimental group that received a ten-week intervention of technology-enhanced inquiry learning with embedded digital literacy scaffolds, and a control group that followed conventional instruction covering the same curricular content. By measuring critical thinking with a validated instrument adapted for the Indonesian context and analyzing data with robust statistical controls, this study aims to provide credible evidence for policymakers and practitioners (Khusnadin, Hariyanti, and Kadir 2025).

The significance of this study is manifold. First, at a theoretical level, it tests the proposition that digital literacy integration can act as a mediational tool for cognitive development, drawing on sociocultural perspectives that view technology as a cultural amplifier when used within guided, collaborative activity (Bainiashova 2025). Second, methodologically, the quasi-experimental approach responds to the call for more rigorous causal evidence in educational technology research, which has been criticized for an over-reliance on self-reported perceptions and correlational designs (Noviyanti, Mariana, and Wiryanto 2025). Third, practically, the findings can inform the design of professional development programs for Indonesian teachers, demonstrating how existing digital resources can be orchestrated to foster thinking rather than merely deliver content. The study is situated in the subject of Bahasa Indonesia (Indonesian language) for eleventh graders, a context where digital literacy integration is particularly relevant because the curriculum requires students to analyze expository and argumentative texts, evaluate information validity, and produce written arguments—objectives that align closely with both digital literacy and critical thinking.

Indonesia's geographical and socioeconomic diversity adds complexity to the digital literacy agenda. The participating schools in this study are typical urban public senior high schools in West Sumatra, equipped with computer laboratories and internet access but not yet routinely embedding technology into critical inquiry. Results from this context can serve as a benchmark for similar schools across the nation, while also highlighting areas where infrastructural and pedagogical support must be strengthened. Prior large-scale assessments, such as PISA 2018, revealed that only a small percentage of Indonesian 15-year-olds could perform at the highest proficiency levels in reading, which requires critical evaluation and reflection. Integrating digital literacy may offer a pathway to elevate these competencies, as digital environments are replete with claims, evidence, and arguments that demand critical scrutiny.However, without deliberate instructional design, students may merely skim digital texts superficially, reinforcing passive information consumption habits (Fantoni and Sasmita 2025).

The intervention designed for this study is grounded in the Synthesis of Digital Literacy and Inquiry model (Aboubacar Barry et al. 2025), which structures learning around four phases: (1) Questioning and planning students generate inquiry questions using digital mind-mapping tools; (2) Gathering and evaluating students locate online sources, assess credibility using a digital evaluation checklist, and annotate findings collaboratively; (3) Synthesizing and creating students construct multimodal digital arguments (e.g., infographics, short videos, podcasts) that integrate evidence; and (4) Reflecting and sharing students present their digital products, receive peer feedback via a learning management system, and write reflective journals. This model ensures that digital tools are not mere add-ons but are integral to the cognitive work of critical inquiry in the classroom. The control group covered the same content types of expository texts, argumentation structures, and rhetorical analysis but through conventional direct instruction, textbook-based exercises, and paper-and-pencil assessments.

The hypothesis guiding this study is that students in the experimental group will demonstrate significantly greater gains in critical thinking skills from pretest to posttest compared to the control group, after controlling for initial differences. The study also explores differential effects on critical thinking subskills induction,

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deduction, evaluation, and inference to identify which cognitive dimensions are most amenable to enhancement through digital literacy integration. Understanding these granular effects can enable the development of more targeted instructional strategies.

Beyond statistical significance, this study examined ts practical significance through effect size estimation. In educational intervention research, it is essential to determine not only whether an effect exists but also its magnitude and educational relevance (Kumari and Sharma 2025). By reporting both Cohen's d and partial eta-squared, this study provides a transparent picture of the intervention's impact. The results are expected to contribute to the growing international literature on digital literacy and to offer actionable insights for the Indonesian educational system as it navigates the post-pandemic landscape, where technology has become inextricably woven into the fabric of teaching and learning.

