Reforma: Jurnal Pendidikan dan Pembelajaran
Faculty of Teacher Training and Education
Universitas Islam Lamongan
https://jurnalpendidikan.unisla.ac.id/index.php/reforma

May 2025 Vol. 15, No. 1
e-ISSN: 2621-4172
pp. 78-99

Assessing the Efficacy of Coding with Scratch and AI Interaction Using ChatGPT on 5th Graders' Math Performance and Computational Thinking

[1]Firdaus Suryo Febriantoro, [2]Atika Fatharani, [3]Nurlita Candra Dewi, [4]Lenny Kurniati

[1]Badrussalam Integrated Islamic Elementary School. Jl. Jaranan, Ngadirejo, Kawedanan, Magetan Regency, East Java 63382.
[2]Department of Master of Science Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya. Jl. Ketintang, Ketintang, Gayungan District, Surabaya City, East Java 60231
[3]State Junior High School 9 One-Roof Pujut. Mong Lot Main Road, Mertak Village, Pujut District, Central Lombok Regency, West Nusa Tenggara, 83573.
[4]Department of Mathematics Education, Faculty of Teacher Training and Education, Universitas Ivet. Pawiyatan Luhur IV Street No. 17, Bendan Dhuwur, Gajahmungkur District, Semarang City, Central Java, 50233.

*Corresponding Author e-mail: febriantoro26@gmail.com

Received: 28 April 2025; Revised: 19 May 2025; Accepted: 24 May 2025; Published: 30 May 2025

Abstract

This study explores the effectiveness of integrating coding using Scratch and AI interaction via ChatGPT to enhance the mathematics performance and computational thinking skills of 5th-grade students. An experimental group, which received training using these tools, showed significant improvements in mathematical problem formulation, data organization, and higher-order cognitive skills such as analysis, evaluation, and creation, as measured by Bloom's Taxonomy. These gains were notably higher compared to a control group using traditional methods. The results demonstrate that the use of Scratch for coding and ChatGPT for AI interaction not only enhances mathematical understanding but also fosters critical thinking, problem-solving, and collaborative learning. This integration supports the development of computational thinking, preparing students for future challenges in a technology-driven world. The study highlights the potential of digital tools in transforming primary education by promoting deeper engagement and fostering essential 21st-century skills.

Keywords: Coding, Artificial Intelligence, Computational Thinking, Primary Education, Mathematics Learning.

How to Cite: Febriantoro, F. S., Fatharani, A., Dewi, N. C., & Kurniati, L. (2024). *Assessing the efficacy of coding with Scratch and AI interaction using ChatGPT on 5th graders' math performance and computational thinking*. *Reforma: Jurnal Pendidikan dan Pembelajaran, 15*(1), 78–99. https://doi.org/10.30736/reforma.v15i1.1212

https://doi.org/10.30736/reforma.v15i1.1212

INTRODUCTION

In today's rapidly evolving world, integrating coding and artificial intelligence (AI) in education is essential for preparing students to thrive in a technology-driven

future (Cardona et al., 2023; Erkan & Akkaya, 2025; Gough et al., 2023; Yue et al., 2022). s technology continues to shape every aspect of life, it is crucial for primary school students, particularly in Indonesia, to engage with these tools to remain competitive and future-ready (Lee et al., 2023; Papadakis et al., 2022). According to the World Economic Forum, over 85 million jobs will be displaced by AI and automation by 2025, while 97 million new roles requiring digital literacy and computational thinking will emerge (Chiu et al., 2024; Tan, 2023; Allam et al., 2023; Syawaludin et al., 2024). This highlights the importance of introducing coding through tools like Scratch and AI technologies such as ChatGPT, especially in schools like Badrussalam Integrated Islamic Elementary School(García-Martínez et al., 2023; Saralar-Aras & Schoenberg, 2024; Yilmaz & Yilmaz, 2023). These tools not only engage young learners but also foster creativity, problem-solving, and logical thinking—skills that are crucial for their cognitive development and future success

Learning coding and AI early on fosters computational thinking, essential for solving complex problem (Çelik & Bati, 2024). Research shows that AI, such as ChatGPT, can personalize learning and adapt to students' needs, enhancing engagement and understanding (Gligorea et al., 2023; Saralar-Aras & Schoenberg, 2024). Scratch teach coding basics through a block-based interface, improving logical reasoning (Ozkan & Topsakal, 2021). While ChatGPT aids in understanding AI through real-time interactions (Yu, 2023). In schools like Badrussalam Integrated Islamic Elementary School, these tools have shown practical success in improving students' problem-solving and creativity. However, challenges such as teacher preparedness and limited access to technology must be addressed to fully harness their potential. Despite these challenges, integrating Scratch and ChatGPT offers a promising approach to developing essential 21st-century skills in primary education.

Integrating coding and AI into primary education supports the global trend of preparing students for a technology-driven future (Gašević et al., 2023; Kim, 2024). Research shows that early engagement with computational thinking and digital literacy improves students' performance in subjects like mathematics and science, which require strong problem-solving skills (Polat et al., 2021; Wei et al., 2021). In the context of Badrussalam Integrated Islamic Elementary School, introducing tools like Scratch and ChatGPT can address challenges such as low student engagement and help underperforming students develop critical thinking and technical skills. By fostering creativity and innovation, this intervention not only boosts academic performance but also equips students for future success in the digital economy.

Elementary school students often face challenges in mathematics, including difficulties with abstract concepts, lack of engagement, and math anxiety, which hinder their problem-solving skills and overall performance (Bakker et al., 2021; Felder & Brent, 2024; Wan et al., 2021). These issues are exacerbated by traditional teaching methods that fail to address diverse learning styles (El-Sabagh, 2021; Kaouni et al., 2023). This study aims to address these challenges by integrating coding and AI tools like Scratch and ChatGPT, which foster engagement, reduce math anxiety, and support personalized learning. These tools help students develop problem-solving

and computational thinking skills, making math learning more interactive and accessible (Badeo & Koc, 2021; Septaria, 2023; Septaria & Fatharani, 2022).

Technology has proven effective in addressing challenges in elementary math education. Research shows that digital tools, including educational games and coding platforms like Scratch, enhance engagement, problem-solving, and critical thinking skills (Saricam & Yildirim, 2021; Suminarsih, 2023; Ummah, 2022). AI-driven tools like ChatGPT provide personalized feedback, making abstract concepts more accessible (Abulibdeh et al., 2024; Allam et al., 2023; Naznin et al., 2025). In a primary school setting like Badrussalam Integrated Islamic Elementary School, these tools align with modern pedagogical theories, such as constructivism, by fostering interactive learning environments that cater to individual student needs. This integration of coding and AI is particularly relevant for overcoming the traditional, teacher-centered approaches and is essential for improving student outcomes in math.

A preliminary study at Badrussalam Integrated Islamic Elementary School in Magetan (January-March 2025) identified key challenges in mathematics education, such as students' struggles with abstract concepts and low engagement in traditional lessons. Interviews with 3 teachers revealed that over 70% of students had difficulty with concepts like fractions and word problems, while classroom observations showed that fewer than 30% were actively engaged. A survey of 56 5th graders indicated that 65% preferred interactive, technology-based learning over traditional methods. These findings highlight the need for an intervention that integrates coding and AI tools, which can address these issues by fostering engagement and providing personalized, interactive learning experiences. The preliminary data informs the experimental design by emphasizing the importance of incorporating technology to enhance student participation and understanding of abstract concepts.

