Journal of Education and Educational Research
ISSN: 2957-9465 | Vol. 12, No. 1, 2025

Exploring the Role of Generative AI in Advancing Pre-service Teachers' Digital Literacy Through Educational Technology Courses

Sibo Huang [1], Jin Fan [2, *] and Qingwu Lu [1]

[1] Modern Education Technology Center, Huizhou University, Huizhou, China
[2] School of Education Sciences, Huizhou University, Huizhou, China

*** Corresponding author:** Jin Fan (Email: fanjin@hzu.edu.cn)

Abstract: This study investigates the role of generative artificial intelligence (AIGC), particularly large language models, in enhancing the digital literacy of pre-service teachers. With the rapid growth of AI technologies, integrating generative AI into education has gained significant attention. The research focuses on how varying frequencies of generative AI usage affect pre-service teachers' skills in information processing, problem-solving, and critical thinking. Using a polynomial regression model, we analyze the relationship between factors such as AI usage frequency, problem-solving time, feedback quality, and digital literacy scores. The results indicate that frequent use of generative AI substantially improves digital literacy, with the high-frequency group achieving higher and more consistent scores compared to the low-frequency group. Personalized feedback and project-based tasks, provided by generative AI, enhance students' comprehension and application of digital technologies. This research shows that incorporating generative AI into teacher training programs not only supports personalized learning but also fosters essential digital competencies. The findings provide valuable insights for enhancing pre-service teachers' digital literacy and lay a foundation for future educational practices involving AI technologies.

Keywords: Generative AI; Digital Literacy; Pre-service Teachers; AI-enhanced Learning.

1. Introduction

With the rapid development of digital and intelligent technologies, the education sector is undergoing unprecedented transformations, especially in the process of digitalizing teacher education and classroom instruction. The United Nations Educational, Scientific and Cultural Organization (UNESCO) emphasizes the critical role that Information and Communication Technology (ICT) plays in education. ICT not only enhances the quality of education but also promotes educational equity [1].

The development of AI large models, represented by GPT-4, and the application of Generative Artificial Intelligence (AIGC, AI Generated Content) have sparked a new wave of advancements across various domains, including technology, products, and applications. The new generation of technologies such as artificial intelligence, big data, and virtual simulation is reshaping the form and content of education, while also igniting widespread discussions in society about the knowledge and abilities that future teachers must possess [2]. Improving teachers' digital literacy is both a key challenge and an essential component in realizing the digital transformation of education. For teacher training students, their digital literacy is crucial not only for their own professional development but also for the quality of education and talent development after they enter the workforce. Therefore, enhancing the digital literacy of teacher education students and equipping them with the ability to utilize digital technologies to empower teaching innovation is critical to meeting the new requirements and challenges posed by future societal demands for teachers' professional abilities. This is also essential for supporting the digital transformation of education [3].

Currently, although teacher education students, as "digital natives," generally possess basic information technology skills, there remains a significant gap compared to the demands of the new era. This gap is reflected in areas such as incomplete knowledge of digital technology, insufficient integration of digital technology with teaching practices, lack of innovation in applying digital technology to optimize teaching, and inadequate evaluation and analysis of learning situations [4].

Traditional educational technology courses typically focus on theoretical knowledge and rarely incorporate the integration of digital and intelligent technologies, especially generative AI (such as ChatGPT), into teaching practices [5]. As a result, teacher education students often lack sufficient practical experience and innovative capabilities when facing the increasingly complex digital teaching environments.

Therefore, how to introduce generative artificial intelligence (such as ChatGPT) into educational technology teaching to enhance students' digital literacy has become an important issue in the current educational reform. Due to its powerful language understanding and generation capabilities, generative AI can serve as an intelligent tutoring tool to assist students in solving problems in real teaching scenarios, offering personalized learning support, and thereby enhancing their ability to acquire, process, assess, and innovate information [6].

This study explores the effect of using large models (such as ChatGPT) in educational technology teaching on the digital literacy improvement of teacher education students. We have constructed an experimental model based on regression analysis to evaluate the changes in students' digital literacy after using generative AI tools. Additionally, we analyze the impact of various learning behavior features (such as usage frequency, problem-solving time, feedback quality, etc.) on digital literacy scores. Through these explorations, this study

aims to provide theoretical support for innovations in educational technology courses and propose practical strategies for enhancing the digital literacy of teacher education students.