II. METHODS

A. *Research Design*

A quasi-experimental, pretest-posttest, nonequivalent control group design was used. Two intact classes from each of two public senior high schools (SMA Negeri) in Padang, West Sumatra, were assigned to either the experimental group (n=64) or the control group (n=64). The schools were purposively selected based on comparable infrastructure (computer lab with stable internet, LCD projectors) and the willingness of administrators and Bahasa Indonesia teachers to participate. Random assignment of individual students was not feasible due to school scheduling constraints; therefore, classes were randomly allocated to conditions at the school level. To mitigate selection threats, pretest scores and demographic variables were measured and used as covariates.

B. *Participants*

The sample comprised 128 eleventh-grade students from the science and social science tracks, aged 15–17 years (M=16.2, SD=0.6). The gender distribution was balanced (52.3% women). Inclusion criteria were regular enrollment in the chosen classes and consent from parents or guardians. Students with identified special educational needs (n=3) were excluded from the analysis because the standardized critical thinking test had not been validated for this population. Prior computer and internet experience was assessed via a self-report questionnaire; 91% of participants had access to a smartphone, and 78% had internet access at home, indicating a relatively high baseline digital access. No significant differences between groups were found in pretest critical thinking scores, age, gender, or prior digital access (all $p>.10$).

C. *Instrument*

Critical thinking was assessed using an adapted version of the Cornell Critical Thinking Test Level X (CCTT-X). The original 71-item multiple-choice test measures four subscales: Induction, Deduction, Evaluation, and Inference. For this study, the test was translated into Bahasa Indonesia and subjected to expert review by two educational psychologists and one Indonesian language expert to ensure linguistic and cultural appropriateness. A pilot test with 45 non-participating students yielded a KR-20 reliability coefficient of .82 for the total scale, with subscale reliabilities ranging from .68 (Evaluation) to .79 (Induction), deemed acceptable for research purposes. Items that showed poor discrimination indices (point-biserial correlation <.20) were revised. The final instrument comprised 60 items and was administered within 60 min. Pretest was conducted one week before the intervention; posttest used a parallel form with identical construct coverage but different item content to minimize practice effects.

D. *Intervention Procedures*

The intervention lasted 10 weeks, with two 90-minute Bahasa Indonesia sessions per week, totaling 20 sessions. Both groups followed the same basic curriculum outline from the Kurikulum Merdeka for Grade XI, covering expository texts, argumentation structures, and elements of rhetoric. The experimental group received instruction designed according to the Digital Literacy-Infused Inquiry (DLI) model (Author, 2021). Each session incorporated the four-phase cycle: (1) Question and Plan students used digital mind mapping (Miro) to formulate inquiry questions about a given topic, such as "Should social media usage be restricted for teenagers?"; (2) Gather and Evaluate students searched the web to collect evidence, applied the CRAAP (Currency, Relevance, Authority, Accuracy, Purpose) test using a shared digital checklist, and annotated sources in Google Docs; (3) Synthesize and Create groups of four created a multimodal argument (digital poster, 3-minute video, or podcast) that integrated at least three credible sources; (4) Reflect and Share students uploaded products to Google Classroom, engaged in structured peer feedback using a rubric emphasizing clarity and evidence quality, and wrote a reflective journal entry.

The teacher facilitated the process by modeling digital evaluation strategies (e.g., lateral reading), prompting Socratic questioning, and providing just-in-time technical assistance. Explicit digital literacy instruction occupied approximately 20% of the total instructional time, while the remaining 80% involved guided inquiry and content-related activities.

The control group received identical content through a conventional approach. The teacher delivered lectures supported by pre-designed slides, assigned textbook readings, and conducted whole-class discussions. Students completed individual worksheets that focused on comprehension questions and basic text analysis. Any technology use was limited to PowerPoint presentations and occasional unguided Internet searches. No explicit instructions on information evaluation or digital creation were provided.

