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Anticipation Guides with GenAI to Improve Text Understanding and Math Literacy in PGSD Students

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ABSTRACT
Text comprehension and mathematical literacy are essential competencies for prospective elementary school teachers. However, students in the Primary School Teacher Education (PGSD) program still face difficulties in interpreting texts and solving mathematical problems, indicating low disciplinary literacy. This study introduces an innovative approach by integrating Anticipation Guides strategy with Generative Artificial Intelligence (GenAI) to improve these competencies. Using a quasi-experimental design with a non-equivalent control group, the study involved 50 PGSD students, divided into an experimental group and a control group. The experimental group received the Anticipation Guides strategy integrated with GenAI, while the control group followed conventional learning methods. Data from pretest and posttest were analyzed using independent sample t-test and MANOVA. The results showed that the experimental group significantly outperformed the control group, with a significant increase in N-gain scores for text comprehension (0.65) and mathematical literacy (0.60). Statistical analysis confirmed a significant effect ($p < 0.001$) with a large effect size, and multivariate analysis revealed a significant impact (Wilks' Lambda = 0.291, $F(2,46) = 55.93$). These findings highlight the effectiveness of integrating GenAI in learning, offering an innovative approach to developing text comprehension and mathematical literacy skills in higher education. The combination of Anticipation Guides and GenAI not only enhances adaptive scaffolding and student engagement but also promotes higher-order thinking skills. This study suggests that this integration is a promising solution to improve text comprehension and mathematical literacy among prospective teachers in the digital era. Future research is expected to explore its long-term application across various subjects.
Keywords: *Anticipation Guides; Generative AI; text comprehension; mathematical literacy; PGSD students*

ABSTRAK

Pemahaman teks dan literasi matematika adalah kompetensi penting bagi calon guru sekolah dasar. Namun, mahasiswa Program Pendidikan Guru Sekolah Dasar (PGSD) masih menghadapi kesulitan dalam menginterpretasikan teks dan memecahkan masalah matematika, yang menunjukkan rendahnya literasi disipliner. Penelitian ini memperkenalkan pendekatan inovatif dengan mengintegrasikan strategi Anticipation Guides dengan Kecerdasan Buatan Generatif (GenAI) untuk meningkatkan kompetensi tersebut. Menggunakan desain kuasi-eksperimental dengan kelompok kontrol yang tidak setara, penelitian ini melibatkan 50 mahasiswa PGSD yang dibagi menjadi kelompok eksperimen dan kelompok kontrol. Kelompok eksperimen menerima strategi Anticipation Guides yang terintegrasi dengan GenAI, sementara kelompok kontrol mengikuti metode pembelajaran konvensional. Data dari pretest dan posttest dianalisis menggunakan uji t sampel independen dan MANOVA. Hasil penelitian menunjukkan bahwa kelompok eksperimen jauh lebih unggul dibandingkan kelompok kontrol, dengan peningkatan signifikan dalam skor N-gain untuk pemahaman teks (0,65) dan literasi matematika (0,60). Analisis statistik mengonfirmasi adanya pengaruh yang signifikan ($p < 0,001$) dengan ukuran efek yang besar, dan analisis multivariat menunjukkan dampak signifikan (Wilks' Lambda = 0,291, $F(2,46) = 55,93$). Temuan ini menyoroti efektivitas pengintegrasian GenAI dalam pembelajaran, menawarkan pendekatan inovatif dalam mengembangkan kemampuan pemahaman teks dan literasi matematik di pendidikan tinggi. Kombinasi Anticipation Guides dan GenAI tidak hanya meningkatkan scaffolding adaptif dan keterlibatan siswa, tetapi juga mendorong keterampilan berpikir tingkat tinggi. Penelitian ini menyarankan bahwa integrasi ini adalah solusi menjanjikan untuk meningkatkan kemampuan pemahaman teks dan literasi matematik di kalangan calon guru di era digital. Penelitian selanjutnya diharapkan dapat mengeksplorasi penerapan jangka panjangnya di berbagai mata pelajaran. **Kata Kunci**: Anticipation Guides; GenAI; pemahaman teks; literasi matematika; mahasiswa PGSD