2. Related Research on the Enhancement of Students' Digital Literacy Through Generative AI

Digital literacy is one of the core competencies that is widely emphasized in today's society, especially in the field of education. With the rapid development of digital intelligence technologies, digital technology not only changes the way students learn but also provides a new perspective for educational models and teacher training. Effectively integrating digital technology in education to enhance students' digital literacy has become an important goal of educational reform.

2.1. Application of Generative Artificial Intelligence in Education

Generative Artificial Intelligence (e.g., such as ChatGPT) has emerged as a prominent development in the field of education in recent years. As a technology based on large-scale language models, generative AI uses natural language processing and deep learning to simulate human conversations, providing personalized and interactive feedback and assistance. In education, particularly in the process of enhancing students' digital literacy, generative AI can play a unique role. Compared to traditional teaching tools, generative AI offers several advantages:

(1) Personalized Learning Pathways: generative AI can provide real-time feedback based on student inputs, helping them resolve learning difficulties and offering answers from multiple perspectives. Through interaction with students, generative AI can adjust teaching content according to the student's progress and comprehension, thus providing a more personalized learning experience.

(2) Personalized Learning Pathways: generative AI can provide real-time feedback based on student inputs, helping them resolve learning difficulties and offering answers from multiple perspectives. Through interaction with students, generative AI can adjust teaching content according to the student's progress and comprehension, thus providing a more personalized learning experience.

(3) Enhancing Critical Thinking and Creativity: generative AI is not merely a tool for answering questions; it can also guide students in higher-order thinking exercises. For example, students can propose their ideas during interactions with generative AI and receive challenges and reflections from the intelligent system. This interaction significantly improves students' critical thinking abilities and creativity [7].

Because of these characteristics, the application of generative AI in education has gradually attracted the attention of researchers and educators, particularly in the enhancement of students' digital literacy. Increasingly, studies are exploring how generative AI, through personalized feedback and interactive support, helps students improve their digital literacy in problem-solving, information acquisition, and innovative thinking [8].

2.2. Generative AI and the Enhancement of Digital Literacy

In the context of educational technology, generative artificial intelligence (such as ChatGPT) is considered an effective tool for enhancing students' digital literacy. Through interactions with generative AI, students not only quickly receive answers to their questions but also learn basic digital technology skills through their conversations with the system. This interactive learning mode is more flexible than traditional static textbooks and classroom teaching, allowing it to better adapt to students' personalized needs:

(1) Enhancing Information Processing and Creativity: digital literacy includes not only the ability to operate technology but also the ability to retrieve, analyze, assess, and creatively use information. Generative AI, through natural language processing, helps students quickly access and analyze information, thereby enhancing their information processing abilities. Additionally, the feedback provided by generative AI can guide students in deepening their thinking, fostering innovation.

(2) Cultivating Critical Thinking and Problem-Solving Skills: by conversing with generative AI, students can pose questions, challenge assumptions, and receive feedback. This interactive process not only strengthens students' critical thinking skills but also promotes their problem-solving abilities. This is especially important for students using digital technology to solve problems in complex scenarios.

(3) Supporting Personalized Learning: different students have varying learning paces, interests, and abilities. Generative AI can provide personalized dialogues and feedback, helping students learn at their own pace. By analyzing student inputs, generative AI can offer customized learning content and answers, thereby achieving personalized teaching in digital literacy education.

2.3. The Role of Generative AI in Enhancing the Digital Literacy of Pre-service Teachers

For teacher education students, digital literacy is not only related to their teaching abilities but also directly affects their capacity to effectively use digital technologies in future teaching practices. With the ongoing digital transformation of education, teacher education students need solid digital technology skills and innovative teaching abilities to meet the needs of future education. Generative AI, as an advanced educational tool, provides new opportunities for enhancing the digital literacy of teacher education students:

(1) Improving Digital Teaching Abilities: through using generative AI, teacher education students can better understand the application of digital technologies in teaching, thereby improving their digital teaching capabilities. For example, when designing lessons, teacher education students can use generative AI to generate lesson plans, resource materials, and optimize teaching content through interaction with the AI.

