

The Role of Digital Metacognitive Prompts Assisted by Gen-AI and Ethnopedagogical Approaches to Improve Writing Skills

Hendra Apriyadi^{1*}, Gunawan Suryoputro², Wini Tarmini³ 

^{1,2,3}Department of Indonesian Language Education, Prof. Dr. Hamka Muhammadiyah University, Jakarta, Indonesia

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ABSTRAK

Pengembangan keterampilan menulis peserta didik, khususnya dalam konteks pendidikan abad ke-21 yang menuntut kemampuan berpikir kritis, reflektif, dan kreatif. Keterampilan menulis yang efektif tidak hanya bergantung pada kemampuan teknis berbahasa, tetapi juga memerlukan kesadaran metakognitif. Namun, kenyataannya banyak siswa masih kesulitan dalam mengembangkan strategi menulis yang terstruktur dan reflektif. Di sisi lain, kemajuan teknologi kecerdasan buatan, khususnya Generative AI (Gen-AI), memberikan peluang besar untuk menciptakan lingkungan belajar digital yang adaptif dan personal, termasuk dalam memberikan prompt metakognitif yang dapat memicu kesadaran berpikir siswa secara lebih mendalam. Tujuan penelitian ini berupaya untuk mengeksplorasi dampak dari prompt metakognitif digital berbantuan Gen-AI dan pendekatan etnopedagogik pada proses pembelajaran kolaboratif dan individu terhadap kemampuan menulis dan kesadaran metakognitif. Penelitian ini menggunakan pendekatan kuasi-eksperimental dengan 200 siswa sekolah menengah atas. Analisis data yang digunakan meliputi uji MANOVA, ANOVA dua arah, dan uji regresi berganda untuk menyelidiki dampak intervensi pada keempat kelompok. Temuan penelitian menunjukkan bahwa integrasi prompt metakognitif digital berbantuan Gen-AI dan pendekatan etnopedagogik dalam menulis kolaboratif secara signifikan dapat meningkatkan pengetahuan dan regulasi metakognitif dibandingkan kelompok intervensi lainnya. Implikasi dari penelitian ini menunjukkan bahwa integrasi prompt metakognitif digital yang didukung oleh teknologi Gen-AI dan pendekatan etnopedagogik dapat menjadi strategi pembelajaran yang efektif dalam meningkatkan keterampilan menulis siswa.

ABSTRACT

Developing students' writing skills, particularly in the context of 21st-century education, demands critical, reflective, and creative thinking. Practical writing skills depend not only on technical language skills but also require metacognitive awareness. However, many students still struggle to develop structured and reflective writing strategies. On the other hand, advances in artificial intelligence technology, particularly Generative AI (Gen-AI), provide significant opportunities to create adaptive and personalized digital learning environments, including providing metacognitive prompts that can stimulate students' deeper thinking awareness. This study aimed to explore the impact of Gen-AI-assisted digital metacognitive prompts and an ethnopedagogical approach to collaborative and individual learning processes on writing skills and metacognitive awareness. This study used a quasi-experimental approach with 200 high school students. Data analysis included MANOVA, two-way ANOVA, and multiple regression to investigate the impact of the intervention on the four groups. The research findings indicate that integrating Gen-AI-assisted digital metacognitive prompts and an ethnopedagogical approach in collaborative writing significantly improved metacognitive knowledge and regulation compared to other intervention groups. The implications of this study suggest that integrating Gen-AI-assisted digital metacognitive prompts and an ethnopedagogical approach can be an effective learning strategy in improving students' writing skills.

*Corresponding author

E-mail addresses: ellysofiar@uhamka.ac.id (Hendra Apriyadi)

1. INTRODUCTION

Students at the secondary school level must not only possess strong writing skills but also be able to assess and improve their writing deficiencies. Therefore, two skills are needed: writing skills and metacognitive awareness. However, this contrasts with the reality in practice, where many students still lack these two learning competencies (Aben et al., 2024; Tenison & Sparks, 2023). Writing is one of the productive language skills that poses the greatest challenges compared to other language skills. Currently, educators and academics have reviewed and suggested changes to various writing teaching techniques (Abraham & Prediger, 2024; Tanrikulu, 2022). To help students achieve their writing goals, the emphasis in teaching writing is on creating a learning environment that enhances the quality of students' writing skills. However, in practice, teaching writing presents many challenges. This is due to the very nature of teaching writing, which aims to convince readers with the arguments presented by the author. Therefore, students must understand the reasoning behind writing and must have direct experience. Writing skills are not acquired instinctively; rather, they require development through reflective thinking, deliberate effort, and a deep commitment to the process (Anggraeni et al., 2025; Supeno et al., 2023). Therefore, to achieve writing goals, students need to develop metacognitive awareness, both for internalization and self-correction techniques to improve the quality of their writing. Students must also have the ability to reevaluate assumptions, choose appropriate syntactic representations, and formulate the author's argument. Therefore, writing skills involve a self-regulatory process consisting of several stages, such as developing a plan, setting a writing goal, organizing ideas, and evaluating (Arendt & Reershemius, 2024; Sefton-Green, 2021).