Treatment fidelity was monitored through weekly observation by a research assistant who attended 30% of sessions in each condition using a standardized checklist. Fidelity scores averaged 94% for the experimental group and 97% for the control group, indicating high adherence.

E. *Data Analysis*

Data were analyzed using the SPSS version 26. Preliminary analyses included checking the assumptions of normality (Shapiro-Wilk), homogeneity of variance (Levene's test), and linearity for covariates. To test the main hypothesis, a one-way between-groups analysis of covariance (ANCOVA) was conducted, with posttest total critical thinking score as the dependent variable, group (experimental vs. control) as the independent variable, and pretest total score and prior digital access score as covariates. Prior digital access was a composite of home internet and device availability, included because of its known association with the development of digital literacy. Effect size was estimated using partial eta-squared (η^2p), and Cohen's d was calculated from adjusted means and pooled standard deviation.

Secondary analyses examined subscale differences via separate ANCOVAs for Induction, Deduction, Evaluation, and Inference, applying a Bonferroni-adjusted alpha level of .0125 to control for familywise error. Additionally, a repeated-measures ANOVA was performed to test the Time x Group interaction for each subscale, and gain scores were compared using independent-samples t-tests as a supplement. Data visualization included bar charts and line plots of the adjusted means.

F. *Ethical Considerations*

The study received ethical clearance from the Institutional Review Board of Universitas Negeri Padang (No. 234/UN35.1.28/KEP/2023). Written informed consent was obtained from the parents and assent from the students. Participation was voluntary, and students could withdraw at any time without any academic penalty. Anonymity was ensured by using coded identifiers. After the study, the control group received a condensed version of the digital literacy intervention to fulfill equity.

III. RESULTS AND DISCUSSION

A. *Preliminary Analyses*

Table 1 presents the descriptive statistics for the pre and posttest critical thinking scores. Before the intervention, the experimental (M=47.31, SD=8.23) and control groups (M=47.88, SD=8.55) showed nearly identical mean scores. An independent-samples t-test confirmed no significant difference ($t(126)=0.39$, $p=.698$, $d=0.07$). The distribution of pretest scores met normality assumptions (Shapiro-Wilk $p>.05$ for both groups), and Levene's test indicated homogeneity of variances ($F(1,126)=0.09$, $p=.761$). At posttest, the experimental group mean rose to 63.42 (SD=7.64), while the control group mean increased modestly to 52.25 (SD=8.12). The correlation between pretest and posttest scores was $r=.66$, $p<.001$, justifying the use of ANCOVA.

Table 1. Descriptive Statistics for Critical Thinking Scores by Group and Time

Measure	Experimental (n=64)			Control (n=64)		
	Pretest M(SD)	Posttest M(SD)	Gain	Pretest M(SD)	Posttest M(SD)	Gain
Total (60)	47.31 (8.23)	63.42 (7.64)	+16.11	47.88 (8.55)	52.25 (8.12)	+4.38
Induction (18)	14.16 (2.91)	16.81 (1.92)	+2.66	14.33 (3.12)	15.22 (2.45)	+0.89
Deduction (15)	11.83 (2.54)	13.67 (1.78)	+1.84	11.94 (2.61)	12.33 (2.21)	+0.39

Measure	Experimental (n=64)			Control (n=64)		
Evaluation (13)	9.45 (2.38)	11.97 (1.84)	+2.52	9.50 (2.41)	10.20 (2.15)	+0.70
Inference (14)	11.88 (2.57)	14.02 (2.01)	+2.14	12.11 (2.68)	12.94 (2.31)	+0.83

Table 1 reveals that both groups improved, but the experimental group's raw gain (+16.11) was more than three times that of the control group (+4.38). Notably, the largest subscale gains for the experimental group occurred in Induction and Evaluation, components directly practiced during the digital source evaluation and synthesis phases.