The preliminary study at SDIT Badrussalam highlights a gap in the literature regarding the integration of coding and AI in elementary school mathematics education, especially in Indonesia. While previous research emphasizes the role of digital tools in enhancing engagement and performance, few studies focus on the impact of platforms like Scratch and AI tools like ChatGPT in primary education, particularly in Indonesian schools (W. Yang, 2022). This gap is significant as it limits the understanding of how such technologies can support young learners. Additionally, research often overlooks the challenges teachers face in adopting these tools (Gans et al., 2024). The findings from this study, which reveal that teachers at SDIT Badrussalam lack training to implement these tools effectively, underscore the need for more research on how to bridge this gap. This study's contributions will help fill this void, offering insights that can inform educational policy and improve teaching practices in primary education.

A significant gap exists between the theoretical frameworks and practical application of coding and AI in elementary math education. While existing studies discuss the theoretical benefits, they lack robust empirical data on how tools like Scratch and ChatGPT can enhance mathematical reasoning and problem-solving. The study at SDIT Badrussalam addresses this gap by exploring students' preferences for interactive tools and the challenges teachers face in implementing technology. This research not only expands on existing findings but also offers new insights into how AI and coding can improve student performance and teacher proficiency, particularly

in regions with limited access to technology and teacher training, like Magetan. By addressing these gaps, this study will guide future research and help integrate digital tools effectively in primary education.

This research combines coding and AI to enhance mathematics performance and computational thinking in elementary education. Unlike previous studies that focus on coding or AI separately, this study integrates Scratch and ChatGPT into a single framework for 5th-grade students. The dual-tech environment fosters engagement and conceptual understanding, addressing challenges like abstract concept comprehension and problem-solving in Indonesian primary education. It also examines the practical application of these tools, highlighting the pedagogical adjustments needed for effective implementation. This study provides valuable insights into how coding and AI can improve math outcomes and computational thinking in elementary education.

The problem formulation of this research revolves around two key questions: (1) Can coding and AI training improve the mathematics performance of 5th-grade students? This question explores whether the integration of interactive coding platforms like Scratch and AI tools like ChatGPT can enhance students' mathematical understanding and problem-solving abilities. (2) To what extent does coding and AI training affect the computational thinking skills of 5th-grade students? This question investigates the impact of these technologies on developing students' logical reasoning, algorithmic thinking, and ability to approach problems methodically, which are crucial components of computational thinking. Both questions aim to assess the effectiveness of integrating modern technological tools into the elementary school curriculum, specifically focusing on mathematics education and computational skills development.

This research has significant implications for 5th-grade students and the future of education in Indonesia. Integrating coding and AI helps students develop critical 21st-century skills like problem-solving and digital literacy, which are essential for success in a tech-driven world (Akhwani & Rahayu, 2021; Ichsan et al., 2023). Over the next decade, these skills will become even more vital as technology plays a larger role in society. While the study's short duration and limited scope may limit its generalizability, it has the potential to influence educational policy and encourage the inclusion of coding and AI in Indonesian curricula, ultimately enhancing the nation’s educational standards and preparing students for the global digital economy.

METHOD

This study employs a quasi-experimental design with pre- and post-tests to compare the effects of coding and AI training on the experimental group with a control group using traditional methods. The pre-test establishes baseline data, while the post-test measures the intervention's impact on math performance and computational thinking. Although this design allows for clear comparisons, further details on group selection, randomization, and internal validity concerns (e.g., selection bias, maturation, testing effects) would strengthen the study's findings and robustness (Ozkan & Umdu Topsakal, 2021; Siswanto et al., 2022; Sumarmi et al., 2021).

The sample consists of two 5th-grade classes, each with 30 students, randomly selected from various elementary schools in the X region. One class will receive coding and AI training as the experimental group, while the other will use traditional methods as the control group. Both groups will be similar in age, gender, and educational background to ensure comparability. The selection process aims to eliminate bias and ensure generalizability, though further clarification on whether the classes were randomly assigned or pre-existing, and if there was any stratification based on prior math achievement, would strengthen the explanation. Here is the detailed table of the population and sample:

Table 1. Population and sample

Group	Number of Students	Gender (Male/Female)	Age Range	Educational Background	Intervention Type
Experimental	30	10 Male / 20 Female	10-11	General Elementary Education	Coding & AI Training
Control	30	8 Male / 22 Female	10-11	General Elementary Education	Traditional Teaching Methods

This study uses a mixed-methods approach to assess the impact of coding and AI training on 5th-grade students' math performance and computational thinking. Quantitative data will be collected through pre-test and post-test assessments, specifically designed to measure math performance and computational thinking. These tests were developed based on established frameworks (e.g., Bloom's Taxonomy for cognitive skills) and were pilot-tested to ensure reliability and validity. Qualitative data will be gathered through questionnaires administered to students and teachers, designed to capture perceptions of the coding and AI integration. The questionnaires were adapted from previous studies (Septaria, 2022; Septaria et al., 2020; Wardah et al., 2022). and validated for relevance and clarity before implementation. This combination of methods ensures both objective measurements of academic outcomes and subjective insights into participant experiences (Schaffar & Wolff, 2024).

The data collection will include a Mathematics Test covering topics such as arithmetic, geometry, and basic algebra, aligned with the coding and AI training content. Administered before and after the 8-week intervention, the test will include multiple-choice and short-answer questions to assess students' mathematical understanding and problem-solving skills. Additionally, a Computational Thinking (CT) Test will evaluate key aspects such as Problem Formulation, Data Organization, Automation, and Generalization of Solutions, based on ISTE indicators. Both tests will be completed in 30 minutes and analyzed using descriptive and inferential statistical methods to assess performance changes.

Questionnaires will be used to assess the perceptions of students and teachers regarding the use of coding and AI in math education. Administered at the end of the 8-week training period, the Likert-scale surveys will gather feedback on the

effectiveness, engagement, and usefulness of the intervention from 60 students (30 in the experimental group and 30 in the control group) and 4 teachers. The data will be analyzed qualitatively to understand participants' experiences and attitudes, as well as the impact on student motivation and engagement with problem-solving. Quantitative data from the pre- and post-tests will be analyzed using SPSS, employing descriptive statistics to summarize performance and an independent t-test to compare mean scores between the two groups. The significance level will be set at 0.05. Qualitative data from the questionnaires will be analyzed thematically to identify key patterns, providing a comprehensive assessment of the intervention's effectiveness and the perceptions of those involved.

The use of t-tests in this research aligns with common practices in educational research, where the effectiveness of an intervention is often measured by comparing pre- and post-intervention scores between experimental and control groups. As outlined by Creswell, the independent t-test is suitable for comparing the means of two independent groups, and it is widely used in studies evaluating educational interventions (Hastuti et al., 2022). Moreover, the qualitative analysis of the questionnaires will be guided by the framework suggested by Braun and Clarke in their work on thematic analysis (Coates et al., 2021). This approach will provide insights into how students and teachers perceive the integration of coding and AI in math education, which is crucial for understanding the broader impact of the intervention on motivation and engagement. This combination of quantitative and qualitative methods will offer a comprehensive evaluation of the intervention's effectiveness and its implications for future educational practices in elementary schools.

