

TikTok-Based Learning Media for Enhancing Elementary Students' Digital Literacy in Coding and AI Education

Nur Fahmi Akhmad ¹, Mujaddid ², Jufri ³

^{1,3} Pendidikan Teknologi Informasi, Institut Teknologi dan Bisnis Nobel Indonesia

² Teknik Industri, Institut Teknologi dan Bisnis Nobel Indonesia

nurfahmi@nobel.ac.id, mujaddid@nobel.ac.id, jufri32@gmail.com

corresponding author: nurfahmi@nobel.ac.id

ABSTRACT

This study aims to develop and evaluate TikTok-based learning media to improve elementary school students' digital literacy in Coding and Artificial Intelligence (AI) learning. The research employed a Research and Development (R&D) approach using the Four-D (Define, Design, Develop, and Disseminate) model. The study was conducted at UPTD SDN 239 Inpres Nipa, Maros Regency, involving 35 fifth-grade students selected through purposive sampling. Data were collected using questionnaires, expert validation instruments, and pretest-posttest assessments, and analyzed using descriptive and comparative statistical techniques. The results indicate that the developed learning media achieved very high validity, with average scores of 3.82 for content validation and 3.89 for media design validation. Practicality testing through small-scale field trials yielded a 92.5% positive student response rate, categorized as very practical. Effectiveness testing demonstrated a significant improvement in students' learning outcomes and digital literacy skills. The experimental group using TikTok-based learning media showed a mean score increase from 62.06 (pretest) to 85.89 (posttest), which was notably higher than that of the control group taught using conventional methods. These findings suggest that TikTok-based microlearning media are effective in enhancing students' digital literacy, computational thinking, and understanding of basic Coding and AI concepts at the elementary school level. This study provides empirical evidence for integrating social media platforms as innovative learning media in digital literacy-oriented education.

Keywords: *tiktok-based learning, digital literacy, coding and artificial intelligence, elementary education*

Submitted	Accepted	Published
06 March 2026	30 May 2026	30 July 2026

Citation	:	Akhmad, N.F., Mujaddid., & Jufri. (2026). TikTok-Based Learning Media for Enhancing Elementary Students' Digital Literacy in Coding and AI Education. <i>Jurnal PAJAR (Pendidikan dan Pengajaran)</i> , 10(4), 507-525. DOI: http://dx.doi.org/10.33578/pjr.v10i4.1471 .
----------	---	--

INTRODUCTION

The rapid development of digital technology has significantly transformed various aspects of human life, including the education sector. In response to these changes, schools are required to adapt their learning strategies to the characteristics and needs of digital-native students. One of the essential competencies that must be developed in the current educational context is digital literacy, which encompasses not only the ability to use digital tools but also critical thinking, problem-solving, and ethical awareness in digital environments (Long & Magerko, 2020; Valtonen et al., 2021). Without adequate digital literacy skills, students may struggle to adapt to the demands of a technology-driven society and the future workforce (Herlinawati et al., 2024).

In line with this urgency, the Indonesian government has emphasized the importance of integrating Coding and Artificial Intelligence (AI) into basic education through the Kurikulum Merdeka. Coding and AI are no longer viewed merely as advanced technical skills but as foundational competencies that support computational thinking, logical reasoning, and problem-solving from an early age (Ng et al., 2021; Su et al., 2023). The Academic Manuscript on Coding and Artificial Intelligence Learning for Basic and Secondary Education highlights that early exposure to these competencies is crucial in preparing students to face the challenges of the Industrial Revolution 4.0 and Society 5.0, where digital and intelligent technologies dominate various sectors of life (Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, 2025). Studies

further indicate that AI literacy at the elementary school level remains underdeveloped and requires targeted pedagogical attention (Chiu & Chai, 2024; Casal-Otero et al., 2023).

Despite these policy directions, implementing coding and AI learning at the elementary school level still faces several challenges. One prominent issue is the limited use of innovative digital learning media that align with students' learning preferences and technological habits (Ningsih et al., 2020). Preliminary observations conducted at UPTD SDN 239 Inpres Nipa, Maros Regency, revealed that conventional teaching methods, such as lectures and printed textbooks, tend to lead to low student engagement. In contrast, students showed higher enthusiasm and creativity when learning activities involved digital devices such as smartphones or laptops (Criollo-C et al., 2021). These findings indicate a mismatch between instructional practices and students' digital characteristics, which may hinder the development of digital literacy skills.

Social media platforms, particularly TikTok, have emerged as one of the most widely used digital applications among children and adolescents. TikTok offers features that support microlearning, visual storytelling, and interactive communication, making it a potential educational medium (Caldeiro-Pedreira & Rodríguez-Vázquez, 2023; Hu & Du, 2022). Previous studies have demonstrated that social media-based learning media can enhance student motivation, engagement, and learning outcomes when appropriately designed and integrated into instructional activities (Akhmad et al., 2024; Puja, 2024; Lobo-Quintero et al., 2024). However, the majority of existing studies focus on secondary education contexts (Lee, 2023; Tarifa-Rodríguez et al., 2024), while empirical evidence regarding the use of TikTok as a structured learning medium for Coding and AI at the elementary school level remains limited (Chiu & Chai, 2024; Su et al., 2023).

Another challenge in using social media for learning is the negative perceptions associated with its use in educational settings. TikTok is often viewed as a platform primarily for entertainment, raising concerns among educators about potential distractions and reduced focus on learning (Sobaih et al., 2022; Manca, 2020). These concerns highlight the need for systematic development and validation of TikTok-based learning media that are pedagogically sound, contextually relevant, and aligned with curriculum objectives. Without a structured development model, the use of social media in education risks being superficial and lacking measurable educational impact (Agustina et al., 2024; Tinenti et al., 2024).

Based on these considerations, this study seeks to develop and evaluate TikTok-based learning media for Coding and Artificial Intelligence learning at the elementary school level using the Four-D (Define, Design, Develop, and Disseminate) development model, with the specific aim of assessing the validity, practicality, and effectiveness of the developed media in improving students' digital literacy skills (Park & Ko, 2022; Astuti et al., 2024). The primary novelty of this study lies in the integration of three interconnected domains TikTok as a learning platform, Coding and Artificial Intelligence as curriculum content, and digital literacy as the targeted competency within a single coherent instructional design grounded in Deep Learning pedagogical principles (Fullan et al., 2018), which has not been previously explored in the literature, particularly in the context of Indonesia's newly established Kurikulum Merdeka (Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, 2025; Ng et al., 2021).

This integration addresses a significant research gap: while a growing body of literature examines social media-based learning, the majority of existing studies have been conducted at the secondary or higher education levels and focus on general subject areas, leaving empirical investigations into TikTok as a structured, pedagogically validated learning medium for Coding and AI at the elementary school level exceptionally scarce (Caldeiro-Pedreira & Rodríguez-Vázquez, 2023; Chiu & Chai, 2024; Su et al., 2023). Theoretically, this study contributes to 21st-century learning frameworks by demonstrating how social media platforms can be systematically validated as instructional media that foster computational thinking and digital literacy at the foundational stage of schooling (Long & Magerko, 2020; Valtonen et al., 2021; Herlinawati et al., 2024). In practice, the developed media offers educators a replicable, evidence-based model for integrating digital platforms into Coding and AI instruction to meet the competency demands of Society 5.0 (Criollo-C et al., 2021; Astuti et al., 2024; Sari et al., 2024).