INTRODUCTION

The ability to comprehend texts and mathematical literacy are two essential competencies for students of the Elementary School Teacher Education Program (PGSD) as future professional educators (Afriyanti et al., 2023; Firmansyah et al., 2023). In the practice of teaching at the elementary school level, teachers are required not only to teach content conceptually but also to foster an understanding of text meaning and relate mathematical concepts to real-life contexts. Unfortunately, various studies indicate that the level of text comprehension and mathematical literacy among PGSD students is still categorized as moderate to low (Murni et al., 2021; Trimurtini et al., 2023)

This issue becomes evident when students face word problems. Many students struggle with identifying key information, understanding the intent of the problem, and converting verbal information into the correct mathematical representation. This indicates a weakness in both reading literacy and numeracy skills simultaneously, which, in the literature, is referred to as disciplinary literacy (Shanahan & Shanahan, 2012). This finding is also consistent with the results of interviews conducted by the researcher with lecturers teaching Mathematics, where students still face difficulties in answering questions based on mathematical literacy. They require a long time to comprehend the content of the problem, and some of them need to read the problem multiple times to understand what concept is being asked. Additionally, many of them are unable to convert the problem in the text into a mathematical form (mathematization).

On the other hand, the teaching strategies used in lectures are often still conventional, onedirectional, with minimal variation, and do not stimulate critical thinking about readings

or problems (Li & Wan, 2022). One potential approach to address this issue is the Anticipation Guides reading strategy, which aims to activate students' prior knowledge, spark curiosity, and guide them to think critically before, during, and after reading a text (Duffelmeyer, 1994). Robinson, (2013) This strategy has been proven to improve reading comprehension and student cognitive engagement. This strategy has been proven to improve reading comprehension and student cognitive engagement. Anticipation Guides not only enhance general text literacy but also help students understand mathematical word problems. By activating prior knowledge and encouraging critical thinking, this strategy helps students identify key information, understand the context of the problem, and link verbal information to mathematical concepts. When combined with Generative AI (GenAI), such as ChatGPT, students can receive personalized feedback and guidance that further strengthens their ability to convert text into the correct mathematical representation.

Along with the advancements of the digital era, education faces the challenge of adapting to the learning needs of the 21st century. Nuranggraeni & Alani, (2025) The main issue is how to create an adaptive, relevant, and personalized learning process for students, considering the diversity of learning styles, individual needs, and the demand for skills. Therefore, to make it more contextually relevant to current technological advancements, this strategy can be strengthened with the integration of generative artificial intelligence (Generative AI/GenAI) such as ChatGPT, which can generate predictive questions, provide automatic feedback, and support a more adaptive learning process. Suryaningrat et al (2021)With this technology, students can receive instant feedback and guidance tailored to their individual needs. A recent finding by Kasneci et al (2023) states that the use of GenAI in learning can expand learning support (scaffolding) and deepen the understanding of concepts being studied, especially in text-based learning and problem-solving.

The importance of text comprehension and mathematical literacy for PGSD students, as well as the significant potential of utilizing GenAI technology in teaching strategies, makes this research focus on the implementation of the Anticipation Guides reading strategy integrated with GenAI (Cheng et al., 2024; Matto et al., 2025). This study can contribute to enhancing students' competence in understanding texts and mathematical literacy. Furthermore, this research is urgent given the demands of the ever-evolving educational landscape in line with the rapid advancement of technology. Alani (2024) The most significant technological abilities of this era reveal that, in addition to technological skills, high-level knowledge skills such as critical thinking, creativity, and communication are also necessary to support other competencies. Therefore, PGSD students, as future educators, must be equipped with strong literacy competencies, both in understanding general texts and mathematical texts (Council, 2012; Lewis-Spector, 2016). Research integrating the Anticipation Guides strategy with GenAI in the context of text comprehension and mathematical literacy for PGSD students is still very limited. Therefore, this study is designed to fill this gap by testing the effectiveness of applying the Anticipation Guides reading strategy integrated with GenAI in improving text comprehension and mathematical literacy among PGSD students. This research can contribute to enhancing students' competence in understanding texts and mathematical literacy.

Research integrating the Anticipation Guides strategy with GenAI in the context of text comprehension and mathematical literacy for PGSD students is still very limited. Therefore, this study is designed to fill this gap by testing the effectiveness of applying the Anticipation

Guides reading strategy integrated with GenAI in improving text comprehension and mathematical literacy among PGSD students. This research is also expected to provide an alternative learning approach that is relevant to the needs of the digital era and the characteristics of Generation Z students.