Based on various studies in this field, several factors contribute to students' challenges in writing, such as planning, generating ideas, and composing texts. Furthermore, students still lack metacognitive awareness and regulation, which are essential for assessing and critiquing their writing (Banihashem et al., 2024; Rezaei et al., 2023). To address this issue, students need support in increasing their awareness of metacognitive knowledge and regulatory abilities to improve their writing skills. This self-regulatory system seeks to engage knowledge, actions, and feelings during the writing learning experience (Birello & Pujola Font, 2020; Rachmawati & Purwati, 2021). Students must engage in the writing mastery process by activating their schemata, applying them to tasks, and selecting the outcomes of their ideas before articulating them in writing. Several previous studies have shown that metacognitive strategies and ethnopedagogical approaches significantly help predict students' writing abilities (Chen & Hapgood, 2019; Rachmawati & Purwati, 2021). These metacognitive strategies include planning, monitoring, reviewing, and evaluating, all of which are directly involved in the writing process. Learning based on metacognition can help students make strategic changes related to their writing goals (Chen & Hapgood, 2019; Pourdana, 2022). Based on findings in metacognition, ethnopedagogical approaches, and collaborative writing studies, instruction emphasizes metacognitive support, which may not address the complex relationship between metacognition and writing procedures. Furthermore, instruction in collaborative learning may not achieve educational goals due to interdependence, personal accountability, teamwork, and suboptimal assessment, which can hinder collaborative learning (Dixon & Cox, 2025; Pourdana, 2022). Considering these constraints, researchers recommend implementing metacognitive strategies to help students learn to manage their own learning in collaborative learning environments. For example, previous research has examined metacognitive instruction and ethnopedagogical approaches in collaborative learning, as well as metacognitive learning without such instruction. Findings indicate that students who received metacognitive guidance, an ethnopedagogical approach, and a collaborative learning intervention demonstrated superior writing skills compared to those who participated solely in a collaborative learning intervention (Domokos & Huey, 2023; Peltzer et al., 2025). Furthermore, other studies examined metacognitive strategies used both in groups and individually to achieve calibration at the high school level. Findings indicated that group calibration of metacognitive strategies was more effective than individual learning. Additional research suggests that integrating digital metacognitive prompts and an ethnopedagogical approach into collaborative learning interventions can improve various skills, such as understanding text structure, applying text structure, content reduction, and abstract writing skills (ElEbyary et al., 2024; Noushad et al., 2024). Improved self-regulation in the learning process can be achieved through educational environments that incorporate metacognitive strategies. Metacognitive strategies in collaborative learning can be an effective way to enhance collaborative writing experiences.

The use of metacognitive prompts and an ethnopedagogical approach assisted by Gen-AI is crucial for improving students' writing skills and metacognitive awareness. Through this intervention, students not only improve their writing skills but also deepen their cultural knowledge and self-assess their writing, enabling them to independently improve the quality of their writing. The capacity for self-monitoring and self-management can be enhanced through collaboration. Using metacognitive strategies, an ethnopedagogical approach, and collaborative learning allows students to engage in various learning