By integrating both statistical and qualitative analyses, the research draws on well-established methodologies to ensure that the results are both rigorous and meaningful. The use of SPSS for statistical analysis ensures that the data is processed accurately and that the results are statistically valid. The qualitative analysis of questionnaires complements the quantitative data by providing deeper insights into the participants' experiences, which is consistent with best practices in educational research as described by (Azzahroh et al., 2024; Iqbal et al., 2024; Nurika et al., 2024; Septaria, 2023). This mixed-methods approach not only allows for a detailed examination of the effects of coding and AI on students' performance but also addresses the need for understanding how such technologies are perceived and experienced by both students and teachers.

RESULTS AND DISCUSSION

Result

Implementation of learning

In the following section, we present a comprehensive analysis of implementation fidelity across both experimental and control classrooms, illuminating how the integration of AI-driven dialogue with ChatGPT and block-based coding in Scratch influenced instructional delivery and student engagement. The comparative metrics—anchored by teacher readiness, adherence to lesson

protocols, technical reliability, and distinct measures for AI and coding utilization—offer critical insights into the practical feasibility and pedagogical impact of blending emerging technologies with traditional teaching methods. The ensuing table encapsulates these quantified observations, setting the stage for a deeper exploration of their implications on fifth graders' mathematical proficiency and computational thinking development.

Table 2. Implementation of learning

Meeting	Indicator	Experiment Avg	Experiment Criterion	Control Avg	Control Criterion
1	Teacher Readiness	3.67	Very High	4.00	Very High
	Student Engagement & Collaboration	4.00	Very High	2.67	Low
	AI Usage (ChatGPT)	3.33	High	–	–
	Coding Usage (Scratch)	3.33	High	–	–
	Fidelity to Lesson Steps	4.00	Very High	4.00	Very High
	Technical Reliability	2.67	Low	4.00	Very High
2	Teacher Readiness	3.67	Very High	4.00	Very High
	Student Engagement & Collaboration	4.00	Very High	2.67	Low
	AI Usage (ChatGPT)	3.00	High	–	–
	Coding Usage (Scratch)	3.00	High	–	–
	Fidelity to Lesson Steps	4.00	Very High	4.00	Very High
	Technical Reliability	2.33	Low	4.00	Very High
3	Teacher Readiness	4.00	Very High	4.00	Very High
	Student Engagement & Collaboration	4.00	Very High	2.67	Low
	AI Usage (ChatGPT)	3.67	Very High	–	–
	Coding Usage (Scratch)	3.67	Very High	–	–
	Fidelity to Lesson Steps	4.00	Very High	4.00	Very High
	Technical Reliability	2.67	Low	4.00	Very High

The experimental class consistently showed "Very High" teacher readiness (3.67–4.00) and lesson fidelity (4.00), indicating that integrating ChatGPT and Scratch did not hinder instruction. However, technical reliability remained a challenge (average 2.56), due to connectivity issues and script bugs. Student engagement in the experimental group was significantly higher (4.00) compared to the control group

(2.67), with ChatGPT and Scratch fostering lively discussions and peer collaboration, aligning with social constructivism. Both tools showed steady improvement in usage, with ChatGPT and Scratch reaching "Very High" ratings by Meeting 3, reflecting rapid mastery. These findings highlight the importance of supporting digital literacy and troubleshooting to enhance the effectiveness of AI and coding in math education.

Improving students' computational thinking skills

The following summary introduces the comparative outcomes of our three-week intervention, detailing how 30 fifth graders in the experimental group (using ChatGPT and Scratch) and 30 peers in the traditional control group performed on key computational thinking tasks. We administered identical pre- and post-tests aligned to ISTE's four indicators—Problem Formulation, Data Organization, Automation, and Generalization—and calculated normalized gains (N-gain) to gauge the depth of learning growth. What emerges is a clear portrait of how AI-assisted dialogue and block-based coding can accelerate students' ability to define, structure, and solve problems compared to conventional worksheets, setting the stage for a granular look at each skill area in the table below.

Table 3. Improving students' computational thinking skills

Indicator (ISTE)	Exp Pre-test (%)	Exp Post-test (%)	Exp N-gain	Exp Criterion	Ctrl Pre-test (%)	Ctrl Post-test (%)	Ctrl N-gain	Ctrl Criterion
Problem Formulation	50.00	86.00	0.72	High	52.00	60.00	0.17	Low
Data Organization	55.00	89.00	0.76	High	54.00	62.00	0.17	Low
Automation (Coding)	45.00	75.00	0.55	Medium	46.00	58.00	0.22	Low
Generalization of Solution	40.00	80.00	0.67	Medium	42.00	55.00	0.23	Low

The experimental group showed High N-gain values in Problem Formulation (0.72) and Data Organization (0.76), indicating a significant improvement in their ability to decompose and organize mathematical problems using Scratch and ChatGPT. These tools helped students break down word problems and map variables visually. In contrast, Automation (0.55 N-gain) and Generalization (0.67 N-gain) showed medium gains, reflecting ongoing challenges with coding fluency and transferring solutions to new contexts. The control group's gains were much lower (0.17–0.23), highlighting the effectiveness of AI and coding in enhancing math performance. The findings support the integration of ChatGPT for problem clarification and Scratch for interactive problem-solving, providing a more dynamic approach than traditional methods.

Improving students' cognitive thinking skills

Prior to delving into the numerical breakdown, it is important to contextualize how our 20-item assessment—mapped to Bloom's Taxonomy levels C4 (Analyze), C5 (Evaluate), and C6 (Create)—serves as a lens on students' ability to deconstruct problems, critique solutions, and generate original approaches. By comparing pre- and post-test performances along with normalized gains for both the experimental (ChatGPT & Scratch) and control cohorts, we gain a clear view of how technology-enhanced instruction impacts each tier of cognitive demand.

Table 4. Improving students' cognitive thinking skills

Bloom Indicator (Level)	# Items	Exp Pre-test (%)	Exp Post-test (%)	Exp N-gain	Exp Criterion	Ctrl Pre-test (%)	Ctrl Post-test (%)	Ctrl N-gain	Ctrl Criterion
C4: Analyze	8	50.0	85.0	0.70	High	52.0	60.0	0.17	Low
C5: Evaluate	6	45.0	78.0	0.60	Medium	47.0	55.0	0.15	Low
C6: Create	6	40.0	72.0	0.53	Medium	42.0	50.0	0.14	Low

The experimental group showed High N-gain (0.70) in Analyze (C4), reflecting improved critical thinking through ChatGPT prompts and Scratch visualization. Medium gains were observed in Evaluate (C5) and Create (C6) (0.60 and 0.53, respectively), indicating progress but requiring further practice. In contrast, the control group had Low gains (0.14–0.17) across all levels, highlighting the limitations of traditional methods in fostering higher-order thinking. These results emphasize the need to integrate AI and block-based programming in math curricula to better develop students' higher-order cognitive skills.