METHOD

Research Design

This study employed a Research and Development (R&D) approach using the Four-D (4-D) development model, originally introduced by Thiagarajan et al. (1974), as adapted by Khodarsih et al. (2025). The 4-D model was selected because it has been recognized as an effective and systematic framework for developing high-quality instructional materials (Nduru et al., 2025). The model consists of four sequential stages: Define, Design, Develop, and Disseminate (Adelia & Rambe, 2025).

The use of the 4-D model enabled a comprehensive needs analysis, systematic product design, expert validation, and effectiveness testing in an authentic learning environment (Oktaviani et al., 2025). Consequently, the developed learning media were expected to meet quality standards and address contemporary educational needs.

Research Site and Period

The study was conducted during the first semester of the 2025–2026 academic year at UPTD SDN 239 Inpres Nipa, Simbang District, Maros Regency, Indonesia. The school was selected based on preliminary observations indicating limited variation in instructional materials, particularly for Coding and Artificial Intelligence (AI) subjects. Furthermore, no previous study had specifically developed TikTok-based learning media for Coding and AI instruction at the research site.

Population and Participants

The population consisted of all fifth-grade students enrolled at the selected school. Participants involved in the development stage were selected purposively. Class selection was based on students' readiness to use digital devices and the implementation of the Coding and Artificial Intelligence curriculum.

Regarding sample size adequacy, a priori power analysis was conducted using G*Power 3.1 (Faul et al., 2007) to determine the minimum required sample for the effectiveness testing phase. For an independent-samples t-test with a two-tailed alpha level of .05, an anticipated large effect size of $d = 0.80$ consistent with prior technology-enhanced learning research (Park & Ko, 2022; Caldeiro-Pedreira & Rodríguez-Vázquez, 2023), and a desired statistical power of .80, the analysis yielded a minimum required total sample of 52 participants. The achieved sample of 35 participants ($n = 18$, experimental; $n = 17$, control) falls below this threshold, a constraint arising directly from the single-school, single-cohort nature of the study site, where the total enrolled fifth-grade population comprised exactly 35 students. This constitutes a recognized limitation of the current study. To mitigate reduced statistical power, the analysis used ANCOVA with pretest scores as a covariate to maximize sensitivity in detecting group differences beyond what a simple posttest comparison would provide (Mirza et al., 2024). The substantial observed effect sizes (Cohen's d ranging from 3.527 to 4.737) further confirm that the intervention effect remained sufficiently robust to remain detectable despite the constrained sample. Nevertheless, replication with larger, more diverse samples across multiple schools is strongly recommended in future research to increase statistical power and external validity.

During the dissemination stage, 35 students participated in the study and were assigned to either the experimental or the control group. Random assignment was employed to ensure group balance and minimize selection bias (Mirza et al., 2024). In addition, one Coding and Artificial Intelligence teacher participated in the evaluation of the developed learning media.

Research Instruments

1. Digital Literacy Indicators

Digital literacy was defined as students' ability to use, understand, and interact with digital technologies effectively and responsibly. The digital literacy indicators were adapted from the UNESCO Digital Literacy Global Framework (DLGF) and the European Digital Competence Framework (DigComp 2.2). The indicators included:

1. Digital Information Literacy: the ability to search, locate, and evaluate information from digital sources.
2. Technical Competence: the ability to operate digital devices and applications.
3. Computational Thinking: the ability to solve problems using algorithmic approaches.
4. Artificial Intelligence Literacy: understanding fundamental AI concepts and applications.
5. Digital Safety: awareness of security and privacy issues in digital environments.
6. Digital Ethics: understanding responsible and ethical technology use.

2. Instrument Blueprint

The instrument was designed to measure improvements in students' digital literacy through pretest and posttest assessments. The test consisted of 20 multiple-choice items covering computational thinking, digital technology, artificial intelligence, and digital safety and ethics.

Table 1. Competency and Indicator digital literacy

Competency Area	Indicator	Cognitive Level	Number of Items	Item Numbers
Computational Thinking	Identifying problem-solving steps	C1–C2	3	1–3
	Applying pattern recognition in new contexts	C3	2	4–5
Digital Technology	Explaining the functions of digital devices	C2	3	6–8
	Analyzing the positive and negative impacts of technology	C4	2	9–10
Artificial Intelligence	Understanding basic AI concepts	C1–C2	3	11–13
	Providing examples of AI applications in daily life	C3	2	14–15
Digital Safety and Ethics	Explaining principles of data security	C2	3	16–18
	Evaluating ethical digital behavior	C5	2	19–20

3. Instrument Validity

Content validity was assessed by three experts: a subject-matter expert in coding and artificial intelligence, a digital learning media expert, and a language expert. Each item was evaluated using a five-point Likert scale based on four criteria: (1) alignment with the indicator, (2) clarity of item formulation, (3) appropriateness of difficulty level, and (4) relevance to the learning content.

4. Instrument Reliability

Instrument reliability was examined using Cronbach's Alpha in a pilot test involving 20 students with characteristics similar to those of the target participants. Reliability was interpreted using the following criteria (George & Mallery, 2003): $\alpha > .80$ (highly reliable), $.70 < \alpha \leq .80$ (reliable), $.60 < \alpha \leq .70$ (moderately reliable), and $\alpha \leq .60$ (unreliable). The pilot test yielded a Cronbach's Alpha coefficient of .82, indicating excellent internal consistency.

Research Procedures

1. Define

At this stage, a comprehensive needs analysis was conducted to identify instructional requirements and specifications for the learning media (Hasnunidah et al., 2025). Activities included analyzing curriculum content, identifying learning objectives, determining content boundaries, specifying media formats suitable for TikTok, and examining contextual opportunities and constraints that could affect implementation.

2. Design

The Design stage focused on creating the initial prototype of the TikTok-based learning media (Rizka et al., 2024). Learning materials were designed as photo-slide content covering four topics: (a) Computational Thinking: Finding Solutions, (b) Digital Technology: Smart, Fun, and Responsible, (c) Artificial Intelligence: A New Friend in the Digital World, and (d) Learning with Artificial Intelligence: The Intelligent System That Continues Learning. The content was adapted to the platform's format and user characteristics (Salam et al., 2025).

3. Develop

The Develop stage focused on media production and validation (Khodarsih et al., 2025). Learning materials were produced in accordance with the design specifications and subsequently validated by content, media, and language experts. A limited trial was then conducted to identify technical issues and students' comprehension difficulties. Revisions were made based on feedback obtained during this phase.

3. Disseminate

The Disseminate stage aimed to evaluate the effectiveness of the developed learning media on a broader scale (Rahayu et al., 2025). The TikTok-based learning media were implemented in the experimental group, while the control group received conventional instruction. Data were collected through pretest and posttest assessments, student questionnaires, and classroom observations. The collected data were analyzed using descriptive and inferential statistical techniques to determine the effectiveness of the developed learning media.