phases, including questioning, showcasing strategies, and helping peers, to enhance metacognitive awareness and identify effective learning approaches (ELEbyary et al., 2024; Mallahi, 2024). Thus, collaborative learning and this ethnopedagogical approach help students improve their self-regulation skills during the writing process. There are several differences between past studies and the current research, such as the metacognitive strategies used in previous studies did not address students' writing needs, and collaborative learning research sometimes leads to interdependence among students, which reduces their individual accountability. The current research differs from previous investigations by addressing and improving upon the limitations of past research; it combines Gen-AI-enhanced metacognitive strategy support and an ethnopedagogical approach in the context of collaborative writing education. Research has shown significant progress in recent years. Several previous studies have highlighted the importance of metacognitive strategies in the writing process, where students are trained to plan, monitor, and evaluate their writing independently. Other research also shows that the use of digital technology, including AI-based applications, can help facilitate the writing process through automated feedback and content personalization. Furthermore, local wisdom-based approaches such as ethnopedagogy are increasingly being researched as contextual and relevant learning strategies for students, particularly in areas with rich local cultures. However, while each of these approaches has been researched separately, the integration of digital metacognitive prompts, Gen-AI technology, and ethnopedagogy is still relatively new and has not been comprehensively explored in the context of writing instruction. Therefore, this study aims to fill this gap by offering an integrated approach that has the potential to strengthen the effectiveness of literacy learning in the digital era. The purpose of this study is to explore the integration of metacognitive strategies and ethnopedagogy approaches in collaborative writing education. This study seeks to explore the integration of digital metacognitive guidance and ethnopedagogical approaches in collaborative and individual learning to enhance students' metacognitive awareness and writing skills.

2. METHOD

This study used a quantitative, quasi-experimental approach by examining various conditions that influence students' metacognitive awareness and writing skills. The variables in this study included collaborative versus individual writing learning environments and metacognitive prompts enhanced by Gen-AI. The dependent variables in this study were writing skills and metacognitive awareness. This study investigated four intervention conditions based on combined results: integrating metacognitive prompts and ethnopedagogical approaches into collaborative writing instruction, integrating metacognitive prompts and ethnopedagogical approaches into individual writing instruction, excluding metacognitive prompts from collaborative writing instruction, and excluding metacognitive prompts from individual writing instruction. This study involved 352 high school students aged 17–20, from various schools, in grades 10–12. Four sets of 88 students each were created: one set for collaborative writing education with metacognitive prompts, one set for individual writing education without metacognitive prompts, one set for collaborative writing education with metacognitive prompts, and one set for individual writing education without metacognitive prompts. The ANOVA test findings showed that the language abilities of the four groups were identical, with $F(3, 166) = 1.071$ and $p = 0.71$. The analysis results indicated that the four groups of students had similar language abilities before the intervention was implemented. To reduce the possibility of extraneous variables, each group was given an intervention with elements tailored to the specific intervention conditions. The criteria and differences between each group are presented in Table 1.

Table 1. Variations and Standards of Intervention In Each Group

Condition	Criteria
Rapid metacognition digital approach + ethnopedagogic + Collaboration	a) All four interventions were used in writing instruction;
	b) Students receive the same writing exercises;
	c) Writing instructors are experienced in all four interventions;
Rapid metacognition digital approach + ethnopedagogic + Individual	d) Students receive the same materials as in writing instruction;
	e) For a total of 17 weeks, each of the four interventions received the same amount of time—two and a half hours per week.
Collaboration	f) The same evaluation techniques are used on students;
Individuals	g) Each student attends the same class. The instructor provides assistance and encourages students to complete their writing assignments.
	Differences in each intervention

Condition	Criteria
Rapid metacognition digital approach + ethnopedagogic + Collaboration	Students work collaboratively on writing assignments based on the metacognitive prompts provided. Over 30 sessions have been conducted.
Rapid metacognition digital approach + ethnopedagogic + Individual Collaboration	Students work on writing assignments individually based on the metacognitive instructions provided. Over 30 sessions have been conducted. Students work collaboratively on writing assignments. Over 30 sessions have been completed.
Individuals	Students work on writing assignments individually. They have completed over 30 sessions.

To better explain the different interventions for each group, an overview of each intervention within each group is provided below. Initially, the collaborative writing learning group focused on integrating digital metacognitive prompts. In this group, students were provided with a digital metacognitive intervention supported by Gen-AI in a collaborative setting. Students were divided into learning groups, with each group consisting of four students per session. The Gen-AI-supported metacognitive prompts included questions that highlighted self-competence in two areas: metacognitive knowledge and metacognitive regulation. Each group member utilized these metacognitive prompts throughout all stages of the writing process. The teacher clarified that responding to the Gen-AI-assisted digital prompts on metacognition could help them write more efficiently. Group members worked collaboratively to improve their writing skills. This collaborative writing process included several phases, such as planning, drafting, reviewing, and revising the essays together.

