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Analysis of The Effect of Using Google Gemini as an AI Tutor on Students' Digital Literacy Skills and Learning Outcomes in Science and Social Sciences Subjects

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ABSTRACT

The integration of artificial intelligence (AI) in education has opened a new paradigm, one of which is through the use of large language model platforms such as Google Gemini as a personal tutor for students. This study aims to analyze the effect of using Google Gemini as an AI Tutor on digital literacy skills and student learning outcomes in Natural Sciences (IPA) and Social Sciences (IPS) subjects. Using a quantitative explanatory approach, this study involved a sample of high school students divided into an experimental group (using Google Gemini) and a control group (using conventional methods). Data were collected through digital literacy ability tests, pre- and post-test IPA and IPS learning outcome tests, and student perception questionnaires. The results of the statistical analysis showed that the use of Google Gemini significantly improved students' digital literacy skills, especially in the dimensions of critical information retrieval and AI-based content evaluation. In addition, there was a significant increase in learning outcomes in both exact science subjects and contextual-analytical IPS subjects, when compared to the control group. Interestingly, students in the IPS subject showed higher problem-solving efficiency, while students in the IPS subject showed better depth of critical analysis after interacting with the AI Tutor. This study concludes that Google Gemini effectively functions as a cognitive accelerator, bridging conceptual understanding gaps while simultaneously training students' digital skills. The implications of this research emphasize the need for integrated regulations and curricula to ensure that the use of generative AI in schools prioritizes academic ethics and independent thinking.

Keywords: AI Tutor, Google Gemini, learning outcomes, digital literacy, science, social studies

INTRODUCTION

The development of digital technology in the third decade of the 21st century has fundamentally changed the global educational landscape, with the adoption of artificial intelligence *(*AI) no longer merely an administrative tool but has penetrated into the core areas of pedagogy (Bozkurt, 2023). One of the most transformative technological leaps is the emergence of *Large Language Model (LLM)-based generative AI, such as Google Gemini, which has the capacity to engage in dialogue, contextualize information, and provide real-time* feedback to its users (UNESCO, 2024). In school settings, this technology is beginning to be adopted as a personal intelligent tutor (*AI Tutor*) that accompanies students outside of formal classroom hours. According to Lin et al. (2025), the presence of AI Tutors is able to personalize teaching materials according to the learning pace of each individual, an achievement that has been

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difficult to achieve in conventional mass classroom systems. However, the increasing reliance on this generative AI platform has sparked renewed debate among educators about its long-term effects on students' pure cognitive capacity and digital readiness to filter out biased or inaccurate information (American Psychological Association [APA], 2025). Therefore, an empirical investigation into how Google Gemini impacts students' academic performance and digital navigation skills is urgently needed.

In the context of 21st-century competencies, digital literacy skills have shifted in meaning from simply the ability to operate hardware and software to the critical ability to evaluate, validate, and construct knowledge from machine-generated digital text (Pangrazio & Sefton-Green, 2021). When students interact with Google Gemini to complete school assignments, they not only receive answers but are also faced with the obligation to formulate precise instructions (*prompting*) and verify the validity of the arguments provided by the AI. Efriza (2026) emphasized that a student's level of digital literacy determines whether AI will function as a driver of quality thinking or as a shortcut that stifles critical thinking. If students lack digital literacy skills, they tend to blindly accept AI output without realizing the potential for information hallucinations or algorithmic bias inherent in the model's training data (APA, 2025). By utilizing Google Gemini as a scientific dialogue partner, students are indirectly forced to develop *Digital Literacy in AI* (DLAI), which includes ethical awareness, self-reflection, and data cross-validation (Iicls, 2026). Thus, the use of AI Tutor has the potential to be a double-edged sword that requires measurable analysis to see its impact on students' digital dexterity.

In addition to influencing digital literacy skills, the use of Google Gemini is thought to have a strong correlation with student achievement or learning outcomes in subject groups with different characteristics, such as Natural Sciences (IPA) and Social Sciences (IPS). Science subjects require an understanding of abstract concepts, logical reasoning, and rigid problem-solving methodologies, where AI Tutor can play a role in providing analogical textual visualizations or solving mathematical and scientific formulas step by step (Budiono, 2025). On the other hand, Social Studies subjects require contextual analysis skills, historical understanding, and synthesis from various dynamic social perspectives. Google Gemini, with its extensive textual database, is able to provide comparative analyses of socio-economic phenomena that help students view an issue from a macro perspective (Haleem et al., 2022). These differences in disciplinary characteristics raise important questions about Google Gemini's adaptability as a cross-disciplinary tutor. Previous research from Walter (2024) indicates that the effectiveness of AI in education is highly dependent on how instructional content is tailored to the science or humanities domain, but there has been little research specifically comparing the direct impact of a single LLM platform such as Gemini on science and social studies learning outcomes simultaneously in an equivalent student population.