RESULTS AND DISCUSSION

Define Phase

The Define phase aimed to identify instructional needs, target learner characteristics, and curriculum requirements relevant to the development of TikTok-based learning media for Coding and Artificial Intelligence. Observations and interviews conducted at UPTD SDN 239 Inpres Nipa, Maros Regency, revealed that existing instructional practices predominantly relied on conventional methods, such as lectures and printed textbooks, resulting in low student engagement and limited development of digital literacy. Analysis of the *Kurikulum Merdeka* framework confirmed that Coding and AI has been formally designated as an elective subject at the elementary school level beginning the 2025/2026 academic year, underscoring the urgency of developing contextually appropriate and technologically engaging learning media.

Design Phase

The Design phase involved systematic planning of the TikTok-based learning media, including selecting instructional content and determining the media format. The learning media was designed using TikTok's photo slide feature, which allows instructional materials to be presented as a sequence of images in a slide-based format. The content was organized according to microlearning principles, enabling the delivery of Coding and Artificial Intelligence concepts in concise, visually structured learning units. Each slide sequence was designed to facilitate understanding of computational thinking, digital technology, and basic Artificial Intelligence concepts while supporting students' development of digital literacy. In addition, a Deep Learning instructional approach was integrated into the media design to promote meaningful learning, critical thinking, and active engagement among elementary school students.

In this study, Deep Learning refers to a pedagogical framework not a computational or machine learning technique grounded in the principles of meaningful, mindful, and joyful learning. This framework, originally conceptualized by Fullan et al. (2018) under the New Pedagogies for Deep Learning (NPDL) model, defines deep learning as the process through which students acquire transferable competencies encompassing the six global dimensions known as the 6Cs: Character, Citizenship, Collaboration, Communication,

Creativity, and Critical Thinking (Pellegrino & Hilton, 2012). As a pedagogical approach, deep learning emphasizes meaningful cognitive engagement through conceptual understanding, reflective thinking, and the ability to transfer knowledge across contexts, in explicit contrast with surface learning, which focuses on rote memorization and decontextualized recall (Asikainen & Gijbels, 2017; Kovac et al., 2023). Meaningful learning, as the first dimension of this framework, encourages students to actively connect new information with prior knowledge and personal experience, thereby fostering deeper conceptual understanding and higher-order thinking skills (Wang et al., 2021; Weng et al., 2023). Mindful learning requires students to engage with learning content with full cognitive attention and reflective awareness, enabling them to critically evaluate information rather than passively receive it (Feriyanto & Anjariyah, 2024). Joyful learning, in turn, cultivates emotional investment in the learning process by creating an environment that students perceive as engaging, personally relevant, and intrinsically motivating (Kemendikdasmen, 2025).

The operationalization of Deep Learning principles within the TikTok-based media design was realized through three interrelated structural decisions. First, to operationalize meaningful learning, each photo-slide unit was explicitly designed to connect Coding and Artificial Intelligence concepts to students' everyday digital experiences, thereby anchoring abstract computational concepts in familiar, personally relevant contexts (Wang et al., 2021). Second, to operationalize mindful learning, the slide sequences incorporated structured reflection prompts, visual cues, and step-by-step problem decomposition tasks that required students to actively process and evaluate each concept before proceeding to the next learning segment (Weng et al., 2023; Kovac et al., 2023). Third, joyful learning was operationalized through the visual design aesthetics of the slides, including the use of age-appropriate illustrations, color-coded concept maps, and character-based storytelling elements aligned with TikTok's engaging visual conventions, all of which are consistent with research demonstrating that positive emotional states during learning enhance retention, motivation, and cognitive engagement (Feriyanto & Anjariyah, 2024; Kemendikdasmen, 2025).

Together, these three dimensions of the Deep Learning framework were not merely decorative features of the media design, but constituted the core pedagogical logic through which the TikTok-based learning media was structured to promote higher-order thinking and digital literacy competencies in alignment with the demands of Indonesia's Kurikulum Merdeka (Fullan et al., 2018; Pellegrino & Hilton, 2012; Setyaningsih et al., 2024).

Develop Phase

1. Description of the Developed Product

The developed learning media used TikTok's photo slide feature, enabling instructional materials to be delivered in a sequence of images arranged in a slide-based format. This format was selected because it allows students to access learning content flexibly while maintaining a structured presentation of concepts. The photo-slide format enables learners to read, observe, and reflect on each learning component at their own pace. The design of the developed product is presented as follows.



Figure 1. The Design Of The Developed Product: Computational Thinking



Figure 2. The Design Of The Developed Product Digital Technology

2. Content/Material Expert Validation

Content validation was conducted by two validators (V1 and V2) to assess the accuracy, material quality, currency, and readability of the developed media. The validation results are presented in Table 1.

Table 1. Content/Material Expert Validation Results

No.	Aspect	Mean Score	Category
1	Accuracy	3.75	Very Valid
2	Content/Material	3.79	Very Valid
3	Currency	3.75	Very Valid
4	Readability	4.00	Very Valid
	Overall Mean	3.82	Very Valid

As presented in Table 1, the content/material validation yielded mean scores of 3.75 for Accuracy, 3.79 for Content/Material, 3.75 for Currency, and 4.00 for Readability, resulting in an overall mean of 3.82, categorized as *Very Valid*. These results indicate that the developed media demonstrates strong alignment with the Coding and AI curriculum, presents accurate, up-to-date content, and is accessible to elementary school learners. The high readability score reflects TikTok's photo-slide format's effectiveness in conveying complex computational concepts in a simplified, age-appropriate manner, consistent with Caldeiro-Pedreira and Rodríguez-Vázquez's (2023) findings.

3. Media Design Expert Validation

Media design validation was similarly conducted by two validators, evaluating four aspects: usability, content quality, visual appearance, and digital literacy integration. The results are presented in Table 2.

Table 2. Media Design Expert Validation Results

No.	Aspect	Mean Score	Category
1	Usability	4.00	Very Valid
2	Content Quality	4.00	Very Valid
3	Visual Appearance	3.90	Very Valid
4	Digital Literacy Integration	3.67	Very Valid
	Overall Mean	3.89	Very Valid

Table 2 reveals that the media design received mean scores of 4.00 for Usability, 4.00 for Content Quality, 3.90 for Visual Appearance, and 3.67 for Digital Literacy Integration, yielding an overall mean of 3.89, categorized as *Very Valid*. The near-perfect scores in usability and content quality confirm that the

TikTok-based media is intuitive, accessible, and pedagogically coherent. The slightly lower score in Digital Literacy Integration (3.67) suggests that while the media adequately incorporates digital literacy elements, further refinement in embedding critical digital competencies such as information evaluation and ethical digital engagement may strengthen the media's contribution to holistic digital literacy development (Long & Magerko, 2020; Valtonen et al., 2021).

Small-Scale Field Trial (Practicality)

Following expert validation, the media underwent a small-scale field trial with 10 elementary school students to assess its practicality. Student responses were measured across multiple dimensions, and the results are presented in Table 3.

Table 3. Small-Scale Field Trial Results: Student Practicality Responses

Respondent	Mean Score	Percentage (%)	Category
R1	3.79	94.6	Very Practical
R2	3.71	92.9	Very Practical
R3	3.71	92.9	Very Practical
R4	3.57	89.3	Very Practical
R5	3.64	91.1	Very Practical
R6	3.64	91.1	Very Practical
R7	3.79	94.6	Very Practical
R8	3.71	92.9	Very Practical
R9	3.93	98.2	Very Practical
R10	3.50	87.5	Very Practical
Mean	3.70	92.50%	Very Practical

As shown in Table 3, student responses from all 10 respondents yielded an overall mean score of 3.70 (92.50%), indicating *Very Practical*. Individual scores ranged from 3.50 (87.5%) to 3.93 (98.2%), indicating a high degree of consistency in perceived practicality across respondents. These findings suggest that the TikTok-based learning media is user-friendly, engaging, and implementable within elementary school learning environments without requiring significant technical adaptation. The high practicality scores align with prior research demonstrating that social media-based instructional tools tend to generate positive student responses when aligned with learners' existing digital habits (Akhmad et al., 2024; Criollo-C et al., 2021).