These stages begin with each student focusing on a section of the essay, and team members draft it. The next step involves the group collectively discussing the essay and making revisions if needed. The instructor assists students in their groups based on their needs. Second, a group focused on integrating digital metacognitive prompts into personal writing instruction. In this group, students received identical digital metacognitive prompts from Gen-AI as those in the metacognitive integration group during collaborative learning. However, the writing assignments were conducted individually using digital metacognitive prompts from Gen-AI. The instructor spent the first 10 minutes explaining everything to all students first. Students had the opportunity to ask questions or seek help if they encountered challenges. Third, a collaborative writing-only learning group. In this group, students collaborated in teams of four to practice writing. They wrote without receiving any guidance or prompts. The writing exercises and assignments were identical to those in the previous group, but they did not receive digital metacognitive prompts from Gen-AI. Fourth, a personal writing skills group. In this group, students worked on the essays individually and did not receive digital metacognitive prompts. Students can also ask the teacher for help if they experience difficulties.

The assessments used in this study included a writing skills test and a metacognitive awareness questionnaire. The assessments were conducted using a traditional format. The writing assignments were timed for 50 minutes. Students were also assessed using a metacognitive awareness inventory based on their individual work pace. The writing assessment included writing an argumentative essay, which is a standard requirement. Students were instructed to write an essay based on a specific topic. An argumentative essay is a form of writing that requires the writer to investigate a topic or theme and complete various steps, including gathering information, organizing it, evaluating evidence, and establishing a stance on the subject. Students were asked to take a stance on a specific issue and write while discussing various aspects, including outlining the problem, integrating solutions, and offering rational arguments. The topics chosen were adolescents having to live with their parents after graduation and adolescents having to move out after completing their education. The writing assessments were conducted before and after the intervention, serving as pretests and posttests. The initial empirical study yielded Cronbach's alpha values of 0.79 and 0.82 for the pretest and posttest phases, indicating that the instrument demonstrated good reliability and met the criteria.

Next, students' metacognitive awareness was evaluated through a self-report inventory for metacognitive writing awareness. This tool was modified from a framework created by Schraw and Dennison (1994). It aims to evaluate students' overall and specific metacognitive understanding of writing skills. Some statements were adapted to align with the research objectives focused on metacognitive writing. For example, "Several options regarding an issue are evaluated before I write," which was originally a general statement. Another item in the metacognitive awareness inventory is "Does my writing meet the stated goals or criteria?" This metacognitive writing awareness inventory includes eight dimensions of knowledge: declarative, procedural, conditional, planning, reviewing, evaluating, information management,

and debugging strategies. The first three elements are categorized under metacognitive knowledge, consisting of 19 questions, while the next five elements are categorized under cognitive regulation, consisting of 33 statements. The metacognitive writing awareness inventory includes 52 statements intended for data analysis purposes. The validity of the test items was evaluated through assessments by experts and language instructors against predetermined writing criteria. Students were administered this metacognitive writing awareness inventory at the pre- and post-intervention stages. The analysis showed a Cronbach's alpha value of 0.76 in the first stage and 0.78 in the second stage. Each group underwent the intervention for 2 hours per week for 18 weeks. In the final stage, students completed a writing skills assessment and answered a metacognitive awareness inventory questionnaire related to writing as a posttest. Four conditions involving metacognitive knowledge and metacognitive regulation factors were analyzed for correlation using MANOVA, a data analysis method used in this study. The influence of the independent variables on the dependent variable was analyzed through the MANOVA test. Furthermore, exploring the potential for improving argumentative essay writing ability was an additional research objective. A two-way ANOVA was conducted during the post-test phase to investigate the potential for improving argumentative essay writing at the pre-test and post-test stages. Furthermore, a multiple regression test was used to investigate the predictive influence of metacognitive knowledge, metacognitive control, and their interaction on students' writing ability. The simultaneous influence of the independent variables on the dependent variable was also analyzed through a multiple regression test. The interaction effect describes the relationship between variables in this regression model. Metacognitive knowledge and regulation are two different variables assessed simultaneously in this multiple regression analysis. Changes induced by the autonomous element in the dependent variable, writing ability, were used to assess the influence of this interaction. The Bonferroni correction was used in this study to minimize errors associated with multiple comparison analysis. The effect size used partial η^2 , with a significance level of p equal to 0.05.