The objective of this study is twofold: first, to assess the effectiveness of the implementation of the Anticipation Guides reading strategy integrated with GenAI in improving PGSD students' text comprehension and mathematical literacy, and second, to compare the performance of students who receive this integrated approach with those who receive conventional learning methods. The study will test the hypothesis that the integration of Anticipation Guides with GenAI will lead to a significant improvement in both text comprehension and mathematical literacy compared to traditional teaching methods. By explicitly stating this hypothesis, the study aims to ensure clarity and rigor in evaluating the impact of the proposed strategy.

METHODS Type and Design

This study uses a Quasi-Experimental method with a Nonequivalent Control Group Design, consisting of an experimental group and a control group was chosen due to its suitability for situations that require a comparison between existing groups, without randomization, as well as its ability to evaluate the impact of a new learning strategy in a realistic context. (Suryaningrat et al., 2021).

Table 1. **Nonequivalent Control Group Design**

Group	Pretest	(Treatment)	Posttest
Eksperimen	O_1	Anticipation Guides with GenAI	O_2
Kontrol	O_3	-	O_4

Keterangan :

O_1 = The pre-test (before the treatment) on the experimental group.

O_2 = Post-test (after the treatment) on the experimental group

O_3 = Pre-test (before the treatment) on the control group

O_4 = Post-test (after the treatment) on the control group

This method is used to measure the effectiveness of the implementation of the Anticipation Guides with GenAI on text Understanding and mathematical literacy among PGSD students. In this study, the independent variable is the Anticipation Guides strategy integrated with Generative AI (GenAI) and The dependent variables are text comprehension and mathematical literacy of PGSD students. To assess text comprehension and mathematical literacy, a test instrument consisting of 2 text comprehension questions and 3 mathematical literacy questions was used. The instrument is validated and reliable. The test was administered to students before (pretest) and after (posttest) the intervention, for both the experimental and control groups. The data obtained from the pretest and posttest were processed and analyzed to

determine the effect of the implementation of Anticipation Guides integrated with GenAI. The sampling technique used in this study is Purposive Sampling. The sample consisted of secondyear students from the Primary School Teacher Education (PGSD) program at the Institut Pendidikan Indonesia Garut who were enrolled in the Elementary School Mathematics Olympiad course, including students from Class A (25 students) and Class B (25 students).

Data and Data Sources

The data presented in this study are used to answer the research questions that were previously established, particularly regarding the effectiveness of the Anticipation Guides reading strategy integrated with GenAI, in enhancing text Understanding and mathematical literacy among PGSD students. The type of data collected is determined by the research approach chosen, which may include quantitative data.

Quantitative data was obtained from the results of the pretest and posttest given to both groups (experimental and control groups). The questions used in this test were designed to measure PGSD students' Text Comprehension and Mathematical Literacy regarding linear algebra concepts, both before and after the treatment. The test includes questions that assess various aspects of understanding linear algebra concepts, such as linear equations and linear inequalities.

The data for this study were obtained from PGSD students at the Institut Pendidikan Indonesia in Garut Regency. The experimental group consisted of 25 students who received instruction using Anticipation Guides with GenAI. The control group, also consisting of 25 students, did not receive instruction using Anticipation Guides with GenAI. To facilitate a comprehensive understanding of the data that has been collected, the following table provides a detailed explanation of the characteristics of the data used in this study, as shown in Table 2.

Table 2.**Characteristics and Analysis of Research Data**

Data type	Data source	Data Collection Instruments	Data Analysis Technique
Quantitative	PGSD students at the Institut Pendidikan Indonesia	Pretest and posttest questions	Statistical analysis (ttest)

The following table presents the types of data used in the study, the sources from which the data were obtained, the instruments employed for data collection, and the data analysis techniques applied. For the purpose of data quantification, pretests and posttests were administered to assess changes in PGSD students' comprehension of texts and mathematical literacy.

Data collection technique

The research instruments used in this study consisted of tests developed based on indicators of mathematical literacy and text comprehension (Alani, 2024) , which include: communication, mathematizing, representation, reasoning and argument, devising strategies for solving problems, using symbolic, formal, and technical language and operations, and using mathematical tools. These instruments were designed in the form of essay questions.