Large-Scale Field Trial (Effectiveness)

The large-scale field trial involved 35 students, divided into an experimental group (n = 18; TikTok-based media) and a control group (n = 17; conventional instruction). A pretest-posttest design was employed, and a comprehensive statistical analysis, including paired t-tests, independent t-tests, N-Gain, Cohen's d (effect size), and ANCOVA, was conducted to evaluate the effectiveness of the developed media.

Descriptive Statistics

Table 4. Descriptive Statistics

Group	n	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Gain
Experimental	18	62.06	7.07	85.89	2.72	+23.83
Control	17	61.24	3.03	75.65	2.32	+14.41

Table 4 shows that both groups entered the study with comparable pretest means (Experimental: M = 62.06, SD = 7.07; Control: M = 61.24, SD = 3.03). Following the intervention, the experimental group demonstrated a substantially higher posttest mean (M = 85.89, SD = 2.72) compared to the control group (M = 75.65, SD = 2.32), reflecting a mean gain of 23.83 points versus 14.41 points for the control group. The

narrower standard deviation in the posttest scores of the experimental group also suggests that TikTok-based instruction produced more uniform learning outcomes across students.

Paired Sample t-Test

Table 5. Paired Sample t-Test Results

Group	t-value	df	p-value	Conclusion
Experimental	-14.96	17	< 0.001	Significant
Control	-19.53	16	< 0.001	Significant

The paired-samples t-test results (Table 5) indicate statistically significant pretest-to-posttest improvements in both groups ($p < 0.001$). The experimental group yielded $t(17) = -14.96$ and the control group $t(16) = -19.53$, both significant at the $\alpha = 0.05$ level. These findings confirm that learning occurred in both conditions; however, the substantially higher posttest mean in the experimental group indicates that TikTok-based instruction produced superior learning gains. This result supports prior evidence that structured digital media interventions can significantly enhance learning outcomes compared to baseline performance (Park & Ko, 2022; Akhmad et al., 2024).

Independent Sample t-Test

Table 6. Independent Sample t-Test Results

Comparison	t-value	df	p-value	Conclusion
Pretest: Exp. vs Control	0.44	33	0.6621	Not Significant (groups equivalent)
Posttest: Exp. vs Control	11.96	33	< 0.001	Significant

The independent-samples t-test (Table 6) confirmed that, prior to the intervention, the two groups showed no statistically significant difference in pretest scores ($t = 0.44$, $p = .662$), establishing equivalence between the groups at baseline. Following the intervention, however, the posttest scores differed significantly ($t = 11.96$, $p < 0.001$), indicating that the TikTok-based media produced significantly superior learning outcomes compared to conventional instruction. This finding is consistent with research demonstrating that well-designed social media learning environments yield measurable advantages over traditional instructional methods (Hu & Du, 2022; Caldeiro-Pedreira & Rodríguez-Vázquez, 2023).

N-Gain Score

Table 7. N-Gain Score Results

Respondent	Pretest	Posttest	N-Gain	Category
E1	60	85	0.625	Medium
E2	56	88	0.727	High
E3	60	80	0.500	Medium
E4	62	86	0.632	Medium
E5	75	90	0.600	Medium
E6	63	84	0.568	Medium
E7	68	87	0.594	Medium
E8	61	89	0.718	High
E9	40	84	0.733	High

E10	60	89	0.725	High
E11	67	85	0.545	Medium
E12	60	88	0.700	High
E13	61	82	0.538	Medium
E14	65	84	0.543	Medium
E15	64	88	0.667	Medium
E16	60	83	0.575	Medium
E17	66	88	0.647	Medium
E18	69	86	0.548	Medium
Mean (Exp.)	62.06	85.89	0.621	Medium
Mean (Control)	61.24	75.65	0.370	Medium

The N-Gain analysis (Table 7) reveals that the experimental group achieved a mean N-Gain of 0.621, categorized as *Medium*, with five students (E2, E8, E9, E10, E12) achieving *High* gain scores (≥ 0.70) and the remaining 13 students falling in the *Medium* category. In contrast, the control group yielded a mean N-Gain of 0.370, which is also categorized as the *Medium* category. Individual N-Gain data for the control group are not reported at the participant level in this study, as the analysis focused on group-level comparison. The considerably higher N-Gain in the experimental group (0.621 vs. 0.370) demonstrates that TikTok-based instruction produced substantially greater normalized learning gains. This finding is consistent with microlearning theory, which posits that short, contextually embedded content segments support more efficient knowledge construction compared to conventional lecture-based delivery (Khlaif & Salha, 2021; Su et al., 2023).

Effect Size (Cohen's d)

Table 8. Effect Size (Cohen's d) Results

Comparison	Cohen's d	Interpretation
Experimental: Pre vs. Post (paired)	3.527	Large Effect
Control: Pre vs. Post (paired)	4.737	Large Effect
Posttest: Experimental vs. Control (independent)	4.044	Large Effect

Cohen's d effect sizes are presented in Table 8. All three comparisons yielded *Large* effect sizes: $d = 3.527$ for the paired pre-post comparison within the experimental group, $d = 4.737$ within the control group, and $d = 4.044$ for the independent posttest comparison. According to Cohen's (1988) conventions, values of $d \geq 0.8$ constitute a large effect. The exceptionally high effect sizes observed in this study are attributable to the very small posttest standard deviations ($SD = 2.72$ and $SD = 2.32$ for the experimental and control groups, respectively), which, when used as the denominator in the Cohen's d calculation, substantially amplify the effect size magnitude. While these values far exceed conventional "large effect" benchmarks, they nonetheless confirm practically significant improvements in student learning outcomes. The magnitude of the effect in the experimental group reflects the instructional potency of TikTok-based media in elevating digital literacy competencies among elementary school students, consistent with prior studies on technology-integrated learning media (Park & Ko, 2022; Caldeiro-Pedreira & Rodríguez-Vázquez, 2023).

Analysis of Covariance (ANCOVA)

Table 9. ANCOVA Results

Source	F-value	df	p-value	Conclusion
Group (after controlling pretest)	149.03	1, 32	< 0.001	Significant
Adjusted Mean — Experimental	85.83	—	—	—
Adjusted Mean — Control	75.71	—	—	—

To control for any residual pretest differences between groups, an Analysis of Covariance (ANCOVA) was performed with pretest scores as the covariate and posttest scores as the dependent variable. The ANCOVA yielded $F(1, 32) = 149.03$, $p < 0.001$, confirming a statistically significant difference between groups in posttest performance even after adjusting for pretest scores. The adjusted means were 85.83 for the experimental group and 75.71 for the control group, representing an adjusted difference of approximately 10.12 points in favor of TikTok-based instruction. These results provide robust evidence that the observed superiority of the experimental group cannot be attributed to pre-existing differences in student ability, and that TikTok-based learning media constitutes a genuinely effective instructional intervention for Coding and AI learning in elementary school contexts (Chiu & Chai, 2024; Ng et al., 2021).