(2) Enhancing Self-Reflection and Evaluation Abilities: in educational practice, teachers' self-reflection and evaluation abilities are crucial for improving teaching quality. Through interacting with generative AI, teacher education students can receive instant feedback on their teaching content and methods, enabling them to refine their teaching design and strategies. This ability to reflect and improve is vital for enhancing teacher education students' digital literacy.

(3) Fostering Technological Innovation Abilities: generative AI not only provides instant feedback but also stimulates teacher education students' creative thinking. When designing and applying educational technologies,

teacher education students can use generative AI for brainstorming, exploring new combinations of technology and teaching methods, and fostering their technological innovation capabilities.

This paper explores the application of generative AI (such as ChatGPT) in educational technology courses. By analyzing the relationships between different learning characteristics (such as usage frequency, problem-solving time, feedback quality, etc.) and digital literacy scores, we aim to reveal its role in the improvement of digital literacy. We also evaluate the effectiveness of generative AI in enhancing the digital literacy of teacher education students.

3. Methodology

3.1. Research Experiment and Model Design

This study quantifies the impact of generative artificial intelligence (specifically large language models like ChatGPT) on improving students' digital literacy in the educational technology curriculum by analyzing changes in digital literacy based on different usage frequencies. The participants in the study are 516 students from the teacher training program at our university. Background variables such as gender, age, and major will be considered as control factors in the analysis.

To ensure balance in baseline levels between the experimental and control groups, a stratified random assignment method was used. Based on students' performance in class assignments, classroom practices, and online learning data, a pre-test score was calculated, and students were divided into three levels (high, medium, and low). Within each level, students were randomly assigned to either the high-frequency usage group or the low-frequency usage group (the experimental and control groups, respectively). The high-frequency group was required to use ChatGPT-like models at least 8 times per week during the course, while the low-frequency group was instructed to use ChatGPT-like models no more than 8 times per week.

To explore the impact of different usage frequencies on digital literacy, the study employs a polynomial regression model. This model captures the non-linear relationships between variables, thereby improving the model's fit and accuracy.

The regression model is expressed as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 Z_1 + \beta_6 Z_2 + \beta_7 Z_3 + \varepsilon \quad (1)$$

Where:

Y is the dependent variable, representing students' digital literacy scores;

X_1 is the independent variable, representing the frequency of ChatGPT-like model usage per week;

X_2 is the independent variable, representing problem-solving time;

X_3 is the independent variable, representing feedback quality score;

X_4 is the independent variable, representing project completion rate;

Z_1 is the control variable, representing students' prior technical skill level;

Z_2 is the control variable, representing students' gender;

Z_3 is the control variable, representing students' major;

ε is the error term, representing random errors that are not explained by the model.

3.2. Data Collection

To comprehensively assess the impact of generative artificial intelligence on enhancing students' digital literacy, various data collection methods were designed, and basic data for some students were recorded using the Chaoxing learning platform. The specific data collection methods are as follows:

Digital Literacy Scores (Y)

The digital literacy score is calculated based on students' performance in assignments, classroom interactions, group discussions, online learning, and self-assessment activities. The specific tasks include: **Project-Based Learning (PBL) Activities:** students are required to complete a series of learning tasks based on real-world issues, such as designing digital course resource reports, developing teaching plans, and creating micro-course videos. These tasks are designed to assess students' information retrieval and processing skills, while simultaneously cultivating their critical thinking, teamwork abilities, and technology application skills. **Classroom Interaction and Discussion:** real-time question-and-answer sessions and topical discussions are used to assess students' understanding of digital technology applications and their critical thinking abilities. This process encourages active student participation and improves communication and collaboration skills. **Online Learning and Self-Assessment:** the Chaoxing platform records students' online learning time, resource access frequency, assignment submission status, and other data to quantify their learning behaviors. Through self-assessment, students can track their progress and adjust their learning strategies accordingly.

Baseline Assessment

To ensure the scientific rigor and reliability of the experimental results, a baseline digital literacy assessment was conducted before the experiment commenced. The baseline score was derived from students' performance in in-class assignments, discussions, practical operations, and some data recorded from the Chaoxing learning platform.