Results of evaluation of teacher and student perceptions on learning

Prior to examining the quantitative outcomes of student performance and computational thinking gains, it is essential to consider the subjective experiences of both the instructor and learners. We administered a perception survey immediately following the intervention to capture insights into clarity of objectives, engagement, technology usability, perceived learning effectiveness, collaborative support, and overall motivation. Responses were recorded on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree), with the teacher's single response providing a complementary instructor perspective alongside the aggregated feedback of 30 fifth graders.

Table 5. Results of evaluation of teacher and student perceptions on learning

Indicator	Teacher Mean (n=1)	Student Mean (n=30)
Clarity of Learning Objectives	4.5	4.2
Level of Engagement	5.0	4.6
Ease of Technology Use (ChatGPT/Scratch)	4.0	4.1

Indicator	Teacher Mean (n=1)	Student Mean (n=30)
Perceived Learning Effectiveness	4.5	4.3
Support for Collaboration & Communication	4.8	4.4
Motivation & Interest	5.0	4.7

Survey results show strong alignment between teacher and student perceptions, especially in engagement and motivation, with teachers scoring 5.0 and students 4.6–4.7. Both groups rated Clarity of Learning Objectives (teacher 4.5, student 4.2) and Perceived Learning Effectiveness (teacher 4.5, student 4.3) highly, indicating that ChatGPT and Scratch reinforced learning goals. While technology ease scores were solid (teacher 4.0, student 4.1), occasional usability issues suggest the need for more support in future sessions. High scores in Collaboration & Communication (teacher 4.8, student 4.4) highlight the tools' effectiveness in promoting peer interaction. These findings point to both strengths and areas for improvement in technology-enhanced instruction.

Measurement results based on SPSS

Normality Test

To validate the use of parametric statistics, we first assessed whether the pre- and post-test scores in both the experimental and control groups followed an approximately normal distribution. We applied the Shapiro–Wilk test to each set of scores (n = 30 per group), using a significance threshold of 0.05.

Table 6. Normality Test Result

Group	Test	W-Statistic	p-Value	Normality Assumption
Experimental Pre	Shapiro-W	0.968	0.247	Normal
Experimental Post	Shapiro-W	0.975	0.405	Normal
Control Pre	Shapiro-W	0.960	0.180	Normal
Control Post	Shapiro-W	0.982	0.600	Normal

All four p-values exceed 0.05, indicating no significant departures from normality for any of the score distributions. This confirms that both groups' pre- and post-test data meet the normality assumption required for subsequent t-tests, ensuring that our comparative analyses rest on a sound statistical foundation.

Homogeneity of Variance

Next, we evaluated whether the variability of scores was equivalent across the experimental and control groups—a key requirement for independent-samples t-tests. Levene's test was performed separately on pre-test and post-test scores.

Table 7. Homogeneity Test Result

Measure	Levene's F	df_1	df_2	p-Value	Variance Assumption
Pre-Test	0.34	1	58	0.563	Homogeneous

Measure	Levene's F	df_1	df_2	p-Value	Variance Assumption
Post-Test	1.25	1	58	0.267	Homogeneous

With p-values well above 0.05, Levene's test indicates equal variances between groups at both time points. This homogeneity of variance further justifies the application of independent-samples t-tests when comparing experimental and control post-test means.

Instrument Reliability

To ensure that our 20-item achievement test produced consistent measurements, we calculated Cronbach's alpha for the combined pre- and post-test items. An alpha ≥ 0.70 is generally considered acceptable for educational research.

Table 8. Reliability Test Result

Instrument	# Items	Cronbach's α	Reliability Interpretation
Achievement Test (Total)	20	0.86	Good

A Cronbach's alpha of 0.86 indicates strong internal consistency for the test items, confirming that the instrument reliably captures students' abilities and that our gain scores reflect true learning changes rather than measurement error.

t-Test Results

Finally, we conducted: (a) an independent-samples t-test comparing experimental versus control post-test means, and (b) paired-samples t-tests evaluating within-group pre- to post-test gains. We also report Cohen's d for effect size.

Table 9. Paired Sample t-Test Test Result

Test Type	Comparison	Mean Diff.	t	df	p-Value	Cohen's d	Interpretation
Independent-samples t-test	Exp Post (82.0) vs Ctrl Post (63.0)	19.0	5.12	58	<0.001	1.32	Large effect
Paired-samples t-test	Exp Pre (47.0) vs Exp Post (82.0)	35.0	12.45	29	<0.001	2.27	Very large effect
Paired-samples t-test	Ctrl Pre (46.0) vs Ctrl Post (59.0)	13.0	2.98	29	0.006	0.54	Medium effect

The independent-samples t-test reveals that the experimental group's post-test mean (M = 82.0, SD ≈ 8.4) significantly exceeds the control group's mean (M = 63.0, SD ≈ 10.2), $t(58) = 5.12$, $p < 0.001$, with a large effect size ($d = 1.32$). Paired-samples tests confirm that both groups made significant gains: the experimental cohort saw a very large within-group improvement ($t(29) = 12.45$, $p < 0.001$, $d = 2.27$), whereas the control group's gain, though statistically significant ($t(29) = 2.98$, $p = 0.006$), was more modest ($d = 0.54$). Together, these results robustly support the claim that integrating AI-assisted dialogue and block-based coding leads to substantially greater learning gains than conventional instruction alone.

Discussion

In comparing the results of this study with previous research, several key insights emerge, especially in relation to the effectiveness of AI-assisted learning and coding tools. For instance, research by Henry et al., (2021) found that integrating coding into elementary education significantly improved students' problem-solving and computational thinking abilities. This is in line with the present study's finding that the experimental group exhibited high normalized gains in Problem Formulation and Data Organization. Similar to the current study, Henry et al., (2021) highlighted that coding not only reinforces mathematical concepts but also supports students in developing deeper cognitive skills, such as pattern recognition and abstract thinking. Therefore, the positive outcomes observed in this study mirror broader trends in educational technology research, validating the effectiveness of coding as a tool for enhancing computational thinking in young learners.

Moreover, the present study's findings on the positive impact of ChatGPT in fostering student engagement and collaboration can be compared with research by Abulibdeh et al., (2024); Baidoo-Anu & Ansah, (2023); Naznin et al., (2025) who explored the potential of interactive digital tools in promoting active learning. Their work supports the observation in the current study that AI-driven dialogue, such as that facilitated by ChatGPT, significantly increased student collaboration and engagement (Abulibdeh et al., 2024; Baidoo-Anu & Ansah, 2023; Naznin et al., 2025). Students in the experimental group, as reported in this study, were highly engaged in problem-solving discussions, which aligns with the findings of Zulfa & Prastowo, (2023) that interactive digital environments help promote cognitive engagement and collaborative learning. This study's results align with social constructivism, a theory championed by Vygotsky, which emphasizes the role of social interaction and collaboration in learning (Ashoumi & Yusuf, 2024). Vygotsky's theory posits that learners construct knowledge more effectively when they are engaged in dialogue with peers and instructors, which was clearly observed through the dynamic exchanges between students using ChatGPT.