Disseminate Phase

Following the completion of the Develop phase, the validated and tested TikTok-based learning media were disseminated on the official TikTok platform to broaden its accessibility for educators and students beyond the research context. The dissemination aimed to promote the media as a replicable instructional resource for Coding and AI learning in elementary schools across Indonesia, in alignment with the government's directive under the *Kurikulum Merdeka* framework. The media's availability on TikTok enables educators to use the content directly within a platform students already use daily, thereby minimizing adoption barriers and maximizing instructional reach.

DISCUSSION OF FINDINGS

The findings indicate that the TikTok-based learning media developed using the Four-D model were valid, practical, and effective in improving students' digital literacy in Coding and Artificial Intelligence. The following sub-sections discuss each quality criterion in turn, situating the results within relevant theoretical frameworks and prior empirical literature.

Validity of the TikTok-Based Learning Media

The content and media design validation results collectively indicate that the developed TikTok-based learning media meet established quality standards for instructional materials at the elementary school level. Content validation yielded an overall mean score of 3.82 (Very Valid), while media design validation produced an overall mean of 3.89 (Very Valid). These outcomes suggest that the developed media demonstrate strong pedagogical coherence, accurate representation of Coding and Artificial Intelligence concepts, and appropriate adaptation to the cognitive and linguistic characteristics of fifth-grade learners.

The high content validity score, particularly the perfect mean of 4.00 for Readability, reflects the effectiveness of TikTok's photo-slide format in translating abstract computational concepts into visually structured, age-appropriate learning units. This finding aligns with prior research demonstrating that microlearning formats characterized by concise, visually segmented content are particularly effective in reducing cognitive overload for younger learners engaging with complex subject matter (Khlaif & Salha, 2021; Su et al., 2023). The Accuracy and Currency dimensions (both 3.75) confirm that the media content is

grounded in contemporary Coding and AI frameworks consistent with the demands of Indonesia's Kurikulum Merdeka (Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, 2025).

In media design validation, the near-perfect scores in Usability (4.00) and Content Quality (4.00) indicate that the TikTok-based interface is intuitive for elementary-age users and that instructional content is coherently sequenced within the platform's photo-slide architecture. However, the comparatively lower score for Digital Literacy Integration (3.67), while still categorized as Very Valid, warrants interpretive attention. This result suggests that although the media successfully incorporates foundational digital literacy elements such as computational thinking and basic AI concepts, the explicit embedding of higher-order competencies, including critical information evaluation, ethical digital engagement, and digital safety awareness, may require further refinement in subsequent iterations. Long and Magerko (2020) emphasize that robust AI literacy frameworks must extend beyond technical skill acquisition to encompass critical agency and ethical reasoning; the present findings indicate that this dimension represents a productive area for development in future versions of the media.

Taken together, the validity results provide strong empirical support for the pedagogical soundness of the developed media, confirming that expert-reviewed instructional materials grounded in the Four-D development model can yield high-quality, curriculum-aligned learning resources for Coding and AI education at the elementary level (Park & Ko, 2022; Astuti et al., 2024).

Practicality of the TikTok-Based Learning Media

The small-scale field trial involving 10 elementary school students yielded a mean practicality score of 3.70 (92.50%), categorized as Very Practical. Individual scores ranged from 3.50 (87.5%) to 3.93 (98.2%), indicating a high and consistent degree of perceived usability across participants. These findings suggest that the developed media is readily implementable in authentic elementary school learning environments without requiring substantial technical adaptation on the part of either students or teachers.

Several factors may account for the high practicality ratings. First, TikTok is a platform that elementary-age students encounter organically in their daily digital lives, thereby substantially reducing the cognitive effort typically required to adopt unfamiliar learning technologies. This phenomenon is consistent with the Technology Acceptance Model (TAM), which posits that perceived ease of use, defined as the degree to which a user believes that engaging with a system requires minimal effort, is a primary determinant of technology adoption in educational contexts (Criollo-C et al., 2021; Sobaih et al., 2022). The photo-slide format, in particular, provides a familiar and low-barrier mode of content navigation that mirrors students' existing patterns of social media consumption, enabling them to direct cognitive resources toward learning content rather than platform mechanics.

Second, the high practicality scores reflect the successful operationalization of the joyful learning dimension of the Deep Learning framework within the media's visual design (Fullan et al., 2018; Kemendikdasmen, 2025). The use of age-appropriate illustrations, character-based storytelling, and color-coded concept maps within each photo-slide unit created an emotionally engaging learning environment that students perceived as personally relevant and intrinsically motivating. Research consistently demonstrates that positive affective states during learning, including enjoyment, curiosity, and a sense of competence, are associated with greater willingness to engage with instructional materials and reduced technology anxiety (Feriyanto & Anjariyah, 2024; Wang et al., 2021). Third, the practicality of the media is further supported by its alignment with the microlearning principle of bite-sized content delivery, whereby each photo-slide sequence presents a single conceptual unit within a visually bounded format, allowing students to process and consolidate learning at a self-regulated pace (Khlaif & Salha, 2021). The practicality results of the present study thus corroborate a growing body of evidence suggesting that social media-based instructional tools generate consistently positive student responses when their design is explicitly aligned with learners' existing digital habits and developmental characteristics (Akhmad et al., 2024; Caldeiro-Pedreira & Rodríguez-Vázquez, 2023).

Effectiveness of the TikTok-Based Learning Media

1. Learning Outcomes and Group Comparison

The effectiveness analysis reveals that TikTok-based learning media produced substantially superior learning outcomes relative to conventional instruction across all statistical measures. The experimental group achieved a posttest mean of 85.89 (SD = 2.72), representing a gain of 23.83 points from the pretest baseline of 62.06, compared to the control group's posttest mean of 75.65 (SD = 2.32), reflecting a gain of 14.41 points from a comparable baseline of 61.24. The independent-samples t-test confirmed that pretest scores were statistically equivalent between groups ($t = 0.44$, $p = .662$), establishing baseline comparability and strengthening the interpretive validity of the post-intervention comparison ($t = 11.96$, $p < .001$).

These findings are consistent with prior research demonstrating that well-designed social media learning environments confer measurable instructional advantages over traditional lecture-based methods, particularly in technology-integrated subject areas (Hu & Du, 2022; Caldeiro-Pedreira & Rodríguez-Vázquez, 2023). The superior performance of the experimental group can be attributed, in part, to the multimodal affordances of TikTok's photo-slide format, which simultaneously engages visual and textual processing channels. This observation aligns with the Cognitive Theory of Multimedia Learning (Mayer, 2009), which posits that integrated visual-verbal presentations promote deeper encoding and more durable knowledge retention than single-channel delivery alone. Furthermore, the narrower posttest standard deviation in the experimental group (SD = 2.72) compared to the control group (SD = 2.32) suggests that TikTok-based instruction produced not only higher average outcomes but also more homogeneous learning gains an indicator of the media's capacity to support differentiated learners within a single instructional format.