Data analysis

Quantitative analysis was conducted on the data obtained from the pretest and posttest scores. Descriptive statistics were used to determine the mean scores and percentage improvement. To identify whether there were statistically significant differences between the experimental and control groups, a Independent Samples Test and MANOVA was performed. This test is considered appropriate for comparing two related groups and measuring the impact of an intervention (Supratman, 2025).

Furthermore, an N-Gain analysis was carried out to assess the improvement in Text Comprehension and Mathematical Literacy of each student. The N-Gain score was calculated by subtracting the pretest score from the posttest score and dividing the result by the difference between the ideal maximum score and the pretest score. The resulting value indicates the extent to which each student's Text Comprehension and Mathematical Literacy improved relative to their initial ability. These scores were then interpreted using predetermined Hake (1998) criteria: low (< 0.3), medium (0.3–0.7), and high (> 0.7).

RESULTS AND DISCUSSION Anticipation Guides Strategy Integrated with GenAI

The GenAI-Based Anticipation Guides Strategy in the learning process. The steps for implementing the Anticipation Guides Strategy are as follows in table 3.

Table 3. **Anticipation Guides Strategy Integrated with GenAI**

Anticipation Guides Strategy Integrated with GenAI	**Description**	Skills being practiced
What I think	• Expressing initial opinions in written or spoken form.	An impressive experience with the Anticipation Guide strategy integrated with GenAI. Using GenAI in mathematics learning.
What the text says	• Reading an initial text/material to compare with predictions (from GenAI). • Identifying key facts, concepts, or arguments from the text (or GenAI).	
	• Reviewing the content of the text or GenAI explanations.	
	• Reflecting on initial predictions using new information from GenAI or texts. • Clarifying opinions based on feedback. • Comparing initial and final outcomes from the learning process.	

	• Responding based on the understood content of the text/material.
Evidence	• Taking notes on parts of the text or GenAI responses that support or contradict the initial prediction. • Writing down quotations from the text or GenAI responses as evidence for support or rebuttal. • Formulating new evidence from discussions or texts. • Presenting justification or reasoning for the final answer.

Effectiveness of Anticipation Guides with GenAI in Improving text Understanding The improvement data (N-gain) of text comprehension scores from the experimental class and the control class were analyzed using the Independent Sample t-test with the assistance of SPSS software version 27. This test was used to determine the effect of applying the Anticipation Guides reading strategy integrated with GenAI on students' improvement in text comprehension ability. The analysis results were obtained by comparing the significance value (Sig. 2-tailed) from the Independent Sample t-test output with the predetermined significance level ($\alpha = 0.05$). Based on the SPSS 27 output, the Sig. 2-tailed value was <0.001, which is lower than the significance level ($\alpha = 0.05$). This indicates that there is a significant difference in text comprehension ability between students who used the Anticipation Guides strategy integrated with GenAI and those who did not. The following table presents the results of the score obtained during the observation conducted in the experimental classas and control shown in Table 4.

Table 4. **Descriptive statistics text Understanding**

Group	N	Minimun N-Gain Score	Maximum N-Gain Score	Mean	SD
Experiment	25	0,33	0,75	0,59	0,099
Control	25	0,14	0,56	0,38	0,11

The point estimate value in the Independent Sample effect sizes was 1.989, which is greater than 0.2. This means that the effect of applying the Anticipation Guides reading strategy integrated with GenAI on students' improvement in text comprehension ability falls into the high category.

The average N-gain score of text comprehension ability among students who used the Anticipation Guides strategy integrated with GenAI (0.59) was higher than the average N-gain score of students who did not use the strategy (0,38). This shows that the application of the Anticipation Guides reading strategy integrated with GenAI can effectively enhance students' text comprehension ability. However, beyond these statistical findings, it is crucial to consider

the broader educational and pedagogical implications of these results in the context of literacy pedagogy and AI-supported teaching.

These findings are supported by Defrioka, (2018); Duffelmeyer, (1994), who emphasizes that the Anticipation Guides strategy helps activate prior knowledge and encourages students to evaluate and revise their understanding as they read, which leads to deeper comprehension. Furthermore, McKenna & Robinson (2002) highlight that this strategy improves students' engagement and metacognitive awareness by prompting them to critically reflect on their reading before and after encountering the text.