3. RESULTS AND DISCUSSION

Results

To address the initial problem formulation, the researcher conducted an evaluation of metacognitive awareness with a focus on metacognitive knowledge and metacognitive regulation during the pre-test and post-test stages. Based on the ANCOVA analysis findings, during the pre-test stage, metacognitive knowledge among the four intervention groups showed no significant difference, with a value of $[F(4, 278) = 1.97, p = 0.56]$, while metacognitive regulation showed a value of $[F(4, 278) = 1.90, p = 0.62]$. Thus, during the pre-test stage, students had equivalent metacognitive awareness to eliminate bias in the research findings. In addition, an evaluation was conducted during the post-test stage to assess the impact of the four interventions on metacognitive knowledge and regulation. The analysis findings are shown in Table 2. Based on the analysis findings, metacognitive knowledge scores during the post-test phase ranged from 1.18 to 4.53, while metacognitive regulation scores varied between 2.38 and 6.42. The next phase involved a MANOVA test, which assessed the equality of the Covariance Matrices with values indicating $(M = 49.425, F = 7.351, p < 0.001)$. Based on the analysis findings, the covariance matrices were different. This value indicates that the null hypothesis has been violated. The next phase involved applying Pillai's criteria in a multivariate analysis to test the effect of the four interventions on metacognitive awareness.

Findings from the multivariate metacognitive assessment. The results of the analysis showed that digital metacognitive prompts significantly influenced students' metacognitive awareness ($V = 0.867, F(2, 176) = 283.052, p < 0.001, \text{partial } g^2 = 0.78$). With a value of $V = 0.834, F(2, 166) = 267.342, p < 0.001, \text{and } \text{partial } g^2 = 0.83$, it was determined that the collaborative learning environment, compared to independent learning, significantly influenced students' metacognitive awareness. With a value of $V = 0.134, F(2, 166) = 13.463, p < 0.001, \text{and } \text{partial } g^2 = 0.15$, the interaction of Gen-AI-assisted digital metacognitive prompts, the ethnopedagogical approach, and the learning environment significantly influenced metacognitive awareness. To evaluate the four interventions regarding the two dimensions of metacognitive awareness, the researchers initially conducted a multivariate test followed by a univariate test. Table 4 presents the results of the univariate test. The analysis results showed that metacognitive encouragement and the ethnopedagogical approach significantly influenced metacognitive knowledge, with a value of $[F(1, 175) = 288.435, p < .001, \text{partial } g^2 = .68]$. Metacognitive knowledge was mainly influenced by the learning environment, as indicated by the statistic $[F(1, 175) = 274.534, p < .001, \text{partial } g^2 = .63]$. The interaction between metacognitive encouragement, the ethnopedagogical approach, and the learning process environment, which had a value of $[F(1, 170) = 1.956, p = .19, \text{partial } \eta^2 = .01]$, did not significantly influence metacognitive knowledge. Furthermore, metacognitive prompts showed a significant effect on

metacognitive regulation, as indicated by the finding $[F(1, 170) = 436.028, p < 0.001, \text{partial } g^2 = 0.73]$. The effect of learning environment on metacognitive control was represented by $[F(1, 170) = 455.342, p < 0.001, \text{partial } \eta^2 = 0.73]$, while the interaction effect between the two was denoted as $[F(1, 175) = 24.362, p < 0.001, \text{partial } g^2 = 0.13]$. Descriptive statistics for metacognitive knowledge and metacognitive regulation at post-test are presented in Table 2. Multivariate test of metacognition in Table 3. Univariate metacognition test results in Table 4.

Table 2. Descriptive Statistics for Metacognitive Knowledge and Metacognitive Regulation at Post-Test.

Metacognition	Condition	Means	Standard deviation	N
Knowledge about metacognition	Individuals	1.18	.350	50
	Collaborative	3.81	.783	50
	Metacognition + ethnopedagogical approach + Individual	3.94	.789	50
Rules metacognition	Metacognition + ethnopedagogic approach + Collaborative	4.53	.745	50
	Individuals	2.41	.756	50
	Collaborative	5.76	.842	50
	Metacognition + ethnopedagogical approach + Individual	5.79	.756	50
	Metacognition + ethnopedagogic approach + Collaborative	7.35	.642	50

Table 3. Multivariate Test of Metacognition

Influence	Mark	F	df hypothesis	df error	Say	Part of η^2
Digital metacognitive prompts and ethnopedagogical approaches by Gen-AI						
Pillai's Trail	0.867	283.05	2	176	0.000	0.78
Learning settings (collaborative and individual)						
Pillai's Trail	0.834	267.34	2	176	0.000	0.83
Digital metacognitive prompts and ethnopedagogical approaches by Gen-AI x learning settings						
Pillai's Trail	0.134	14.463	2	168	.000	0.15

Table 4. Univariate Metacognition Test Results

Source	Type III sum of squares	df	Mean square	F	Say	Part of η^2
Digital metacognitive prompts by Gen-AI						
Metacognitive knowledge	147.432	1	142.435	288.435	0.000	0.68
Metacognitive regulation	183.562	1	183.562	436.028	0.000	0.73
Learning settings						
Metacognitive knowledge	114.531	1	124.538	274.534	0.000	0.63
Metacognitive regulation	192.052	1	192.045	455.342	0.000	0.73