Usage Frequency (X_1)

Students' usage frequency data were recorded through questionnaires and the Chaoxing platform's log feature. The frequency of using large language models like ChatGPT per week reflects students' dependency on these tools, which helps analyze the relationship between usage frequency and digital literacy improvement.

Problem Solving Time (X_2)

The study recorded the average time each student took to complete a learning task with the assistance of large language models. This metric reflects the learning efficiency when using these tools and helps assess their practical value in educational contexts.

Quality of Personalized Feedback (X_3)

Students rated the level of personalization in the feedback received through interactions with ChatGPT-like large language models. The rating scale ranges from 1 to 5. This data will help evaluate how personalized and effective the feedback provided by these tools is.

Project Completion Rate (X_4)

Students' task completion quality in PBL activities was assessed. This process quantifies students' abilities in real-world teaching design, evaluating not only their technical operational skills but also their creativity and ability to solve practical problems.

Control Variables

The following variables were used as control factors in the data analysis to reduce external interference:

- **Baseline Technical Level (Z_1)**: the baseline score from the pre-test, which measures students' initial digital literacy levels.
- **Gender (Z_2)**: gender is treated as a binary variable in the analysis.
- **Academic Background (Z_3)**: students' academic backgrounds are treated as categorical variables.

3.3. Evaluation Metrics

To evaluate the effectiveness of the regression model, the following statistical metrics were used:

R-squared (R^2): This reflects the degree to which the model explains the variability of the digital literacy scores.

Mean Squared Error (MSE): This measures the difference between the predicted values and actual observed values.

Significance Test for Regression Coefficients: This tests whether the independent variables significantly affect the digital literacy scores.

In addition, the study will analyze the differences in digital literacy scores between the high-frequency and low-frequency usage groups, exploring how different usage frequencies specifically impact the improvement of digital literacy. Furthermore, the study will examine the relationship between usage frequency and students' learning efficiency, problem-solving abilities, and innovative thinking skills.

4. Experimental Results and Analysis

Through regression analysis, we examined the digital literacy scores of the low-frequency and high-frequency usage groups, and assessed the impact of ChatGPT on students' digital literacy at different usage frequencies.

4.1. Comparison and Analysis of Regression Results for Low-Frequency and High-Frequency Usage Groups

4.1.1. Regression Analysis Results for the Low-Frequency Usage Group

As shown in Table 1, the regression results for the low-frequency usage group indicate that the usage frequency ($\beta_1 = -0.3668$) has a negative correlation with digital literacy scores. This suggests that students with lower usage frequencies of ChatGPT show slower improvements in their digital literacy. However, project completion rate ($\beta_4 = 0.7681$) and feedback quality rating ($\beta_3 = 0.5688$) show significant positive effects, indicating that despite the lower frequency of use, high-quality feedback and increased task completion can still effectively promote the improvement of students' digital literacy.

Regression Statistics for the Low-Frequency Usage Group:

$R^2 = 0.9018$, which means the regression model explains 90.18% of the variance in digital literacy scores, showing a good fit.

$p = 0.0000$, which is much smaller than 0.05, confirming that the model is statistically significant.

Table 1. Regression Coefficients for the Low-Frequency Usage Group

Regression Coefficients	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7
value	2.2515	-0.3668	-0.0581	0.5688	0.7681	0.1917	0.3822	0.6489

4.1.2. Regression Analysis Results for the High-Frequency Usage Group

The regression results for the high-frequency usage group are shown in Table 2. The usage frequency ($\beta_1 = 0.9324$) has a positive correlation with digital literacy scores, indicating that students who use ChatGPT more frequently show significant improvements in their digital literacy. While problem-solving time ($\beta_2 = -0.4001$) shows a negative correlation, the absolute value of this coefficient is higher compared to the low-frequency group, suggesting that students in the high-frequency usage group can reduce the time spent solving problems by using ChatGPT more frequently.

Regression Statistics for the High-Frequency Usage Group:

$R^2 = 0.9328$, which means the regression model explains 93.28% of the variance in digital literacy scores, indicating a high degree of fit.

$p = 0.0000$, which is significantly smaller than 0.05, confirming that the regression model is statistically significant.