2. Normalized Learning Gain (N-Gain)

The N-Gain analysis revealed a mean normalized gain of 0.621 (Medium) in the experimental group, compared with 0.370 (Medium) in the control group. Although both groups fall within the same broad category, the substantially higher N-Gain in the experimental group ($\Delta = 0.251$) demonstrates that TikTok-based instruction generated considerably greater normalized learning efficiency. This result is consistent with microlearning theory, which holds that delivering instructional content in concise, contextually embedded segments supports more efficient knowledge construction than conventional, lecture-based approaches (Khlaif & Salha, 2021; Su et al., 2023).

It is noteworthy, however, that the experimental group's mean N-Gain did not reach the High category threshold (≥ 0.70), despite the large absolute gains observed. Five of the 18 experimental participants achieved High N-Gain scores (≥ 0.70), while the remaining 13 fell within the Medium range. Examination of individual scores suggests that students with lower pretest baselines (notably E9, pretest = 40) tended to achieve higher N-Gain values, consistent with the well-established ceiling effect inherent to the N-Gain formula: students who begin from a higher baseline have proportionally less room for normalized improvement (Hake, 1998). Additionally, the exclusive use of the photo-slide format may have constrained the instructional ceiling for higher-achieving students who could have benefited from more dynamic content formats such as short-form video or challenge-based activities. This interpretive observation points to a productive design consideration for future iterations of TikTok-based instructional media.

3. Effect Size and Practical Significance

All three Cohen's d comparisons yielded Large effect sizes: $d = 3.527$ for the paired pre-post comparison within the experimental group, $d = 4.737$ within the control group, and $d = 4.044$ for the independent posttest comparison between groups. While these values substantially exceed Cohen's (1988) conventional large-effect benchmark of $d \geq 0.80$, their exceptional magnitude is a direct function of the very small posttest standard deviations observed in both groups (SD = 2.72 and SD = 2.32, respectively). When posttest score distributions are highly homogeneous, as is the case in tightly controlled instructional settings with small cohorts the denominator in the Cohen's d formula is reduced, thereby mathematically amplifying

the effect size irrespective of the actual mean difference. This statistical artifact does not invalidate the findings; rather, it underscores the need to interpret the magnitude of the effect size in the context of sample characteristics and score distributions (Park & Ko, 2022). Notwithstanding this caveat, the consistently large effect sizes across all comparisons confirm that the instructional impact of TikTok-based media on students' digital literacy outcomes is practically meaningful and not attributable to chance variation.

4. ANCOVA and Internal Validity

To address residual concerns regarding pre-existing group differences, an Analysis of Covariance (ANCOVA) was conducted with pretest scores as the covariate. The analysis yielded $F(1, 32) = 149.03$ ($p < .001$), with adjusted posttest means of 85.83 for the experimental group and 75.71 for the control group an adjusted difference of approximately 10.12 points in favor of TikTok-based instruction. This finding provides robust evidence that the observed between-group differences in posttest performance cannot be attributed to pre-intervention differences in student ability, and that the instructional effect of the developed media is genuine and statistically stable after covariate adjustment. The convergence of results across paired t-tests, independent t-tests, N-Gain analysis, and ANCOVA collectively strengthens the internal validity of the effectiveness claim, consistent with recommendations for multi-method statistical triangulation in small-sample educational research (Mirza et al., 2024; Faul et al., 2007).

5. Theoretical and Practical Contributions

The present study contributes to the existing literature on social media-based learning in several interconnected ways. Theoretically, the findings extend 21st-century learning frameworks by providing empirical evidence that social media platforms, when systematically developed, expert-validated, and pedagogically grounded, can serve as effective instructional media for fostering computational thinking and digital literacy at the foundational stage of schooling (Long & Magerko, 2020; Valtonen et al., 2021). Specifically, the integration of Deep Learning principles (Fullan et al., 2018) within a TikTok-based microlearning design offers a replicable pedagogical model that operationalizes meaningful, mindful, and joyful learning within a constrained-format social media environment, a theoretical contribution that has not been previously documented in the literature about elementary Coding and AI education (Chiu & Chai, 2024; Ng et al., 2021).

In practice, the developed media provides educators and curriculum designers with a validated, evidence-based template for integrating digital platforms into Coding and AI instruction, aligned with the competency demands articulated in Indonesia's Kurikulum Merdeka (Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, 2025). The media's availability on the TikTok platform eliminates the adoption barriers typically associated with purpose-built educational applications, enabling teachers in resource-constrained school settings to leverage existing digital infrastructure without additional technological investment. This accessibility characteristic is particularly significant given ongoing concerns in Indonesian elementary education regarding the limited availability of innovative instructional media for newly introduced Coding and AI subject content (Ningsih et al., 2020; Criollo-C et al., 2021).

6. Limitations

Several limitations of this study should be acknowledged to ensure appropriate interpretation of the findings. First, the study involved 35 participants from a single elementary school, a sample size that falls below the minimum of 52 participants identified through a priori power analysis for an independent-samples t-test at 80% statistical power and a large effect size threshold ($d = 0.80$; Faul et al., 2007). Although the large observed effect sizes and the application of ANCOVA mitigate concerns about statistical detectability, the constrained sample limits the precision of effect size estimates. It restricts the generalizability of findings to other school contexts, student populations, and geographic settings. Replication across multiple schools with larger, more diverse samples is therefore essential before broader instructional recommendations can be

advanced. Second, the intervention was implemented exclusively using TikTok's photo slide feature, without systematically comparing alternative content formats available on the same platform. The N-Gain analysis suggests that the photo-slide format may impose an instructional ceiling for higher-achieving students, and future studies should empirically investigate whether other TikTok content modalities yield differential effects on digital literacy and computational thinking outcomes. Third, the study was conducted within a single semester, precluding assessment of the long-term retention of digital literacy competencies. Longitudinal designs incorporating delayed posttests and repeated-measures analyses are recommended to evaluate the durability of the observed learning gains over extended time periods.

CONCLUSIONS AND RECOMMENDATION

This study concludes that the TikTok-based learning media developed through the Four-D (Define, Design, Develop, and Disseminate) model are valid, practical, and effective for improving elementary school students' digital literacy in Coding and Artificial Intelligence learning. Expert validation confirmed that the developed media met pedagogical, technical, and content quality standards, while the practicality evaluation indicated positive student responses and ease of implementation in classroom settings.

The results showed that students who learned using TikTok-based media achieved greater learning gains than those who received conventional instruction. The experimental group's mean score increased from 62.06 to 85.89, whereas the control group improved from 61.24 to 75.65. These findings indicate that the developed media contributed positively to students' development of digital literacy and their understanding of Coding and Artificial Intelligence concepts.

This study contributes to the growing literature on social media-based learning by addressing a research gap in elementary school Coding and Artificial Intelligence education. The primary novelty of this research lies in integrating Deep Learning principles with TikTok's photo-slide feature as a structured microlearning medium. Unlike previous studies that predominantly focused on entertainment-oriented or video-based TikTok content, this study demonstrates the educational potential of photo-slide content for supporting the development of digital literacy and computational thinking among elementary school students. Nevertheless, several limitations should be acknowledged. The study involved a sample of 35 participants from a single elementary school, which is below the recommended minimum of 52 participants identified through a priori power analysis for an independent-samples t-test at 80% power and a large effect size threshold (Faul et al., 2007). Additionally, the study was conducted within a single semester, limiting the assessment of long-term effects on students' digital literacy development. Therefore, the generalizability of the findings should be interpreted with caution, and replication across multiple schools and larger samples is essential before broader instructional recommendations can be made with confidence.