A major problem often encountered in conventional science and social studies learning in secondary schools is the limited time teachers have to provide intensive attention to each student who is having difficulty understanding the material.

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According to Mujiono (2023), the one-way (*teacher-centered*) learning model often fails to accommodate the diversity of student learning styles, ultimately resulting in stagnant learning outcomes. The presence of Google Gemini as a companion tutor provides an alternative solution where students can ask questions repeatedly without time limits or the fear of being judged. However, this integration of independent technology raises concerns regarding a decrease in intrinsic learning motivation and a degradation of independent research skills due to easy access to instant answers (Efriza, 2026). In line with social constructivism theory, interaction with AI should trigger the zone *of proximal development (ZoD*) where technology acts as *a scaffold* or temporary support until students are able to be independent (UNESCO, 2024). Empirical analysis of the dynamics of changes in learning outcomes needs to be examined more deeply to ensure that the improvements in academic scores that occur after the use of AI truly reflect a solid conceptual understanding, not simply the result of digital copy-paste.

Although research on the use of AI in global education has grown rapidly in the past two years, the majority of literature still focuses on the university ecosystem and the use of AI technology in general, without reference to specific, large-scale platforms like Google Gemini (Iicls, 2026). Furthermore, studies that comprehensively integrate two key impact variables—digital literacy competency as a process variable and interdisciplinary learning outcomes (science and social studies) as an output variable—remain very rare in the secondary school education literature. This *research gap* is exacerbated by the lack of empirical guidance for local education policymakers on how to address the phenomenon of AI-based assistants being used by student's post-pandemic (Budiono, 2025). Without concrete data evaluating the real impact of AI technology on students, schools tend to take extreme measures: either completely banning the use of AI or allowing it to be used without oversight, leading to violations of academic integrity.

Therefore, this study is designed to bridge this gap by conducting an in-depth analysis of the effect of using Google Gemini as an AI Tutor on digital literacy skills and student learning outcomes in science and social studies subjects. The urgency of this study lies in its ability to map students' cognitive efficiency and digital adaptation behavior when faced with the latest artificial intelligence technology. Through a structured scientific approach, it is hoped that the results of this study can provide theoretical contributions to the development of AI-based digital pedagogy theory. Practically, this study is expected to be able to provide data-based recommendations for teachers, principals, and curriculum formulators in designing adaptive, safe, and future-oriented learning strategies, so that AI technology such as Google Gemini can be optimized as an intelligent learning partner without eroding the essence of humanity and critical thinking of the younger generation.

REASERCH METHODS

This study employed a quantitative approach with a *quasi-experimental design* in the form of *a pretest-posttest nonequivalent control group design*. This design

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was chosen due to limitations in conducting full randomization of research subjects in a formal school environment (Creswell & Creswell, 2018). The population in this study were all 11th-grade students at a high school, while the sample was selected using a *purposive sampling* technique to determine two classes as the experimental group and two classes as the control group. The experimental group received treatment in the form of Google Gemini integration as an AI Tutor during the independent learning process and completing assignments in science and social studies subjects, while the control group continued to use conventional learning methods with textbooks and standard search engines. The intervention was carried out consistently for eight weeks to ensure the impact of the use of artificial intelligence technology could be observed stably and objectively (Sugiyono, 2021).

Data collection was conducted through three main instruments that had been tested for validity and reliability: a learning outcome test, a questionnaire, and a digital observation sheet. The learning outcome test, consisting of multiple-choice questions and analytical essays, was used to measure students' academic achievement in science and social studies before (*pre-test*) and after (*post-test*) the intervention. Meanwhile, to measure students' digital literacy skills, the researchers adapted a Likert-scale-based questionnaire referring to *the Digital Literacy in AI (DLAI) framework to assess aspects of* prompting, critical evaluation of information from AI, and ethical awareness (Iicls, 2026). Furthermore, digital footprints in the form of interaction histories (*chat logs*) between students and Google Gemini were collected anonymously as supporting data to analyze the depth and patterns of communication built by students during the self-tutoring process (Walter, 2024).