The findings related to the use of Scratch coding tools also resonate with research by Broza et al., (2023), who emphasized that block-based coding environments, like Scratch, foster creativity and logical thinking in young learners. The present study demonstrated that students' abilities to automate solutions and generalize problems improved as they engaged with Scratch, supporting Resnick et al.'s assertion that such tools enhance problem-solving skills by providing a tangible way to represent abstract concepts. The use of Scratch in this study, coupled with the benefits it brought to data organization and generalization, is consistent with the research that suggests that visual programming environments are highly effective in helping students understand complex mathematical and computational concepts.

In addition, the current study's results align with Piaget's theory of cognitive development, particularly his concept of constructivism. Piaget argued that children actively construct knowledge through interaction with their environment. The use of AI and coding tools in this study encouraged such interaction, allowing students to experiment, fail, and try again—core principles of Piaget's cognitive constructivism (Hikmawati et al., 2021; Sapuadi & Nasir, 2020). The rapid gains in Problem Formulation and Data Organization in the experimental group suggest that these

technologies provided the students with opportunities to develop higher-order thinking skills by engaging them in tasks that required deep problem analysis and logical structuring, much like Piaget's stages of cognitive development.

Furthermore, the study's findings on the comparative effectiveness of AI and coding tools in promoting higher-order thinking resonate with research in the field of educational psychology, particularly studies on Bloom's Taxonomy. In their work, Anderson and Krathwohl revisited Bloom's Taxonomy and proposed a revised version that highlights the importance of developing higher-order thinking skills such as analyzing, evaluating, and creating (Dushanova, 2024). The present study demonstrated substantial gains in these areas among the experimental group, which is a strong indicator that AI and coding tools can foster the development of these skills in students. In particular, the high N-gain scores in the Analysis category reflect a significant improvement in students' abilities to decompose complex mathematical problems, mirroring Anderson and Krathwohl's assertion that learning technologies can promote deeper cognitive engagement and mastery of complex concepts.

In addition, this study's findings on the role of ChatGPT in scaffolding students' understanding of problem statements and assisting in task formulation align with Sweller's Cognitive Load Theory. According to Sweller, cognitive load should be optimized during learning by providing supportive structures that reduce extraneous cognitive load (Dakopolos et al., 2024; Lyublinskaya & Kaplon-Schilis, 2022). ChatGPT, by prompting students with targeted questions and guiding them through problem formulation, likely served as a scaffold, reducing the cognitive load associated with problem-solving. This scaffolding allowed students to focus on deeper problem-solving processes, which may explain the higher performance levels observed in the experimental group.

The marked improvement in students' cognitive skills, particularly in higher-order thinking (analyze, evaluate, and create), also draws parallels with the work of Sulisworo et al., (2021), who found that teaching strategies that actively engage students in creating and evaluating their learning foster the most significant improvements in achievement. The integration of ChatGPT and Scratch allowed students to engage in both creating their own projects and evaluating the solutions of their peers, consistent with Hattie's assertion that interactive, student-centered learning environments lead to better cognitive outcomes. These tools, by facilitating creativity and critical thinking, empowered students to take ownership of their learning and engage deeply with the content, reinforcing Hattie's findings on the efficacy of active learning strategies.

The results of this study also contribute to the growing body of evidence supporting the integration of AI into classroom settings, particularly in elementary education. As AI tools like ChatGPT and Scratch continue to evolve, they offer even more potential to enhance learning outcomes. According to a study by Bewersdorff et al., (2023), AI can personalize learning experiences for students, adapting to their needs and providing instant feedback, thus promoting individualized learning. The present study showed that ChatGPT's dialogic prompts and Scratch's interactive interface enabled students to engage with content in personalized ways that were not possible with traditional instruction. The high engagement and collaborative learning observed in this study suggest that the effective integration of AI can provide tailored

learning experiences that significantly enhance student performance and foster deeper cognitive skills.

Finally, comparing the present study with theories of gamification also proves insightful. Gamification research, such as that by Azzouz Boudadi & Gutiérrez-Colón, (2020), suggests that elements of game design—such as immediate feedback, rewards, and opportunities for mastery—can significantly boost motivation and engagement in learning. Scratch, with its visual feedback and block-based design, can be considered a form of gamified learning that encourages trial-and-error and problem-solving. The positive responses in terms of student motivation and engagement in this study, particularly the high scores for collaboration and communication, reflect the power of gamified learning tools in promoting student-centered, interactive learning experiences.

In conclusion, the findings from this study are consistent with and build upon existing educational theories and research, highlighting the substantial benefits of integrating AI and block-based coding tools into elementary education. These tools not only foster computational thinking and higher-order cognitive skills but also enhance student engagement and collaboration, providing a compelling case for their continued and expanded use in classrooms worldwide.

CONCLUSION

Based on the research findings, it can be concluded that the integration of coding and artificial intelligence (AI) training through platforms like Scratch and ChatGPT significantly enhances 5th-grade students' math performance and computational thinking skills. The experimental group, using these technologies, showed much greater progress compared to the control group, which relied on traditional teaching methods. The most notable improvements were observed in skills such as problem formulation and data organization, indicating that the use of AI and coding has a profound impact on helping students grasp abstract mathematical concepts. Additionally, survey results revealed that students were more engaged and motivated in technology-driven learning, contributing to the development of higher cognitive skills. Therefore, this study supports the importance of incorporating technology into the elementary school curriculum to better prepare students for the challenges of an increasingly technology-driven world.

RECOMMENDATION

Based on the findings of this study, it is recommended that educational institutions integrate coding and AI tools, such as Scratch and ChatGPT, into the curriculum for elementary school students, especially in subjects like mathematics. Teachers should receive training and support in using these technologies effectively, as their successful implementation can foster deeper cognitive engagement, problem-solving skills, and computational thinking. Additionally, further research should explore the long-term impact of these tools on student learning outcomes across different subjects and educational settings. To address any technical challenges, such as connectivity issues, it is essential to invest in infrastructure improvements and provide continuous professional development for educators. By incorporating these

innovative tools, schools can better prepare students for the future workforce and enhance their digital literacy from an early age.

Author Contributions

The authors of this study contributed to the research in various capacities. Conceptualization of the study was led by Firdaus Suryo Febriantoro and Lenny Kurniati, while the methodology and research design were primarily developed by Firdaus Suryo Febriantoro. Data collection and analysis were conducted by Firdaus Suryo Febriantoro and Badrussalam Integrated Islamic Elementary School's faculty. Writing the original draft and finalizing the manuscript was carried out by Firdaus Suryo Febriantoro, with input and revisions from Lenny Kurniati. The authors share equal responsibility for validating the results and ensuring the integrity of the research. All authors have read and agreed to the final version of the manuscript for publication.

Funding

This research received no external funding. The study was conducted using the resources available at Badrussalam Integrated Islamic Elementary School and was supported by the authors' institutional affiliations. Any expenses incurred for the study, including those related to data collection and analysis, were covered by the authors' personal and institutional resources. The absence of external funding ensures that the findings and interpretations in the study are unbiased and independent of any financial influence.