Source	Type III sum of squares	df	Mean square	F	Say	Part of n2
Digital metacognitive prompts + ethnopedagogical approach by Gen-AI * learning settings						
Metacognitive knowledge	0.857	1	0.956	1.956	0.190	0.01
Metacognitive regulation	9.569	1	9.645	24.362	0.000	0.14

In addition, post hoc analysis was performed by modifying the mean values through pairwise comparisons. Based on the results of the analysis, the group utilizing digital metacognitive prompts in collaborative learning demonstrated significantly superior metacognitive knowledge compared to the other intervention groups, with p values recorded for each digital metacognitive prompt in individual learning (p = 0.05), collaborative writing learning group (p = 0.05), and individual writing learning (p = 0.01). In addition, it was found that the average level of paired metacognitive awareness, specifically digital metacognitive prompts and ethnopedagogical approaches of the AI-gen group in individual writing learning, exceeded that of the solo individual writing learning group, with a p value of 0.05. Students in the group focused on collaborative writing demonstrated greater metacognitive awareness than those in individual writing learning, with a p value of 0.05. In addition, metacognitive regulation examinations were observed in each intervention group as detailed below. Students in the collaborative writing learning group using Gen-AI-assisted digital metacognitive prompts showed greater improvement compared to the individual writing learning group with the same prompts (p: 0.05) in collaborative writing learning (p: 0.05) and individual writing learning (p: 0.05). Furthermore, it was found that metacognitive regulation in the Gen-AI-assisted digital metacognitive prompt group, combined with individual writing learning, was better than metacognitive regulation in the individual writing group alone. Metacognitive regulation in group learning through an ethnopedagogical approach and collaborative writing was superior to group learning through individual writing. In addition, a two-way ANOVA analysis was conducted to explore the variation in the effects of combining digital metacognitive prompts and ethnopedagogical approaches in collaborative versus individual learning on writing skills. Before conducting the analysis, the researcher examined the variation in writing skills during the pretest stage. Based on the analysis results, no significant differences emerged in the pretest conditions, with a value of $[F(3, 168) = 1.62, p = 0.68]$. However, during the posttest phase, writing skills in each group showed significant differences. The findings from the evaluation of each group's writing skills are shown in Table 5.

Table 5. Results of Descriptive Statistical Analysis of Writing Ability in the Post-Test Phase.

Condition	Means	Standard deviation	N
Individuals	7.62	1.31	50
Collaborative	9.21	1.356	50
Metacognition + ethnopedagogical approach + Individual	12.64	0.842	50
Metacognition + ethnopedagogic approach + Collaborative	14.73	0.946	50
Total	12.82	4.245	200

Table 6. Test of the Influence Between Subjects on Writing Ability

Source	Type III sum of squares	df	Mean square	F	Say	Part of n2
Digital metacognitive prompts + ethnopedagogical approach	521.783	1	521.783	493.683	0.000	0.78
Learning settings	171.462	1	182.546	173.435	0.000	0.54
Digital metacognitive prompts by Gen-AI * learning settings	5.263	1	5.263	6.745	0.029	0.05

Based on the analysis results, students in the collaborative writing learning group using metacognitive prompts showed the highest writing proficiency compared to the other groups, with a score of (M = 13.68, SD 0.924). This was followed by the metacognitive prompt group involved in individual writing learning with a score (M = 12.64, SD 0.842), then the collaborative writing learning group with a score (M = 9.21, SD 1.356), and finally, the individual writing group with a score (M = 7.62, SD 1.31). In

addition, to assess the impact of the group on writing skills, a two-way analysis of variance was conducted. Based on the results of the Levene test for equality of variance, the assumption of equality of variance was established based on the criteria that gave a value $[F(3, 167) = 1.824, p = 0.167]$. In addition, the analysis of the between-subject effect test is presented in Table 6. Multiple regression test of the contribution of metacognitive awareness to writing ability in Table 7.