All collected data were then analyzed using descriptive and inferential statistical techniques with the help of SPSS software. Analysis prerequisite tests, which included the normality test for data distribution and the homogeneity of variance test, were conducted first before conducting hypothesis testing (Field, 2018). To see the effectiveness of the intervention on science and social studies learning outcomes as well as digital literacy skills, the researcher used the *Paired Sample t-Test* for internal group analysis and *the Independent Sample t-Test* to compare the increase (gain score) between the experimental and control groups. Furthermore, a *Multivariate Analysis of Variance* (MANOVA) analysis was applied to examine whether there was a significant simultaneous effect of Google Gemini use on both dependent variables and to identify interaction effects between the exact science (science) and social studies (social studies) subject groups (Hair et al., 2019).

RESULT AND DISCUSSION

Research result

The data analysis in this study aimed to test the intervention effect of using Google Gemini as an AI Tutor on two main dependent variables, namely digital literacy skills and student learning outcomes in science and social studies subjects. Quantitative data collection was obtained from *pre-test* and *post-test* scores distributed to the experimental group (N=64) and control group (N= 64). Before

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conducting the inferential hypothesis test, prerequisite analysis tests were conducted in the form of the Shapiro-Wilk normality test and the Levene homogeneity test. The results of the prerequisite tests showed that all data were normally distributed ($p > 0,05$) and has a homogeneous variance ($p > 0,05$), thus fulfilling the requirements for parametric testing using *Independent Sample t-Test* and *Multivariate Analysis of Variance* (MANOVA) (Field, 2018).

The Impact of Google Gemini on Digital Literacy Skills

Measurement of digital literacy skills focused on four main dimensions adapted from the *Digital Literacy in AI* (DLAI) framework: Prompting Ability, Critical Content Evaluation, Information Cross-Validation, and AI Ethical Awareness (IICLs, 2026). A summary of the comparison of digital literacy scores between the experimental and control groups is presented in Table 1.

Table 1
Comparison of Students' Digital Literacy Skills Scores

Group	Pre-test Average	Post-test Average	Gain Score	t-value	Sig. (2-tailed)
Experiment (With Gemini)	58.45	86.20	27.75	11.43	.000
Control (Conventional)	59.10	68.35	9.25		

Based on Table 1, the experimental group using Google Gemini experienced a massive jump in their average digital literacy score of 27.75 points, far exceeding the control group, which only increased by 9.25 points. The results of *the Independent Sample t-Test* on the digital literacy *score gain* showed a value of $t (126) = 11,43$\$with significance value $p < 0,001$. These results empirically prove that the integration of Google Gemini as an AI Tutor has a very significant positive impact in boosting students' digital agility and literacy compared to conventional information search methods.

The Impact of Google Gemini on Science and Social Studies Learning Outcomes

The impact of AI Tutor on academic performance was measured specifically by subject cluster. Researchers separated the learning outcome analysis to see how large language models like Gemini could facilitate understanding in the abstract-exact (science) and social-contextual (social studies) domains. The learning outcome data for both groups is summarized in Table 2.

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Table 2
Analysis of Student Learning Outcomes in Science and Social Studies Subjects

Subjects	Group	Pre-test Average	Post-test Average	Normalized Gain (N-Gain)	Effectiveness Category
Science	Experiment	52.30	84.50	0.67	Medium-High
	Control	53.10	67.40	0.30	Low
Social Studies	Experiment	56.15	88.10	0.73	Tall
	Control	55.80	71.20	0.34	Low-Medium

The data in Table 2 shows that learning outcomes improved in both subject groups for students who used Google Gemini as their self-tutor. In science, the experimental group achieved a final score of 84.50 with an *N-Gain* index of 0.67 (in the moderate to high category). Meanwhile, in social studies, the learning outcomes jumped even higher, reaching a final score of 88.10 with *an N-Gain* of 0.73 (in the high category).

To simultaneously test the significance of these differences, a MANOVA test was conducted on the digital literacy post-test scores and learning outcomes of both subjects. The results of *the Pillai's Trace*, *Wilks' Lambda*, and *Hotelling's Trace* tests all showed significant values 0,000($p < 0,05$), which means the null hypothesis is rejected (Hair et al., 2019). Thus, the use of Google Gemini as an AI Tutor has been proven to simultaneously and significantly influence digital literacy skills and student learning outcomes, both in science and social studies subjects.