Acknowledgment

The authors would like to express their sincere gratitude to Badrussalam Integrated Islamic Elementary School for their cooperation and support in conducting this research. Special thanks to the teachers and students who participated in the study, as their involvement and feedback were essential to the success of the research. The authors also appreciate the guidance and insights provided by colleagues and mentors in the field of educational technology, which helped shape the direction of the study. Finally, the authors wish to acknowledge the valuable feedback from anonymous reviewers, which improved the quality of the manuscript.

Conflict of interests

The authors declare that there are no conflicts of interest related to the research or the publication of this study. There was no financial or personal interest that could have influenced the research process, data analysis, or interpretation of the findings. The authors affirm that the study was conducted with the highest ethical standards and transparency, and that all findings are presented objectively and truthfully.

REFERENCES

Abulibdeh, A., Zaidan, E., & Abulibdeh, R. (2024). Navigating the confluence of artificial intelligence and education for sustainable development in the era of industry 4.0: Challenges, opportunities, and ethical …. *Journal of Cleaner Production*. https://www.sciencedirect.com/science/article/pii/S0959652623046851

Adhikari, B., Dhakal, S., & Jha, A. (2024). Maximizing Student Engagement in Coding Education with Explanatory AI. *2024 IEEE Frontiers in Education …*. https://ieeexplore.ieee.org/abstract/document/10893108/

Akhwani, A., & Rahayu, D. W. (2021). Analisis Komponen TPACK Guru SD sebagai Kerangka Kompetensi Guru Profesional di Abad 21. *Jurnal Basicedu*, *5*(4), 1918–1925. https://doi.org/10.31004/basicedu.v5i4.1119

Allam, H., Dempere, J., Akre, V., Parakash, D., & ... (2023). Artificial intelligence in education: an argument of Chat-GPT use in education. *2023 9th …*. https://ieeexplore.ieee.org/abstract/document/10184267/

Ashoumi, H., & Yusuf, M. A. (2024). Pendidikan Inklusi: Integrasi Konsep Konstruktivistik Vygotsky dan Landasan Al-Qur'an untuk Mendukung SDGs 4. *Intelektual: Jurnal Pendidikan Dan …*. https://ejournal.uit-lirboyo.ac.id/index.php/intelektual/article/view/6308

Azzahroh, S. N. F., Septaria, K., & Wulandari, S. A. (2024). Pengaruh Model Pembelajaran Inkuiri Bermuatan Nature Of Science (NOS) Terhadap Argumentasi Ilmiah Pada Topik Zat Aditif. *Jurnal Penelitian Sains Dan Pendidikan …*.

Azzouz Boudadi, N., & Gutiérrez-Colón, M. (2020). Effect of Gamification on students' motivation and learning achievement in Second Language Acquisition within higher education: a literature review 2011-2019. *The EuroCALL Review*, *28*(1), 40. https://doi.org/10.4995/eurocall.2020.12974

Badeo, J. M. O., & Koc, B. C. U. O. K. (2021). Use of Comic-based Learning Module in Physics in Enhancing Students' Achievement and Motivation. *Science Education International*, *32*(2), 131–136. https://doi.org/10.33828/sei.v32.i2.6

Baidoo-Anu, D., & Ansah, L. O. (2023). Education in the era of generative artificial intelligence (AI): Understanding the potential benefits of ChatGPT in promoting teaching and learning. *Journal of AI*. https://doi.org/10.61969/jai.1337500

Bakker, A., Cai, J., & Zenger, L. (2021). Future themes of mathematics education research: An international survey before and during the pandemic. *Educational Studies in Mathematics*. https://doi.org/10.1007/s10649-021-10049-w

Bewersdorff, A., Zhai, X., Roberts, J., & Nerdel, C. (2023). Myths, mis-and preconceptions of artificial intelligence: A review of the literature. *… Education: Artificial Intelligence*. https://www.sciencedirect.com/science/article/pii/S2666920X2300022X

Broza, O., Biberman-Shalev, L., & Chamo, N. (2023). "Start from scratch": Integrating computational thinking skills in teacher education program. *Thinking Skills and Creativity*. https://www.sciencedirect.com/science/article/pii/S187118712300055X

Cardona, M. A., Rodríguez, R. J., & Ishmael, K. (2023). *Artificial intelligence and the future of teaching and learning: Insights and recommendations*. policycommons.net. https://policycommons.net/artifacts/3854312/ai-report/4660267/

Çelik, İ. N., & Bati, K. (2024). The Effect of Cooperative Learning on Academic Performances and Computational Thinking Skills in the Computational Problem-Solving Approach. *Informatics in Education*. https://www.infedu.vu.lt/journal/INFEDU/article/788

Chiu, T. K. F., Ahmad, Z., Ismailov, M., & Sanusi, I. T. (2024). What are artificial intelligence literacy and competency? A comprehensive framework to support them. *Computers and Education …*. https://www.sciencedirect.com/science/article/pii/S2666557324000120

Coates, W. C., Jordan, J., & Clarke, S. O. (2021). A practical guide for conducting qualitative research in medical education: Part 2—Coding and thematic analysis. *AEM Education and Training*. https://doi.org/10.1002/aet2.10645

Dakopolos, A., Condy, E., Smith, E., Harvey, D., Kaat, A. J., Coleman, J., Riley, K., Berry-Kravis, E., & Hessl, D. (2024). Developmental associations between cognition and adaptive behavior in intellectual and developmental disability. *Journal of Neurodevelopmental Disorders*, *16*(1), 1–12. https://doi.org/10.1186/s11689-024-09542-z

Dushanova, N. (2024). Traditional-based learning versus phenomenon-based learning. In *Conference Proceedings: Fostering Your …*. jainkwellpublishing.com. https://jainkwellpublishing.com/index.php/conferences/article/view/335

El-Sabagh, H. A. (2021). Adaptive e-learning environment based on learning styles and its impact on development students' engagement. *International Journal of Educational Technology in Higher Education*, *18*(1). https://doi.org/10.1186/s41239-021-00289-4

Erkan, A., & Akkaya, S. (2025). An Investigation of Coding Education Practices in terms of Primary School Students' Algorithmic Thinking Skills and Students' Opinions. *Journal of Education in Science, Environment and …*. https://jeseh.net/index.php/jeseh/article/view/769

Felder, R. M., & Brent, R. (2024). *Teaching and learning STEM: A practical guide*. books.google.com. https://books.google.com/books?hl=en%5C&lr=%5C&id=7ST7EAAAQBAJ%5C&oi=fnd%5C&pg=PA13%5C&dq=problem+based+learning+science+education+science+creativity%5C&ots=NGwNvGNtpW%5C&sig=6_ORM6WC0fOkSu7JSadjUl64wA8

Gans, N., Zohery, V., Jaffe, J. B., Ahmed, A., Kim, L., & Lombardi, D. (2024). Socio-Scientific Learning During the COVID-19 Pandemic: Comparing In-person and Virtual Science Learning Using Model-Evidence Link Diagrams. *Journal of Science*

Education and Technology, *33*(2), 251–262. https://doi.org/10.1007/s10956-023-10046-z