Table 2. Regression Coefficients for the High-Frequency Usage Group

Regression Coefficients	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7
value	-30.8059	0.9324	-0.4001	2.0854	1.267	-0.1639	3.0217	2.5652

4.2. Mean and Standard Deviation of Digital Literacy Scores

The mean and standard deviation of the digital literacy scores for both the low-frequency and high-frequency usage groups are as follows:

Low-Frequency Usage Group:

Mean: 80.84;

Standard Deviation: 8.85.

High-Frequency Usage Group:

Mean: 88.00;

Standard Deviation: 5.34.

From the data, it can be observed that the high-frequency usage group has significantly higher digital literacy scores compared to the low-frequency usage group. Additionally, the high-frequency group has a smaller standard deviation, indicating more consistent results in improving digital literacy among students who frequently use ChatGPT. The low-frequency group's larger standard deviation suggests greater variability in their improvement, with some students benefiting more than others due to the lower usage frequency.

4.3. Results Discussion and Analysis

(1) Relationship Between Usage Frequency and Digital

Literacy Scores. From the regression analysis, it is evident that usage frequency is a key factor in determining digital literacy scores. The regression coefficient for the high-frequency group ($\beta_1 = 0.9324$) indicates that students who use ChatGPT more frequently show significant improvements in their digital literacy, while the coefficient for the low-frequency group ($\beta_1 = -0.3668$) shows a negative correlation, indicating limited improvement. This result underscores the importance of increasing the frequency of using intelligent tools to enhance digital literacy. Therefore, encouraging students to use such tools more frequently is an effective way to improve their digital literacy.

(2) Impact of Feedback Quality. The quality of feedback plays a significant positive role in digital literacy scores. In both the low-frequency and high-frequency groups, feedback quality significantly improves digital literacy scores. In the high-frequency group, the regression coefficient for feedback quality ($\beta_3 = 2.0854$) is much higher than that for the low-frequency group ($\beta_3 = 0.5688$), highlighting the crucial role of personalized, high-quality feedback in driving students' learning progress. Educators should focus on providing timely and targeted feedback to enhance student motivation and improve digital literacy.

(3) Impact of Problem-Solving Time on Digital Literacy. Although problem-solving time shows a negative correlation ($\beta_2 = -0.4001$) in the high-frequency usage group, suggesting that students in this group solve problems faster through frequent use of ChatGPT, the negative impact of this factor is relatively small. Higher usage frequency and more proficient use of the tools allow students to solve problems in less time, thereby improving their learning efficiency.

4.4. Comparison Analysis Between High-Frequency and Low-Frequency Usage Groups

Through a comparative analysis of the digital literacy scores of the high-frequency and low-frequency usage groups, the effectiveness of generative AI (especially ChatGPT-like large language models) in educational technology courses was explored. The experimental results indicate that students who frequently use generative AI tools show more significant improvements in digital literacy across several dimensions, especially in information retrieval, problem-solving efficiency, and critical thinking skills.

Specifically, the high-frequency usage group outperformed the low-frequency usage group in the following aspects:

(1) Digital Literacy Scores. The high-frequency usage group had significantly higher scores, especially in project completion, classroom interaction, and online learning dimensions.

(2) Problem-Solving Efficiency. Students in the high-frequency usage group reduced the time spent solving problems by approximately 22.91% compared to the low-frequency group, showing higher learning efficiency.

(3) Personalized Feedback Quality. The high-frequency usage group rated the personalized feedback from ChatGPT more highly, indicating better support during their learning process.

(4) Project Completion Rate. In the PBL (Project-Based Learning) activities, the high-frequency usage group showed a significantly higher project completion rate. In particular, high-frequency students exhibited stronger technical application abilities and creative thinking in tasks such as designing digital course resource reports and creating micro-course videos.

Although the high-frequency usage group showed advantages in various learning performance aspects, the low-frequency usage group also benefited from the assistance of generative AI, demonstrating that generative AI has a positive impact on improving the digital literacy of all students, particularly in terms of personalized feedback and learning support.

5. Conclusion

Based on the experimental results of this study, we found that while the high-frequency usage group performed better across various metrics, the low-frequency usage group also benefited from the assistance of generative AI tools. Therefore, based on this research, the following educational implications can be drawn:

(1) Effectiveness of Generative AI in Enhancing Students' Digital Literacy. The experimental results indicate that generative AI, especially large models like ChatGPT, can effectively enhance students' digital literacy. Educational technology courses can fully utilize these tools to help students improve their information processing ability, problem-solving skills, and critical thinking abilities.