B. *Main Analysis: ANCOVA on Total Critical Thinking Score*

A one-way ANCOVA was used to examine the effect of the intervention on posttest total scores, controlling for pretest scores and prior digital access. Preliminary checks confirmed the homogeneity of regression slopes (interaction term $p=.312$) and linearity. Levene's test was non-significant, $F(1,126)=0.31$, $p=.581$. The ANCOVA results (Table 2) show a significant main effect of group, $F(1,124)=127.84$, $p<.001$, with a very large effect size (partial $\eta^2=.508$). The covariate pretest was also significant ($p<.001$), but prior digital access was not ($p=.413$), indicating that initial digital access did not confound the results.

Table 2. ANCOVA Summary for Posttest Total Critical Thinking Score

Source	SS	df	MS	F	p	η^2p
Pretest	2314.57	1	2314.57	88.02	<.001	.415
Digital Access	17.82	1	17.82	0.68	.413	.005
Group	3361.29	1	3361.29	127.84	<.001	.508
Error	3261.15	124	26.30			
Total	9038.42	127				

Adjusted posttest means, computed at the covariate grand mean of pretest=47.59 and digital access=3.12, are displayed in Figure 1. The experimental group's adjusted mean was 63.28 (SE=0.61) compared to 52.14 (SE=0.61) for the control group, a difference of 11.14 points on the 60-point scale. The effect size, expressed as Cohen's d, based on the adjusted means and pooled pretest standard deviation (8.39), was 1.33. When calculated using the pooled posttest SD (7.88), $d=1.42$, confirming a large effect size.

C. *Subscale Analyses*

To understand the differential effects, separate ANCOVAs were conducted for each subscale, with a Bonferroni-corrected alpha of .0125. The results are summarized in Table 3. All four subscales showed statistically significant differences favoring the experimental group after controlling for the respective pretest scores. Induction exhibited the largest effect size ($\eta^2p=.467$), followed by Inference ($\eta^2p=.384$), Deduction ($\eta^2p=.329$), and Evaluation ($\eta^2p=.284$). The adjusted mean differences ranged from 1.70 (Evaluation) to 2.76 (Induction).

Table 3. Summary of Subscale ANCOVA Results and Effect Sizes

Subscale	F(1,124)	p	η^2p	Adj. Mean Exp	Adj. Mean Ctrl	d
Induction	108.63	<.001	.467	16.84 (0.23)	14.08 (0.23)	1.27
Deduction	60.91	<.001	.329	13.69 (0.18)	12.11 (0.18)	0.96
Evaluation	49.18	<.001	.284	11.93 (0.20)	10.23 (0.20)	0.94

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Subscale	F(1,124)	p	η²p	Adj. Mean Exp	Adj. Mean Ctrl	d
Inference	77.24	<.001	.384	14.15 (0.22)	12.24 (0.22)	1.10

Note. All p-values were Bonferroni-adjusted within each subscale. Adj. Means presented with standard errors. d = Cohen's d based on the adjusted means and pooled posttest SD.

D. *Repeated Measures and Gain Score Analysis*

A 2 (Time) x 2 (Group) mixed ANOVA on total scores revealed a significant Time x Group interaction, $F(1,126)=225.41$, $p<.001$, $\eta^2p=.641$, confirming that the pattern of change differed across groups. Simple main effects showed that the experimental group improved significantly from pretest to posttest ($F(1,63)=414.12$, $p<.001$, $d=1.91$), while the control group's improvement was smaller but also significant ($F(1,63)=39.21$, $p<.001$, $d=0.52$). An independent-samples t-test on gain scores (posttest minus pretest) indicated a highly significant difference, $t(126)=14.82$, $p<.001$, $d=2.62$, with the experimental group gaining 11.73 points more than the control group.

E. *Additional Analysis by Gender and School*

To explore potential moderators, gender was added as a second independent variable in a 2×2 ANCOVA. Neither the main effect of gender ($p=.194$) nor the Gender x Group interaction ($p=.628$) was significant, indicating that the intervention worked equally well for male and female students. Similarly, a preliminary check of school effect using hierarchical linear modeling (not detailed due to only two clusters) showed that school-level intraclass correlation was <.01, supporting the use of ANCOVA at the individual level.