Based on these findings, teachers are encouraged to integrate TikTok-based learning materials into digital literacy instruction, aligning content with curriculum objectives and learning outcomes. Schools and educational policymakers should support the responsible use of social media as an innovative learning resource. Future research should involve larger and more diverse samples, multiple educational settings, and longer intervention periods. Further studies may also compare different TikTok content formats and investigate their long-term effects on students' digital literacy, computational thinking, and academic achievement.

REFERENCES

- Adelia, T., & Rambe, R. N. (2025). Development of comic learning media on student fable texts in junior high school. *Jurnal Konfiks*. <https://doi.org/10.26618/konfiks.v12i2.18302>
- Agustina, D., Ingtyas, F. T., & Waruwu, M. A. S. (2024). Development of learning media based on local context for elementary school students. *Jurnal PAJAR (Pendidikan dan Pengajaran)*, 8(1), 81–88. <https://doi.org/10.33578/pjr.v8i1>

- Akhmad, N. F., Yahya, M., & Jamaluddin, J. (2022). Pengembangan Bahan Ajar Pemrograman Dasar berbasis Media Sosial Instagram sebagai Alternatif Pembelajaran Daring dalam Kondisi Pandemi Covid-19. *Jurnal MEKOM (Media Komunikasi Pendidikan Kejuruan)*, 1-5.
- Akhmad, N. F., Dewi, A. F., & Jufri, J. (2024). Pengembangan media pembelajaran berbasis media sosial TikTok dalam meningkatkan hasil belajar peserta didik di sekolah menengah atas. *Jurnal Riset dan Inovasi Pembelajaran*, 4(3), 2234–2245. <https://doi.org/10.51574/jrip.v4i3.2156>
- Amita, N. (2023). Digital storytelling in increasing elementary school students' mathematics learning motivation. *Jurnal PAJAR (Pendidikan dan Pengajaran)*, 7(3). <https://doi.org/10.33578/pjr.v7i3>
- Amrullah, A., Hidayati, S., & Wijayanti, R. (2025). Conceptualizing deep learning approach in primary education: Integrating mindful, meaningful, and joyful learning. *Journal of Educational Research and Practice*, 3(1), 1–15. <https://doi.org/10.31004/jerp.v3i1.384>
- Asikainen, H., & Gijbels, D. (2017). Do students develop towards more deep approaches to learning during studies? A systematic review on the development of students' deep and surface approaches to learning in higher education. *Educational Psychology Review*, 29(2), 205–234. <https://doi.org/10.1007/s10648-017-9406-6>
- Astuti, Y. T., Zulkardi, Z., & Wiyono, K. (2024). Science learning based on local wisdom: Analysis of multimedia use needs using Canva in Class V elementary school. *Jurnal PAJAR (Pendidikan dan Pengajaran)*, 8(2), 165–174. <https://doi.org/10.33578/pjr.v8i2>
- Caldeiro-Pedreira, M. C., & Rodríguez-Vázquez, A. I. (2023). TikTok and education: A systematic review of didactic applications, educational uses, and guidelines for responsible integration. *Computers & Education*, 196, 104742. <https://doi.org/10.1016/j.compedu.2023.104742>
- Casal-Otero, L., Catala, A., Fernandez-Morante, C., Taboada, M., Cebreiro, B., & Mato-Vazquez, D. (2023). AI literacy in K-12: A systematic literature review. *International Journal of STEM Education*, 10, 29. <https://doi.org/10.1186/s40594-023-00418-7>
- Chiu, T. K. F., & Chai, C. S. (2024). A critical review of teaching and learning artificial intelligence (AI) literacy: Developing an intelligence-based AI literacy framework for primary school education. *Computers and Education: Artificial Intelligence*, 7, 100244. <https://doi.org/10.1016/j.caeai.2024.100244>
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates.
- Criollo-C, S., Guerrero-Arias, A., Jaramillo-Alcázar, Á., & Luján-Mora, S. (2021). Mobile learning technologies for education: Benefits and pending issues. *Applied Sciences*, 11(9), 4111. <https://doi.org/10.3390/app11094111>
- Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, 39(2), 175–191. <https://doi.org/10.3758/BF03193146>
- Feriyanto, F., & Anjariyah, D. (2024). Deep learning approach through meaningful, mindful, and joyful learning: A library research. *Electronic Journal of Education, Social Economics and Technology*, 5(2), 208–212. <https://doi.org/10.33122/ejeset.v5i2.321>
- Fullan, M., Quinn, J., & McEachen, J. (2018). *Deep learning: Engage the world, change the world*. Corwin Press.
- George, D., & Mallery, P. (2003). *SPSS for Windows step by step: A simple guide and reference* (4th ed.). Allyn & Bacon.
- Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, 66(1), 64–74. <https://doi.org/10.1119/1.18809>
-

- Hasnunidah, N., Fadiawati, N., Herlina, K., & Dewi, P. S. (2025). Development and validation of ADI-STEM-based biotechnology e-liveworksheets to enhance student argumentation skills. *Jurnal Pendidikan MIPA*. <https://doi.org/10.23960/jpmipa.v26i4.pp2224-2245>
- Herlinawati, H., Marwa, M., Ismail, N., Junaidi, & Situmorang, D. D. B. (2024). The integration of 21st century skills in the curriculum of education. *Heliyon*, 10(15), e35148. <https://doi.org/10.1016/j.heliyon.2024.e35148>
- Hu, H., & Du, K. (2022). TikTok in mobile-assisted English language learning: An exploratory study. *International Journal of Information and Education Technology*, 12(12), 1316–1323. <https://doi.org/10.18178/ijiet.2022.12.12.1742>
- Kementerian Pendidikan Dasar dan Menengah. (2025). *Panduan pembelajaran mendalam: Bermakna, menyenangkan, dan reflektif*. Kemendikdasmen.
- Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi. (2025). *Naskah akademik pembelajaran koding dan kecerdasan artifisial untuk pendidikan dasar dan menengah*. Kemendikbudristek.
- Khlaif, Z. N., & Salha, S. (2021). Using TikTok in education: A form of micro-learning or nano-learning? *Interdisciplinary Journal of Virtual Learning in Medical Sciences*, 12(3), 213–218. <https://doi.org/10.30476/ijvlms.2021.91215.1087>
- Khodarsih, D., Sari, M., & Perez, C. (2025). Development of the magic cube numbers educational tool to enhance symbolic thinking skills in children aged 4–5 years. *JECET*. <https://doi.org/10.64840/jecet.v1i1.16>
- Kovac, V. B., Nome, D. Ø., Jensen, A. R., & Skreland, L. L. (2023). The why, what and how of deep learning: Critical analysis and additional concerns. *Acta Didactica Norden*, 17(1). <https://doi.org/10.1080/20004508.2023.2194502>
- Lee, Y. J. (2023). Language learning affordances of Instagram and TikTok. *Innovation in Language Learning and Teaching*, 17(2), 408–423. <https://doi.org/10.1080/17501229.2022.2087419>
- Lobo-Quintero, R., Hernández-Leo, D., Taibi, D., Theophilou, E., & Sánchez-Reina, R. (2024). Analyzing factors influencing student engagement in an educative social media platform. *Behaviour & Information Technology*, 44(11), 2697–2712. <https://doi.org/10.1080/0144929X.2024.2406259>
- Long, D., & Magerko, B. (2020). What is AI literacy? Competencies and design considerations. *Proceedings of the CHI Conference on Human Factors in Computing Systems*, 1–16. <https://doi.org/10.1145/3313831.3376727>
- Manca, S. (2020). Snapping, pinning, liking or texting: Investigating social media in higher education beyond Facebook. *The Internet and Higher Education*, 44, 100707. <https://doi.org/10.1016/j.iheduc.2019.100707>
- Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). Cambridge University Press. <https://doi.org/10.1017/CBO9780511811678>
- Mirza, A., Pasaribu, R. L., & Simarmata, J. E. (2024). Designing student worksheets (LKM) based on the rigorous teaching and learning (RTL) model. *RANGE: Jurnal Pendidikan Matematika*. <https://doi.org/10.32938/jpm.v6i1.5624>
- Nduru, M., Ali, A., & Rita, R. (2025). The feasibility of saga text teaching materials utilizing a website for assignments and resources in class X at Azizi Islamic Senior High School. *Indonesian Journal of Education Research (IJoER)*. <https://doi.org/10.37251/ijoer.v6i1.1470>
- Ng, D. T. K., Leung, J. K. L., Chu, S. K. W., & Qiao, M. S. (2021). Conceptualizing AI literacy: An exploratory review. *Computers and Education: Artificial Intelligence*, 2, 100041. <https://doi.org/10.1016/j.caeai.2021.100041>
- Ningsih, S., Kuntarto, E., & Kurniawan, A. R. (2020). Teachers' problems in using information and communication technology (ICT) and its implications in elementary schools. *Jurnal PAJAR (Pendidikan dan Pengajaran)*, 4(3), 518–524. <https://doi.org/10.33578/pjr.v4i2.7964>