Table 7. Multiple Regression Test of the Contribution of Metacognitive Awareness to Writing Ability

	Variables	B	Standard error	B	Sir ²
Written results	Metacognitive knowledge	0.584**	0.382	0.462	0.28
	Metacognitive regulation	0.542**	0.157	0.463	0.50
	Metacognitive knowledge *	0.198**	0.050	0.960	0.089
	Metacognitive regulation				
	Model summary	Intercept = 6.342			
		R ² = 0.824			
		Adjusted R ² = 0.73			
		R = 0.89			
		Standard Error			
		Estimate = 1.082			

Based on the results of the analysis of the between-subject effect test shown in Table 6, a significant effect of digital metacognitive prompts was observed with a value of $[F(1, 170) = 493.683, p \leq .001, \text{partial } g^2 = .78]$, the effect of the learning environment was recorded with a value of $[F(1, 170) = 182.546, p \leq .001, \text{partial } g^2 = .54]$, and the interaction effect between Gen-AI-assisted digital metacognitive prompts and the learning environment on writing skills was found to be $[F(1, 170) = 6.745, p \leq .05, \text{partial } g^2 = .05]$. Based on the post hoc analysis, it was determined that the writing ability of the metacognitive integration group in collaborative writing instruction was assessed against other groups. Furthermore, students who used digital metacognitive prompts showed superior writing skills compared to those who underwent personalized writing learning interventions. Students who participated in collaborative learning interventions showed superior skills compared to those involved in individual writing learning interventions. Next, a multiple regression analysis was conducted to explore how metacognitive awareness predicts writing ability. The analysis findings are shown in Table 7. Based on the analysis findings, metacognitive knowledge and regulation play a significant role. Furthermore, the relationship between metacognitive knowledge and regulation significantly influences writing ability.

Discussion

Regarding metacognitive skills, research findings indicate that interventions that promote metacognitive integration in collaborative writing education have the greatest impact on improving metacognitive knowledge and self-regulation. This finding aligns with previous research showing that learners' self-regulation can be enhanced through digital metacognitive prompts embedded in the curriculum and collaborative learning (Fadila et al., 2024; Lenkaitis et al., 2019). Collaborative learning environments and ethnopedagogical approaches can help students understand the application of metacognitive strategies. Learners who receive Gen-AI-supported metacognitive guidance in group learning will encounter diverse interpretations that lead to discussions about the significance of learning content (Anggraeni et al., 2025; Rachmawati & Purwati, 2021). Furthermore, stimulating questions can also lead to negotiation. During the learning process, questions can encourage students to reflect on their learning journey, increase metacognitive awareness, and enable them to plan, monitor, and assess their writing output (Feng, Junjie, et al., 2024; Leggette et al., 2019). This conclusion is in line with previous research which shows that the essence of collaborative learning and ethnopedagogic approaches involves various components such as scaffolding, thought-provoking questions, reflective models, feedback, monitoring, and evaluation.

Further findings indicate that students who were provided with digital metacognitive prompts through the Gen-AI intervention during collaborative writing lessons showed the greatest improvement in their essay writing skills compared to other methods (Chen & Hapgood, 2019; ElEbyary et al., 2024; Peltzer et al., 2025). This improvement in writing skills occurred because the Gen-AI-supported digital metacognitive prompts and the ethnopedagogical approach they received could trigger metacognitive processes and the ability to apply effective writing strategies. This is supported by various previous studies showing that Gen-AI-assisted digital metacognitive prompts have a significant impact on writing skills

(Feng, Lawrence, et al., 2024; Köcher et al., 2023) Furthermore, these digital metacognitive prompts can help students apply writing strategies while simultaneously utilizing regulatory skills to improve writing skills. The Gen-AI-supported digital metacognitive prompt intervention and the ethnopedagogical approach help students reflect on the writing strategies they use, thus enabling them to utilize their resources effectively. This method will motivate students to undertake various steps such as monitoring, assessing, and reflecting on their writing after completing the assignment. This is in line with previous studies showing that digital metacognitive prompt training significantly improves students' writing skills and writing quality (Fernandez & Guilbert, 2024; Kim et al., 2024). Improved writing skills through metacognitive prompts and an ethnopedagogical approach occur because these prompts help students develop various writing strategies, and metacognitive regulation enhancers increase students' awareness of the relationship between metacognitive prompts and writing quality.