The integration with Generative AI (GenAI) further amplifies this process by providing instant feedback, predictive prompts, and adaptive scaffolding, enabling students to interact with the material in a more personalized and reflective manner. According to Kasneci et al (2023), GenAI tools like ChatGPT can support reading comprehension through interactive dialogues that simulate real-time tutoring, thus enhancing learners' conceptual understanding and analytical thinking. This aligns with constructivist learning theory, which posits that learners build new knowledge upon their prior experiences through active engagement and reflection (Vygotsky & Cole, 1978).

Effectiveness of Anticipation Guides with GenAI in Improving mathematical literacy

The improvement data (N-gain) of mathematical literacy scores from the experimental and control classes were analyzed using the Independent Sample t-test, assisted by SPSS software version 27. This test was conducted to determine the effect of implementing the Anticipation Guides reading strategy integrated with GenAI on students' improvement in mathematical literacy skills. The analysis results were obtained by comparing the significance value (Sig. 2tailed) from the Independent t-test output with the predetermined significance level ($\alpha = 0.05$). The following table presents the results of the score obtained during the observation conducted in the experimental classas and control shown in Table 5.

Table 5. **Descriptive statistics mathematical literacy**

Group	N	Minimun N-Gain Score	Maximum N-Gain Score	Mean	SD
Experiment	25	0,42	0,75	0,64	0,07
Control	25	0,29	0,73	0,45	0,10

Based on the SPSS 27 output, the Sig. 2-tailed value was <0.001, which is lower than the significance level ($\alpha = 0.05$). This indicates that there is a statistically significant difference in mathematical literacy ability between students who used the Anticipation Guides strategy integrated with GenAI and those who did not.

The point estimate value in the Independent Sample effect sizes was 2.020, which is greater than 0.2. This means that the effect of applying the Anticipation Guides reading strategy integrated with GenAI on improving students' mathematical literacy ability falls into the high category.

The average N-gain score of mathematical literacy skills among students who used the Anticipation Guides strategy integrated with GenAI (0.64) was higher than that of students who did not use the strategy (0,45). This indicates that the application of the Anticipation

Guides reading strategy integrated with GenAI can effectively improve students' mathematical literacy skills.

These findings are theoretically supported by PISA (2019) and Jablonka (2011), which defines mathematical literacy as the capacity to formulate, apply, and interpret mathematics in various contexts. Teaching strategies that activate prior knowledge and promote contextual reasoning are essential for building this capacity. The Anticipation Guides strategy fosters students' ability to predict, reflect, and revise their thinking, which is aligned with key processes in mathematical modeling and reasoning (Duffelmeyer & Baum, 1992; McKenna & Robinson, 2002).

Furthermore, integrating Generative AI tools into mathematics learning enhances the scaffolding process by offering personalized prompts, visual explanations, and instant feedback. According to Kasneci et al (2023), GenAI systems can simulate dialogic learning and encourage students to think aloud while solving complex problems, which supports deeper mathematical understanding and metacognitive regulation.

This integration also aligns with constructivist learning theory, particularly Vygotsky's concept of the Zone of Proximal Development (ZPD) (Vygotsky & Cole, 1978), which posits that learners can achieve higher cognitive development through guided interaction and scaffolding. GenAI, in this context, acts as an adaptive guide that bridges the gap between what learners can do independently and what they can achieve with support.

Effectiveness of Anticipation Guides with GenAI in Improving text Understanding and mathematical literacy

The MANOVA test was employed in this study due to the presence of two dependent variables—text comprehension ability and mathematical literacy—which were analyzed simultaneously to determine the effect of implementing the Anticipation Guides reading strategy integrated with GenAI. The experimental group received treatment in the form of the Anticipation Guides strategy integrated with GenAI, whereas the control group did not use this strategy. By using MANOVA, it can be determined whether the strategy had a significant simultaneous effect on both abilities. Before conducting the MANOVA, assumption tests for normality, homogeneity of covariance, and linearity between dependent variables were carried out to ensure the validity of the analysis. The following table presents the results of the a Independent Samples Test and MANOVA Table 5.