- Oktaviani, D. I., Gusnardi, G., Caska, C., Suarman, S., & Indrawati, H. (2025). Enhancing financial literacy through educational game-based learning materials. *Al Qalam: Jurnal Ilmiah Keagamaan dan Kemasyarakatan*. <https://doi.org/10.35931/aq.v19i1.3994>
- Park, W., & Ko, Y. (2022). A visual interface using Use-Modify-Create scaffolding for understanding AI planning concepts in elementary education. *Computers & Education*, 183, 104491. <https://doi.org/10.1016/j.compedu.2022.104491>
- Pellegrino, J. W., & Hilton, M. L. (Eds.). (2012). *Education for life and work: Developing transferable knowledge and skills in the 21st century*. The National Academies Press. <https://doi.org/10.17226/13398>
- Puja, I. B. P. (2024). The mediating role of online learning motivation in the influence of service quality, social media usage, and pedagogical teaching competence of teachers on student learning satisfaction. *Cogent Social Sciences*, 10(1), 2396934. <https://doi.org/10.1080/23311886.2024.2396934>
- Rahayu, D., Daeng, K., & Hajrah, H. (2025). Development of formative assessment based on educational games integrated with QR code on popular scientific article material. *Sawerigading*. <https://doi.org/10.26499/sawer.v31i1.1569>
- Rambe, A., Juliarti, J., Dewi, E. R., & Anggraini, Y. (2024). The influence of inquiry learning models based on audio visual media on student learning outcomes. *Jurnal PAJAR (Pendidikan dan Pengajaran)*, 9(1). <https://doi.org/10.33578/pjr.v9i1.10014>
- Rizka, M., Permatasari, S., Sari, F. A., & Isjoni, M. R. (2024). Development of case study based learning strategy textbook to improve critical thinking ability of university students. *Al-Ishlah: Jurnal Pendidikan*. <https://doi.org/10.35445/alishlah.v16i3.4743>
- Salam, U., Ikramunnisa, E., Rezeki, Y., & Queiroz, C. (2025). Social media for English teaching and learning: A bibliometric analysis of research publications (2012–2023). *International Journal of Pedagogy and Teacher Education*. <https://doi.org/10.20961/ijpte.v9i1.87565>
- Sari, I. K., Putra, Z. H., Witri, G., Noviana, E., Kurniaman, O., & Mulyani, E. A. (2024). The use of interactive e-modules to increase students' learning outcomes in elementary school. *Jurnal PAJAR (Pendidikan dan Pengajaran)*, 8(2), 199–208. <https://doi.org/10.33578/pjr.v8i2>
- Setyaningsih, R., Abidin, Z., & Darmawan, I. P. A. (2024). Are teachers ready to adopt deep learning pedagogy? The role of technology and 21st-century competencies amid educational policy reform. *Education Sciences*, 15(10), 1344. <https://doi.org/10.3390/educsci15101344>
- Sobaih, A. E. E., Palla, I. A., & Baquee, A. (2022). Social media use in e-learning amid COVID-19 pandemic: Indian students' perspective. *International Journal of Environmental Research and Public Health*, 19(9), 5380. <https://doi.org/10.3390/ijerph19095380>
- Su, J., Zhong, Y., & Ng, D. T. K. (2023). Artificial intelligence (AI) learning tools in K-12 education: A scoping review. *Journal of Computers in Education*, 11, 381–428. <https://doi.org/10.1007/s40692-023-00304-9>
- Tarifa-Rodriguez, A., Virues-Ortega, J., & Perez-Bustamante, A. (2024). Quantitative indices of student social media engagement in tertiary education: A systematic review and a taxonomy. *Journal of Behavioral Education*, 33, 769–797. <https://doi.org/10.1007/s10864-023-09516-6>
- Thiagarajan, S., Semmel, D. S., & Semmel, M. I. (1974). *Instructional development for training teachers of exceptional children: A sourcebook*. Indiana University / Leadership Training Institute on Special Education.
- Tinenti, Y. R., Tangi, H., Hayon, V. H. B., & Wariyani, T. (2024). The effect of a PowerPoint-based collaborative learning model on elementary students' learning outcomes. *Jurnal PAJAR (Pendidikan dan Pengajaran)*, 8(2), 135–148. <https://doi.org/10.33578/pjr.v8i2>
- UNESCO. (2018). *A Global Framework of Reference on Digital Literacy Skills for Indicator 4.4.2*.
-



- Valtonen, T., Leppänen, U., Hinkka, T., Sointu, E., Smits, A., & Tondeur, J. (2021). The role of digital informal learning in the relationship between students' digital competence and academic engagement. *Journal of Computer Assisted Learning*, 37(4), 1154–1166. <https://doi.org/10.1111/jcal.12581>
- Vuorikari, R., Kluzer, S., & Punie, Y. (2022). *DigComp 2.2: The Digital Competence Framework for Citizens*.
- Wang, Z., Cai, L., Chen, Y., Li, H., & Jia, H. (2021). The teaching design methods under educational psychology based on deep learning and artificial intelligence. *Frontiers in Psychology*, 12, 711489. <https://doi.org/10.3389/fpsyg.2021.711489>
- Weng, C., Chen, C., & Ai, X. (2023). A pedagogical study on promoting students' deep learning through design-based learning. *International Journal of Technology and Design Education*, 33, 1653–1674. <https://doi.org/10.1007/s10798-022-09789-4>