F. *Discussion*

The present study set out to examine the impact of deliberate digital literacy integration on secondary students' critical thinking skills in the Indonesian context. The findings provide robust evidence that a ten-week, technology-enhanced inquiry intervention can produce substantial gains in critical thinking, with a large effect size (partial $\eta^2=.508$, $d=1.42$) relative to conventional instruction. This section interprets these results in light of the theoretical frameworks and prior research, discusses the practical implications for Indonesian education, acknowledges limitations, and suggests future directions.

The magnitude of the effect observed in this study is considerably larger than those reported in many previous meta-analyses of educational technology interventions. Cheung and Slavin (2013) found an overall effect size of $d=0.16$ for technology's impact on student achievement in K-12 settings, and Abrami et al. (2015) reported an average $d=0.30$ for critical thinking instruction. Even within digital literacy-specific studies, Kong (2014) reported $d=0.63$ for a similar secondary school intervention. The larger effect observer in the present study may be attributable to several factors. First, the intervention was not merely technology-enhanced but technology-integrated in a manner that made digital literacy tasks the vehicle for critical inquiry. Students were not passive recipients of digital content; they actively created, evaluated, and critiqued digital arguments. This generative processing is known to produce deep learning (Alhajji 2024). Second, the sustained 20-session duration allowed for iterative practice and feedback, which is critical for developing complex cognitive skills (Fauzi, Jannah, and Fikri 2025). Third, the specific cultural and curricular alignment using Bahasa Indonesia textual analysis as the content anchor ensured ecological validity and intrinsic motivation, as students perceived the activities as directly relevant to their academic success.

The ANCOVA results, which controlled for pretests and prior digital access, strengthen the causal inference. The non-significance of prior digital access as a covariate suggests that the intervention's effect was not merely a function of students' pre-existing technology familiarity; rather, it was the structured pedagogical use of technology that mattered. This finding echoes Cui, et al. (2025), who argued that the digital divide is not only about access but also about usage students need scaffolded opportunities to use technology for cognitive empowerment (Cui et al. 2025).

The substantial gain observed in the control group ($d=0.52$) also deservesfurther discussion. Even conventional instruction, which involved some analytical writing and discussion, led to modest critical thinking improvement. This indicates that the Bahasa Indonesia curriculum inherently fosters analytical skills. However, the differential gain of more than 11 points on the CCTT-X scale underscores the added value of integrating digital literacy. In practical terms, the experimental group moved from a mean performance around the 40th percentile to approximately the 75th percentile on the test norms, a shift that represents a meaningful advancement in students' ability to evaluate arguments and draw reasoned conclusions.

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The subscale analysis revealed that all four dimensions Induction, Deduction, Evaluation, and Inference improved significantly, but Induction and Inference showed the largest effect sizes. Induction, which involves judging whether evidence supports a hypothesis, was heavily practiced during the "Gather and Evaluate" phase, where students applied the CRAAP framework to online sources. They had to decide whether a given piece of information strengthened or weakened their argument, which was an inductive reasoning task. The collaborative annotation and peer critique likely amplified this effect, as students had to articulate and defend their inductive judgments, making their reasoning visible and subject to refinement (Alicwadey and Lagawid 2025).

Inference, the ability to derive logical conclusions from given information, was central to the "Synthesize and Create" phase. When constructing a multimodal argument, students must integrate multiple pieces of evidence and present a coherent and logical conclusion. The iterative feedback loop receiving rubric-based peer critiques and revising products provided a metacognitive scaffold that strengthened their inferential skills. This aligns with Halpern (1998), who emphasized that critical thinking instruction must include opportunities for students to explain their reasoning and receive feedback on that reasoning.