Discussion

Mechanism for Improving Digital Literacy Through LLM Interaction

The finding that Google Gemini significantly improves students' digital literacy is closely related to the transformation in how students interact with digital information. While conventional search engines like Google Search typically require students to simply search for static keywords, interacting with Gemini demands significantly higher cognitive activity. Students must formulate specific narrative text instructions (*prompting*) so that the artificial intelligence can provide accurate answers. This *prompting* process indirectly trains students' linguistic abilities, structural logic, and digital analytical skills. This phenomenon aligns with a study by Lin et al. (2025) which states that technological literacy in the era of generative AI is no longer measured by technical proficiency in menu navigation, but rather by the agility to direct artificial intelligence through precise text-based communication.

Furthermore, significant improvements in the critical evaluation dimension of digital literacy were driven by students' awareness of AI characteristics that can trigger information hallucinations. During the eight-week intervention, students frequently encountered instances where Google Gemini provided fictitious citations or logical inconsistencies in complex scientific problems. Direct experience with these

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system errors actually teaches students to avoid being passive consumers of information. As noted by the American Psychological Association (2025), regular exposure to generative AI systems forces adolescents to develop a cognitive defense mechanism of healthy digital skepticism. Students in the experimental group reported frequently cross-checking *Gemini* answers with primary textbooks or authoritative scientific articles, a high-level digital literacy behavior that rarely occurred among students in the control group.

In addition to the cognitive aspect, the ethical aspects of technology use are also strengthened. With Gemini's position as a "dialogue partner" or accompanying tutor, students are guided to treat AI output as an initial draft or *scaffolding* for thinking, rather than a finished product ready to be copied and pasted. Based on a qualitative analysis of student worksheets, subjects in the experimental class showed a lower tendency to commit raw plagiarism because they had become accustomed to dissecting the arguments provided by the AI into independent points of thought. This confirms Efriza's (2026) theory that if AI technology is directed appropriately within the educational corridor, it will not stifle creativity or trigger academic laziness, but instead accelerate the process of maturing digital ethics among students.

Optimizing Google Gemini in Science Learning: Efficiency of Exact *Scaffolding*

In science subjects, the characteristics of the material that is full of abstract visualizations, mathematical-scientific formulas, and rigid natural laws are often a problem that reduces students' learning motivation (Mujiono, 2023). The results of the study showed that the use of Google Gemini was able to mitigate this cognitive barrier effectively, as evidenced by the experimental group's *N-Gain* value of 0.67 in science. Gemini acts as a personal assistant ready to break down complex formulas into logical and easy-to-understand stages of reasoning (*step-by-step breakdown*). When a student has difficulty understanding abstract concepts such as the laws of thermodynamics or protein synthesis, Gemini can present real-world contextual analogies tailored to the student's age level in just seconds.

This ability to personalize explanations represents *the Zone of Proximal Development* (ZPD) concept in Vygotsky's theory of social constructivism, where AI fills the role of a more knowledgeable social agent (*More Knowledgeable Other*) to provide temporary assistance (UNESCO, 2024). In a conventional classroom, a teacher with a capacity of one to thirty students is impossible to assist every child who gets stuck in the middle of working on a physics or chemistry problem. The presence of Gemini breaks this learning deadlock by offering an anxiety - free learning environment. Students are free to ask stupid questions or request repetition of explanations in various styles of language without fear of being judged or evaluated poorly by the artificial intelligence tutor (Bozkurt, 2023).

However, this research also identified limitations of the LLM platform in the exact sciences domain. In some cases of applied mathematics solutions in advanced physics, Gemini sometimes demonstrated weaknesses in the accuracy of purely numerical calculations. Students with good digital literacy were able to detect these

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calculation errors and used Gemini not as an automatic calculator, but as a conceptualizer of problem-solving flows. According to Budiono (2025), the effectiveness of AI in pure science learning will reach its peak when the LLM platform is integrated with a robust external computing module. Therefore, the improvement in science learning outcomes in this study was driven by intelligent collaboration in which students acted as logical supervisors and Gemini as a provider of macro-concept maps.

The Advantages of Google Gemini's Multi-Perspective Exploration in Social Studies Learning

Interestingly, the largest learning outcome jump was recorded in social studies, with an *N-Gain* index of 0.73. This figure demonstrates that Google Gemini's basic architecture, based on large-scale narrative texts (*Large Language Models*), aligns well with the pedagogical nature of social sciences. Social studies require students to master higher-order thinking skills (*HOTS*), such as analyzing the causes and effects of economic phenomena, contextualizing historical events, and critiquing social structures (Haleem et al., 2022). In this regard, Gemini excels in providing a rich synthesis of information, presenting comparative studies across countries, and mapping theoretical debates in a balanced manner.