Table 6**. Results of the a Independent Samples Test and MANOVA Point**

SPSS 27 Analisis	Sig. (2 tailed)	Wilks' Lambda	Hotellin g's Trace	Ability Estimate (Cohen's d)	Sig F
text Understanding	<0.001			1,989	

Independen t Samples Test	mathematical literacy	<0.001	2,020				
MANOVA	text Understanding and mathematical literacy			<0.001	0,015	2,47	1568,967

The results of the MANOVA using Wilks' Lambda indicated a significant multivariate difference between the experimental and control groups in terms of text comprehension and mathematical literacy abilities (Wilks' Lambda = 0.015, F(2, 47) = 1568,967, p < 0.001). This finding suggests that the application of the Anticipation Guides reading strategy integrated with GenAI had a significant simultaneous impact on both variables.

These findings are theoretically grounded in multiliteracies theory, which emphasizes that literacy in the 21st century involves not only the ability to decode text, but also to critically analyze, apply, and communicate information across multiple modalities and domains (Cazden et al., 1996; Kulju et al., 2018). The simultaneous improvement in both text comprehension and mathematical literacy suggests that integrating anticipatory reading strategies with advanced technologies like GenAI supports cross-disciplinary literacy development—a core element of 21st-century education (Presnell, 2022).

Moreover, the integration of Generative AI (GenAI) plays a critical role in promoting adaptive learning environments where students can engage with content dynamically and contextually(Arar et al., 2025; Cordero et al., 2024; Law, 2024). According to Kasneci et al (2023), GenAI systems facilitate personalized scaffolding and foster metacognitive reflection, which are essential for learners to make meaningful connections between prior knowledge and new concepts.

In line with Vygotsky's Sociocultural Theory (Daniels, 1996), which underscores the importance of mediated learning and social interaction, GenAI can be viewed as a form of digital mediation that extends the learner's cognitive zone of proximal development (ZPD). Through feedback, questioning, and elaboration, GenAI enhances students' abilities to comprehend complex texts and solve mathematical problems—both of which require higherorder thinking skills (Borge et al., 2024; Lee & Low, 2024).

Educational Implications

The significant impact observed on both text comprehension and mathematical literacy has several educational implications:

1 Active Learning and Critical Thinking: By engaging with the text, making predictions, and receiving feedback, students are encouraged to become active participants in their learning process, rather than passive recipients of information. This aligns with the pedagogical goals of developing critical thinking and problem-solving skills, which are essential for 21st-century learners.

2 Integration of AI in Pedagogy: The integration of GenAI into teaching strategies represents a significant step forward in AI-supported pedagogy. It allows for more dynamic, personalized learning experiences that can be tailored to the pace, preferences, and needs of individual students. This type of teaching is particularly relevant in the digital era, where personalized learning is becoming a key priority.

3 Adaptive Scaffolding: The use of GenAI provides adaptive scaffolding, a key element in Vygotsky's Zone of Proximal Development (ZPD). By offering personalized feedback and predictions, GenAI helps bridge the gap between what students can achieve independently and with support, thereby promoting higher cognitive development.

CONCLUSION

This study demonstrates that the integration of the Anticipation Guides reading strategy with Generative AI (GenAI) significantly improves both text comprehension and mathematical literacy among students of the Elementary School Teacher Education (PGSD) program. The use of quantitative analysis—including Independent Sample t-tests and MANOVA— confirmed statistically significant differences between the experimental and control groups across both domains. Students who were taught using the GenAI-integrated Anticipation Guides strategy showed higher average N-gain scores in text comprehension and mathematical literacy compared to those who did not receive the treatment.

Furthermore, the multivariate analysis using Wilks' Lambda indicates that the application of this integrated strategy has a strong and simultaneous positive impact on both dependent variables. These findings highlight the potential of combining traditional reading strategies with emerging technologies such as GenAI to enhance 21st-century learning outcomes. This approach not only promotes deeper understanding but also encourages critical thinking and personalized learning experiences.

However, there are certain limitations in this study that must be acknowledged. Firstly, the sample size was relatively small, which may limit the generalizability of the results to a broader population. Additionally, the study was conducted within a specific educational context (the PGSD program), and the findings may not be directly applicable to other teacher education programs or educational levels. Another limitation is the short duration of the intervention, which does not allow for an assessment of the long-term effects of the GenAIintegrated Anticipation Guides strategy.

Therefore, it can be concluded that the Anticipation Guides strategy, when supported by GenAI, is an effective and innovative instructional approach to foster essential literacy competencies in teacher education programs. Future research may explore the long-term impacts of this integration and its applicability across various subjects and educational levels, as well as consider larger sample sizes and diverse educational contexts to further validate and expand upon these findings.

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