Evaluation had a relatively smaller effect (d=0.94). One possible explanation is that credibility evaluation is a particularly challenging skill that requires extensive domain knowledge and a skeptical disposition. Wineburg and McGrew (2016) found that even university students struggle with lateral reading and often default to reliance on superficial website features. However, ten weeks may be insufficient to fully transform evaluation habits. Additionally, the Evaluation subscale of CCTT-X includes items that require distinguishing between observation and inference and assessing the reliability of observational statements skills that may be more detached from the internet-specific tasks practiced. Nevertheless, the significant improvement suggests that digital literacy integration does begin to build evaluative capacities.

Induction showed the highest effect, which may reflect the synergy between digital search activities and hypothesis evaluation. The digital environment provides an abundance of claims and counter-claims; the DLI model channeled students' natural curiosity into a structured process of evidence weighing, directly exercising induction. Educators seeking to maximize critical thinking gains might focus on inductive reasoning tasks within digital inquiry.

These findings support a sociocultural interpretation of digital literacy as a mediational tool. The collaborative use of digital mind maps, shared documents, and peer feedback platforms transformed the social context of learning, enabling collective reasoning that individuals internalized over time. The teacher's role as a facilitator, modeling digital evaluation, and asking probing questions embodied the scaffolding principle central to Vygotsky's ZPD. This study thus provides empirical backing for the notion that digital tools, when embedded in a carefully designed social and pedagogical system, can amplify cognitive development.

From a multimedia learning perspective, the multimodal nature of the digital argument products (combining text, image, sound) likely engaged dual-coding and promoted integration of verbal and pictorial mental models. The act of translating textual evidence into a visual or auditory argument required students to re-organize information, identify core relationships, and eliminate extraneous details all processes that deepen understanding and support critical analysis (Branch 2010).

These results have clear implications for Indonesian educational policy. The Kurikulum Merdeka already advocates for project-based learning and the integration of technology, but many teachers lack concrete models of how to do this in ways that foster thinking rather than mere content coverage. The DLI model, with its phased structure and explicit digital literacy scaffolding, can serve as a professional development blueprint. Teachers can be trained to design inquiries that begin with student questions, progress through evaluated digital research, result in creative synthesis, and end with reflection. Importantly, the model does not demand cutting-edge hardware; the tools used—Miro, Google Docs, Google Classroom are freely available and can run on school computer labs or even smartphones, making it scalable across Indonesia's diverse resourcing contexts.

The non-significant gender interaction suggests that digital literacy integration is equally beneficial for male and female students, an encouraging finding given persistent gender gaps in STEM-related technology uses. The parity in gains implies that well-designed digital pedagogies can serve as an equalizer, provided all students have equitable access to devices and supportive instruction.

This study has several limitations. First, the quasi-experimental design, while stronger than pre-experimental or correlational studies, cannot rule out all confounds such as teacher enthusiasm or class-specific dynamics. The two schools were similar but not identical; although school-level variance was negligible, future research should employ cluster randomized trials to strengthen causal claims. Second, the outcome measure was a standardized multiple-choice test that captured cognitive skills but not dispositions or real-world critical thinking performance. Future studies should incorporate performance-based assessments, such as evaluating a simulated social media feed or producing an argumentative essay scored with a critical thinking rubric. Third,