The findings of this study further demonstrate that the cooperative learning environment and ethnopedagogical approach foster student interaction, motivating them to discuss and reach consensus while completing essay writing assignments. Insights into the role of collaborative writing learning have been provided in previous research. In this collaborative writing learning environment, students are motivated to engage in various tasks, including planning, composing, evaluating, and improving writing assignments (Foxworth et al., 2019; Kim, Lee, et al., 2025). These collaborative activities can develop and enhance students' skills in integrating ideas and receiving peer feedback, as well as fostering their self-regulation skills. These skills enable students to recognize discrepancies between the quality of their writing and expectations, allowing them to more efficiently evaluate and correct errors after completing the writing process (Foxworth et al., 2019; Garcés-Manzanera, 2024; Kim, Lee, et al., 2025). Therefore, the results regarding the impact of integrating Gen-AI-assisted metacognitive prompts and an ethnopedagogical approach in collaborative learning on writing skills emerge from the simultaneous function of metacognitive prompts in the collaborative learning context. These results are in line with metacognition theory, which states that Gen-AI-assisted metacognitive prompts during collaborative learning improve students' understanding of information in writing, which in turn reduces cognitive load and improves writing quality (Garcés-Manzanera, 2024; Kim, Detrick, et al., 2025).

Further findings indicate that metacognitive knowledge and regulation can predict the quality of students' writing skills. Higher levels of metacognitive awareness are closely associated with improved writing skills. These findings align with previous research identifying metacognition as a key predictor of academic achievement. Metacognitive awareness helps students manage cognitive resources, evaluate their writing strengths and weaknesses, and implement effective strategies. Learners with strong metacognitive awareness can set writing goals and apply appropriate techniques to organize, monitor, and assess their writing (Han, 2024; Khojasteh et al., 2025). Effective strategy choices are also shaped by students' metacognitive awareness. However, if the application of a writing strategy remains ineffective, students can modify their approach until it is deemed effective. These findings align with previous research showing that students with limited metacognitive awareness struggle to set writing goals and face challenges in effectively planning, monitoring, and assessing their writing (Karaog, 2017; Ke & Zhou, 2024; Khasanah & Yulianto, 2024). Specifically, metacognitive regulation is a more accurate predictor of writing ability than metacognitive knowledge. Metacognitive regulation refers to the self-regulating ability to plan, monitor, and evaluate students' thoughts. This skill significantly improves writing ability. Many previous studies support the benefits of metacognitive regulation (Birello & Pujola Font, 2020; Supeno et al., 2023). Students with strong metacognitive regulation skills are generally better able to adapt metacognitive writing strategies, facilitating strategy selection, resource utilization, and assessment of their writing.

The implications of this study indicate that the integration of digital metacognitive prompts supported by Gen-AI technology and an ethnopedagogical approach can be an effective learning strategy in improving students' writing skills. These results provide an important contribution to the development of technology-based learning models that not only emphasize cognitive aspects but also accommodate local cultural values and encourage higher-order thinking awareness. For teachers, this approach can be an innovative alternative in designing writing activities that are more contextual, reflective, and meaningful. For educational policymakers, these findings provide a basis for encouraging the integration of adaptive smart technology with local wisdom in the learning curriculum, particularly in literacy learning. Meanwhile, for educational technology developers, these research results open opportunities to design digital learning systems that are not only adaptive in content but also responsive to students' metacognitive needs and cultural backgrounds. This study has several limitations that require attention. First, the scope of the study was limited to eighth-grade students in two specific schools, so generalizing the results to other levels or regions requires caution. Second, the implementation of Gen-AI technology as a support for metacognitive prompts is highly dependent on the readiness of digital infrastructure and the technological literacy of students and teachers, which can vary across schools. Third, although an ethnopedagogical approach has

been integrated, the exploration of local cultural values has not been conducted in depth across all stages of writing learning. Based on these limitations, it is recommended that future research encompass a broader and more diverse population and explore the integration of Gen-AI in other learning contexts beyond writing skills. Furthermore, intensive training is needed for teachers in implementing technology and cultural approaches holistically, so that the benefits of this approach can be applied sustainably across various educational contexts.

4. CONCLUSION

The study findings indicate that combining Gen-AI-supported metacognitive prompts and an ethnopedagogical approach in collaborative writing education significantly improved metacognitive knowledge and regulation more than other intervention groups. Furthermore, the metacognitive intervention and ethnopedagogical approach in collaborative learning can improve students' writing skills. Improved writing skills and metacognitive awareness occur because metacognition in collaborative learning helps students process information, fosters metacognitive awareness, and allows for reflection on their writing, leading to significant improvements in their writing skills. Improved writing skills emerged specifically from the digital metacognitive prompts and ethnopedagogical approach provided by Gen-AI, which can trigger metacognitive processes and enable the implementation of effective writing strategies. This increase in metacognitive awareness can also predict students' writing skills. Specifically, writing skills are more strongly predicted by metacognitive regulation characteristics than by metacognitive knowledge elements.

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