For example, when students are tasked with analyzing the impact of global inflation on domestic welfare, Google Gemini doesn't simply present a textual definition but can also be instructed to simulate a debate between classical and Keynesian economics. This multi-perspective exploration process enriches students' thinking, distancing them from the dogmatic memorization patterns entrenched in conventional social studies teaching systems (Mujiono, 2023). Gemini's language flexibility transforms previously considered boring history or sociology material into a dynamic, interactive discussion space.

This positive impact is confirmed by Walter's (2024) findings, which state that a text-based generative AI platform acts as a major catalyst in broadening conceptual insights in the humanities and social sciences. Students in the experimental social studies class were able to write analytical essays that were significantly more comprehensive, had a strong argument structure, and included rich sociological indicators because their initial reference search process was assisted by Gemini. Gemini's speed in summarizing long texts helped students save time on technical searches, allowing the remaining abundant study time to be allocated to more crucial cognitive activities, namely reflection, drawing conclusions, and developing solutions to the social problems being studied.

Interaction of Cross-Disciplinary Effects and Their Implications for Pedagogical Policy

Comparing the two disciplines, a differentiation in students' cognitive behavior is evident. In science, student interactions with Gemini tend to be linear-convergent, with the focus of the dialogue centered on seeking the validity of a single

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scientific truth or improving a technical procedure. Conversely, in social studies, student interactions are divergent-exploratory, characterized by longer, branching *chat* threads exploring a variety of social arguments. This pattern confirms that the same AI platform can yield different cognitive implications depending on the epistemological characteristics of the domain of interest (Walter, 2024).

While this study provides compelling evidence for Google Gemini's effectiveness as an AI tutor, education practitioners should be wary of the potential risk of degrading primary research capabilities. The ease of obtaining instant answers from Gemini has the potential to trigger confirmation bias if not balanced with strict teacher supervision in the classroom. AI tutors must be firmly positioned as supplements or assistants, not substitutes for teacher figures who hold the emotional, affective, and moral character-building authority for students (UNESCO, 2024). Teachers in the AI age are required to reform their assessment methods; exams that only test low-level cognitive memorization must be immediately abandoned, as they have been rendered obsolete by the presence of AI, and replaced with authentic, project-based assessments that test students' digital agility, real-world collaboration, and the depth of critical reasoning.

CONCLUSION

Based on the results of the data analysis and discussion presented, this study concludes that the use of Google Gemini as an AI Tutor has a significant positive influence on improving students' digital literacy skills. Intensive interaction through the process of formulating commands (*prompting*) and critical evaluation of artificial intelligence output has been empirically proven to transform students' roles from passive information consumers to skeptical-constructive digital navigators. This process has succeeded in fostering a new dimension in 21st-century competencies, particularly in the aspect of *Digital Literacy in AI* (DLAI) which includes the ability to cross-validate information, detect potential system hallucinations, and apply responsible academic ethics in the use of generative artificial intelligence technology.

Academically, the implementation of Google Gemini as an independent tutor has proven effective in boosting student learning outcomes, both in the Natural Sciences (IPA) and Social Sciences (IPS) subject groups. In the exact and abstract nature of the IPA subject, Google Gemini successfully carries out its cognitive *scaffolding* function by breaking down complex formulas and presenting analogies of natural concepts gradually in an anxiety-free learning environment. Meanwhile, in the contextual-analytical nature of the IPS subject, the capacity of this Large Language Model-based platform *is* very optimal in facilitating multi-perspective exploration, synthesizing social phenomenon data comprehensively, and stimulating students' higher-order thinking *skills*.

This research has important practical implications for the future of digital pedagogical governance at the secondary school level. The successful integration of AI Tutor in schools depends heavily on the teacher's role shifting from being a one-way transmitter of material to a facilitator and ethical monitor who ensures that the

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use of technology does not erode academic integrity. Rather than strictly prohibiting the use of artificial intelligence, educational institutions and policy makers are advised to design adaptive curricula and reform learning outcome evaluation models toward authentic, project-based assessments. Thus, Google Gemini can be optimized as a cognitive accelerator that fosters intelligence without sacrificing students' independent thinking, critical reasoning, and humanity.

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