García-Martínez, I., Fernández-Batanero, J. M., & ... (2023). Analysing the impact of artificial intelligence and computational sciences on student performance: Systematic review and meta-analysis. *… in Educational Research*. https://doi.org/10.7821/naer.2023.1.1240

Gašević, D., Siemens, G., & Sadiq, S. (2023). Empowering learners for the age of artificial intelligence. *… and Education: Artificial Intelligence*. https://www.sciencedirect.com/science/article/pii/S2666920X23000097

Gligorea, I., Cioca, M., Oancea, R., Gorski, A. T., Gorski, H., & Tudorache, P. (2023). Adaptive Learning Using Artificial Intelligence in e-Learning: A Literature Review. *Education Sciences*, *13*(12). https://doi.org/10.3390/educsci13121216

Gough, P., Bown, O., Campbell, C. R., & ... (2023). Student responses to creative coding in biomedical science education. *… Biology Education*. https://doi.org/10.1002/bmb.21692

Han, E. S., Park, Y. J., Yurgelun-Todd, D., & ... (2024). Comparing the effectiveness of game literacy education and game coding education in improving problematic internet gaming. *Frontiers in …*. https://doi.org/10.3389/fpsyt.2024.1377231

Hastuti, K., Susanti, H., & Erfando, T. (2022). Evaluasi Kebijakan Program MBKM dalam Meningkatkan Capaian Pembelajaran Lulusan Perguruan Tinggi. *Edukatif : Jurnal Ilmu Pendidikan*, *4*(6), 7445–7454. https://doi.org/10.31004/edukatif.v4i6.4119

Henry, J., Hernalesteen, A., & Collard, A. S. (2021). Teaching Artificial Intelligence to K-12 Through a Role-Playing Game Questioning the Intelligence Concept. *KI - Kunstliche Intelligenz*, *35*(2), 171–179. https://doi.org/10.1007/s13218-021-00733-7

Hikmawati, H., Suastra, I. W., & ... (2021). Ethnoscience-based science learning model to develop critical thinking ability and local cultural concern for junior high school students in Lombok. *… Penelitian Pendidikan IPA*. https://jppipa.unram.ac.id/index.php/jppipa/article/view/530

Ichsan, I., Suharyat, Y., Santosa, T. A., & ... (2023). The effectiveness of STEM-based learning in teaching 21 st century skills in generation Z student in science learning: A meta-analysis. *Jurnal Penelitian …*. https://jppipa.unram.ac.id/index.php/jppipa/article/view/2517

Iqbal, M., Dias, J. M., Sultan, A., Raza, H. A., & Zaman, L. uz. (2024). Effectiveness of blended pedagogy for radiographic interpretation skills in operative dentistry - a comparison of test scores and student experiences at an undergraduate dental school in Pakistan. *BMC Medical Education*, *24*(1), 1–10.

https://doi.org/10.1186/s12909-024-05062-5

Kaouni, M., Lakrami, F., & Labouidya, O. (2023). The Design of An Adaptive E-learning Model Based on Artificial Intelligence for Enhancing Online Teaching. *International Journal of Emerging Technologies in Learning*, *18*(6), 202–219. https://doi.org/10.3991/ijet.v18i06.35839

Kim, J. (2024). Leading teachers' perspective on teacher-AI collaboration in education. *Education and Information Technologies*. https://doi.org/10.1007/s10639-023-12109-5

Lee, S., Yun, S., Jeong, S., & Woo, T. (2023). Advancements in Coding Education through the Serious Game "COngDING." *디지털콘텐츠학회논문지 (J. DCS)*. http://journal.dcs.or.kr/xml/38962/38962.pdf

Lockwood, J., Williams, L., Martin, J. L., Rathee, M., & Hill, C. (2022). Effectiveness, User Engagement and Experience, and Safety of a Mobile App (Lumi Nova) Delivering Exposure-Based Cognitive Behavioral Therapy Strategies to Manage Anxiety in Children via Immersive Gaming Technology: Preliminary Evaluation Study. *JMIR Mental Health*, *9*(1). https://doi.org/10.2196/29008

Lyublinskaya, I., & Kaplon-Schilis, A. (2022). Analysis of Differences in the Levels of TPACK: Unpacking Performance Indicators in the TPACK Levels Rubric. *Education Sciences*, *12*(2). https://doi.org/10.3390/educsci12020079

Mom, P., Mom, S., Phann, S., Srieng, K., & Kong, S. O. (2024). Implementing Stem Project To Improve Students' Creativity and Learning Outcomes in the Concept of Circulatory System. *INSECTA: Integrative Science Education and Teaching Activity Journal*, *5*(1), 121–129. https://doi.org/10.21154/insecta.v5i1.8270

Muzana, S. R., Jumadi, Wilujeng, I., Yanto, B. E., & Mustamin, A. A. (2021). E-STEM project-based learning in teaching science to increase ICT literacy and problem solving. *International Journal of Evaluation and Research in Education*, *10*(4), 1386–1394. https://doi.org/10.11591/IJERE.V10I4.21942

Naznin, K., Mahmud, A. Al, Nguyen, M. T., & Chua, C. (2025). ChatGPT Integration in Higher Education for Personalized Learning, Academic Writing, and Coding Tasks: A Systematic Review. *Computers*. https://www.researchgate.net/profile/Abdullah-Mahmud-16/publication/388661164_ChatGPT_Integration_in_Higher_Education_for_Personalized_Learning_Academic_Writing_and_Coding_Tasks_A_Systematic_Review/links/67a6834e207c0c20fa7e1356/ChatGPT-Integration-in-Hig

Nurika, L., Septaria, K., & Setyannigsih, S. (2024). *Implementing Science Creativity in Junior High School Students Using A Pirporsal Learning Model on Energy Resources*. *13*(1), 36–41. https://doi.org/10.20961/inkuiri.v13i1.80289

Ozkan, G., & Topsakal, U. U. (2021). Exploring the effectiveness of STEAM design

processes on middle school students' creativity. … *Journal of Technology and Design Education*. https://doi.org/10.1007/s10798-019-09547-z

Ozkan, G., & Umdu Topsakal, U. (2021). Exploring the effectiveness of STEAM design processes on middle school students' creativity. *International Journal of Technology and Design Education*, *31*(1), 95–116. https://doi.org/10.1007/s10798-019-09547-z

Papadakis, S., Kalogiannakis, M., & Gözüm, A. I. C. (2022). STEM, STEAM, computational thinking, and coding: Evidence-based research and practice in children's development. *Frontiers in Psychology*. https://doi.org/10.3389/fpsyg.2022.1110476

Polat, E., Hopcan, S., Kucuk, S., & ... (2021). A comprehensive assessment of secondary school students' computational thinking skills. *British Journal of* …. https://doi.org/10.1111/bjet.13092

Sapuadi, S., & Nasir, M. (2020). Penanggulangan Miskonsepsi Menggunakan Pendekatan Konflik Kognitif. *Al-Mudarris (Jurnal Ilmiah Pendidikan Islam)*, *3*(1), 81–92. https://doi.org/10.23971/mdr.v3i1.2036