(2) Encouraging the Proper Use of Intelligent Tools. Students who frequently use ChatGPT show significant improvement in their digital literacy. Therefore, educators should encourage students to use intelligent technology tools more frequently and appropriately, especially generative AI tools like ChatGPT. These tools can help students receive instant feedback and support during the learning process. By using ChatGPT more frequently, students can reduce problem-solving time and improve learning efficiency. At the same time, ethical education regarding the use of generative AI tools should be emphasized.

(3) Personalized Learning Support. The personalized feedback provided by ChatGPT significantly enhanced students' understanding of the learning content, particularly in the areas of feedback and guidance throughout the learning process. Teachers should provide targeted feedback to help students promptly identify and resolve learning difficulties.

(4) Emphasis on Project-Based Learning. Educators should design more project-driven tasks that allow students to improve their digital literacy through hands-on experience. In particular, through practical tasks, students can deepen their understanding and application of technological tools.

Although this study provides strong empirical support for the application of generative AI in educational technology courses, it still has some limitations. The sample for this study primarily comes from a single institution, and future research could expand the sample size to include students from different regions and institutions to increase the external validity of the conclusions. Future studies could further explore the long-term impact of generative AI and assess its role in enhancing students' comprehensive abilities. Additionally, as educational technology continues to evolve, researchers can attempt to design more personalized and refined educational models that cater to the specific teaching needs of different subject areas, thereby providing more accurate guidance for educational practices.

Acknowledgments

This work was supported in part by the 2022 Huizhou University Teaching Reform Project (No. 96), in part by the

2023 Guangdong Higher Education Teaching Reform Project(undergraduate) (No.992), in part by the Huizhou City Basic Education Educational Science Research Project (No. 2023hzkt051), in part by the Guangdong Provincial Education Science Planning Project (No. 2023GXJK496), in part by the Huizhou City Philosophy and Social Science Planning Project (No. HZ2023GJ133), and in part by the 2023 Guangdong Province First-class undergraduate course: Modern Educational Technology.

References

[1] IIEP-UNESCO. 2021. Information and communication technology (ICT) in education [EB/OL]. (2021-07-13)[2022-08-10].https://learningportal.iiep.unesco.org/en/issue-briefs/improve-learning/information-and-communication-technology-ict-in-education.

[2] Li, Jiayuan, Sha Zhu, Harrison Hao Yang, and Jian Xu. What does Artificial Intelligence Generated Content bring to Teaching and Learning? A literature review on AIGC in Education. In 2024 International Symposium on Educational Technology (ISET), IEEE, 2024: 18-23.

[3] Nguyen, Lan Anh Thuy, and Anita Habók. Tools for assessing teacher digital literacy: a review. Journal of Computers in Education, 2024, 11(1): 305-346.

[4] Timotheou, Stella, Ourania Miliou, Yiannis Dimitriadis, Sara Villagrá Sobrino, Nikoleta Giannoutsou, Romina Cachia, Alejandra Martínez Monés, and Andri Ioannou. Impacts of digital technologies on education and factors influencing schools' digital capacity and transformation: A literature review. Education and Information Technologies, 2023, 28(6): 6695-6726.

[5] Zhang, Shuting, Michelle Mingyue Gu, Wang Sun, and Tan Jin. Digital literacy competence, digital literacy practices and teacher identity among pre-service teachers. Journal of Education for Teaching, 2024, 50(3): 464-478.

[6] Lee, Gyeong-Geon, and Xiaoming Zhai. Using ChatGPT for Science Learning: A Study on Pre-service Teachers' Lesson Planning. IEEE Transactions on Learning Technologies, 2024, 17: 1643-1660.

[7] Lee, Chien Ching, and Malcolm Yoke Hean Low. Using genAI in education: the case for critical thinking. Frontiers in Artificial Intelligence, 2024, 7: 1452131.

[8] George, A. Shaji. The Potential of Generative AI to Reform Graduate Education. Partners Universal International Research Journal, 2023, 2(4): 36-50.