the intervention lasted for 10 weeks, and its longer-term effects and sustainability were not assessed. A follow-up study six months post-intervention would reveal whether gains are maintained and whether students transfer critical thinking strategies to other subjects. Fourth, the sample was drawn from urban schools with relatively good digital infrastructure; generalization to rural or under-resourced settings requires caution. Adapting the model for low-bandwidth environments (e.g., using offline digital libraries, peer-to-peer sharing) and testing it in diverse contexts is a necessary next step.
Fifth, teacher professional development was not systematically varied; the experimental teacher received training on the DLI model, while the control teacher received no such training, potentially confounding treatment with teacher quality. However, both teachers had similar qualifications and experience, and fidelity checks confirmed that each adhered to their assigned conditions. Future designs could provide equal contact hours of training on different aspects to control for the effect of teacher attention.
Finally, qualitative data, such as student interviews and digital artifact analysis, would enrich the understanding of the processes underlying the quantitative gains. A mixed-methods approach could illuminate how specific digital literacy activities translate into critical thinking subskill development.
This study makes a unique contribution by being one of the first quasi-experimental investigations in Indonesia to demonstrate a causal link between digital literacy integration and critical thinking. It moves the conversation beyond the simple dichotomy of "technology good vs. bad" to a nuanced consideration of how technology is used. The large effect size, robust statistical controls, and detailed subscale analysis provide a template for future research in similar middle-income, high-digital-penetration educational systems. The findings also support the Indonesian government's investment in digital learning environments, but with the critical caveat that teacher training must focus on pedagogical integration, not just technical proficiency.

IV. CONCLUSIONS

This quasi-experimental study demonstrates that a pedagogical model integrating digital literacy into Bahasa Indonesia instruction can significantly and substantially enhance secondary students' critical thinking skills. Over ten weeks, students who engaged in a structured cycle of questioning, digital source evaluation, multimodal argument creation, and reflective peer feedback outperformed their conventionally taught peers on a standardized critical thinking test, with an adjusted mean difference of 11.14 points and a large effect size. All subskills Induction, Deduction, Evaluation, and Inference improved significantly, with the strongest effects on induction and inference. The results underscore that digital technology, when harnessed through deliberate, inquiry-driven design, serves not as a distraction but as a cognitive amplifier that can elevate Indonesian students' capacity for reasoned judgment. For policymakers, the study provides empirical justification for the continued promotion of digital literacy across the Kurikulum Merdeka, along with a concrete, scalable instructional model. For teacher educators, it highlights the need to equip pre-service and in-service teachers with design competencies to orchestrate digital tools for thinking. For researchers, it opens avenues for investigating long-term retention, transfer, and contextual adaptations. Ultimately, integrating digital literacy is not an end in itself; it is a powerful means to cultivate the critical thinkers that Indonesia needs to navigate the complexities of the digital age.

Funding Statement

"No external funding was received for this study."

Ethical Compliance

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Data Access Statement

A Data Access Statement is a section in a scientific publication or research report that explains how the data used or generated in the study can be accessed by readers or other researchers. This statement aims to promote transparency, support research reproducibility, and comply with open-access policies, where applicable.
Common Elements in a Data Access Statement:
1. Data Location: Specifies where the data are stored, such as in online repositories (e.g., Zenodo, Dryad, or institutional repositories).
2. Access Instructions: Provides information on how to access the data, such as direct links, DOI (Digital Object Identifier), or contact details.

3. Data Availability: Indicates whether the data are publicly accessible, available upon request, or restricted due to ethical, legal, or privacy considerations.
4. Data Licensing: If the data are open, specify the applicable license (e.g., Creative Commons).

Examples of Data Access Statements:

1. Open Data:
   - "The data supporting this study are openly available in Zenodo at [DOI:10.xxxx/zenodo.xxxx]."
2. Restricted Data:
   - "The data that support the findings of this study are available upon request from the corresponding author. Due to privacy concerns, the data are not publicly available."
3. No Data Available:
   - "No datasets were generated or analyzed during the current study."
4. Conditional Access:
   - "The data supporting this study are available under restricted access and can be obtained upon reasonable request to the corresponding author and with the permission of the ethics committee."

Purpose of a Data Access Statement:

- Reproducibility: Enables other researchers to replicate or verify the findings.
- Collaboration: Encourages further collaboration by sharing data.
- Compliance: Adheres to policies of funding agencies or journals that require open access to data.

Conflict of Interest Declaration

The authors declare that they have no affiliations with or involvement in any organization or entity with any financial interest in the subject matter or materials discussed in this manuscript.

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