Saralar-Aras, I., & Schoenberg, Y. C. (2024). Unveiling the synergistic nexus: AI-driven coding integration in mathematics education for enhanced computational thinking and problem-solving. *The Mathematical Education*. https://koreascience.kr/article/JAKO202417776455279.pdf

Saricam, U., & Yildirim, M. (2021). The Effects of Digital Game-based STEM Activities on Students' Interests in STEM Fields and Scientific Creativity: Minecraft Case. *International Journal of Technology in Education and Science*, *5*(2), 166–192. https://doi.org/10.46328/ijtes.136

Schaffar, B., & Wolff, L. A. (2024). Phenomenon-based learning in Finland: a critical overview of its historical and philosophical roots. *Cogent Education*, *11*(1). https://doi.org/10.1080/2331186X.2024.2309733

Septaria, K. (2022). Kemampuan Bertanya Versus Hasil Belajar Kognitif Mahasiswa: Analisis Korelasi Kemampuan Bertanya Pada Level Mahasiswa IPA. … *Jurnal Ilmiah Pendidikan IPA) Universitas Bhinneka* …. https://scholar.archive.org/work/nrj6scsrtngshoeg4ojo3lu7vq/access/wayback/https://jurnal.stkippgritulungagung.ac.id/index.php/eduproxima/article/download/2665/pdf

Septaria, K. (2023). Media Ular Tangga dan Literasi: Analisis Pengaruh Materi Mitigasi Bencana Banjir pada Siswa Sekolah Menengah Pertama. *SPEKTRA: Jurnal Kajian Pendidikan Sains*, *9*(1), 1–13. https://doi.org/10.32699/spektra.v9i1.263

Septaria, K., Dewanti, B. A., & Afidah, M. I. El. (2020). Development Of Module Disaster Mitigation Based On Stem For Secondary Schools. *Jurnal Peneliltian*

Pendidikan IPA, *5*(2), 61–68.

Septaria, K., & Fatharani, A. (2022). Manga versus webtoon: Alternative science learning module based on Dr Stone. *Jurnal Inovasi Pendidikan IPA*. https://journal.uny.ac.id/index.php/jipi/article/view/43389

Siswanto, S., Hartono, H., Subali, B., & Masturi, M. (2022). Infusing Explicit Argumentation in Science Reading Activities: Helping Prospective Science Teachers Reduce Misconception and Foster Argumentation Skills. *Pegem Egitim ve Ogretim Dergisi*, *12*(3), 177–189. https://doi.org/10.47750/pegegog.12.03.19

Sulisworo, D., Drusmin, R., Kusumaningtyas, D. A., Handayani, T., Wahyuningsih, W., Jufriansah, A., Khusnani, A., & Prasetyo, E. (2021). The Science Teachers' Optimism Response to the Use of Marker-Based Augmented Reality in the Global Warming Issue. *Education Research International*, *2021*. https://doi.org/10.1155/2021/7264230

Sumarmi, Bachri, S., Irawan, L. Y., & Aliman, M. (2021). E-module in blended learning: Its impact on students' disaster preparedness and innovation in developing learning media. *International Journal of Instruction*, *14*(4), 187–208. https://doi.org/10.29333/iji.2021.14412a

Suminarsih, S. (2023). Peningkatan Pemahaman Konsep Fisika Dan Keterampilan Literasi Digital Melalui Proyek Video Pembelajaran Menggunakan Model Project Based Learning. *Orbith: Majalah Ilmiah Pengembangan Rekayasa Dan Sosial*, *19*(1), 27–35.

Syawaludin, A., Raihan, S., Kusumajati, W. K., Pettalongi, S. S., & Wahab, A. (2024). The Impact of of Hybrid Learning Models on Student Engagement and Academic Performance in Post-Pandemic Education. *Journal of Social Science*, *1 (5)*(1), 371–385. https://doi.org/10.1515/edu-2022-0228

Tan, S. (2023). Harnessing Artificial Intelligence for innovation in education. *Learning Intelligence: Innovative and Digital …*. https://doi.org/10.1007/978-981-19-9201-8_8

Ummah, M. S. (2022). PELAKSANAAN LITERASI DIGITAL DALAM MENINGKATKAN KEMAMPUAN LITERASI SISWA. *J u r n a l L I T E R A S I*, *6*(1), 142–156. http://scioteca.caf.com/bitstream/handle/123456789/1091/RED2017-Eng-8ene.pdf?sequence=12&isAllowed=y%0Ahttp://dx.doi.org/10.1016/j.regsciurbeco.2008.06.005%0Ahttps://www.researchgate.net/publication/305320484_SISTEM_PEMBETUNGAN_TERPUSAT_STRATEGI_MELESTARI

Wan, Z. H., Jiang, Y., & Zhan, Y. (2021). STEM education in early childhood: A review of empirical studies. *Early Education and Development*. https://doi.org/10.1080/10409289.2020.1814986

Wardah, I., Septaria, K., Mahbubah, K., & Mubarok, H. (2022). The Effect of Project Based Learning (PjBL) Model on Students' Science Literacy in Social Studies Subjects. *Jurnal Penelitian Dan Pengkajian Ilmu Pendidikan: E-Saintika*, *6*(2), 108–119. https://doi.org/10.36312/esaintika.v6i2.738

Wei, X., Lin, L., Meng, N., Tan, W., & Kong, S. C. (2021). The effectiveness of partial pair programming on elementary school students' computational thinking skills and self-efficacy. *Computers \&education*. https://www.sciencedirect.com/science/article/pii/S0360131520302219

Yang, W. (2022). Artificial Intelligence education for young children: Why, what, and how in curriculum design and implementation. *Computers and Education: Artificial Intelligence*. https://www.sciencedirect.com/science/article/pii/S2666920X22000169

Yang, X., Zhang, M., Kong, L., Wang, Q., & Hong, J. C. (2020). The Effects of Scientific Self-efficacy and Cognitive Anxiety on Science Engagement with the "Question-Observation-Doing-Explanation" Model during School Disruption in COVID-19 Pandemic. *Journal of Science Education and Technology*, 380–393. https://doi.org/10.1007/s10956-020-09877-x

Yilmaz, R., & Yilmaz, F. G. K. (2023). The effect of generative artificial intelligence (AI)-based tool use on students' computational thinking skills, programming self-efficacy and motivation. *Computers and Education: Artificial Intelligence*. https://www.sciencedirect.com/science/article/pii/S2666920X23000267

Yu, H. (2023). Reflection on whether Chat GPT should be banned by academia from the perspective of education and teaching. *Frontiers in Psychology*. https://doi.org/10.3389/fpsyg.2023.1181712

Yue, M., Jong, M. S. Y., & Dai, Y. (2022). Pedagogical design of K-12 artificial intelligence education: A systematic review. *Sustainability*. https://www.mdpi.com/2071-1050/14/23/15620

Zulfa, F. N., & Prastowo, A. (2023). Pemanfaatan Video Interaktif Dalam Menumbuhkan Keaktifan Siswa Pada Pembelajaran IPA di Madrasah Ibtidaiyah. *Edukatif : Jurnal Ilmu Pendidikan*, *5*(5), 1833–1841. https://doi.org/10.31004/edukatif.v5i5.5589