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EFFECTIVENESS OF AI-INTEGRATED COLLABORATIVE WRITING AMONG UNIVERSITY EFL STUDENTS IN WRITING FLUENCY

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Abstract: This research aims to investigate the effectiveness of AI-integrated collaborative writing on writing fluency of EFL students in higher education. The method employed was quantitative with quasi- experimental design. There were 40 students divided into experimental and control groups. Technique of collecting data was writing tests before and after the treatment. The technique of analyzing data used paired sample t-tests and independent sample t-tests for determining writing ability and comparisons between groups. The results showed that both groups experienced improvements in writing ability, but the experimental group using AI integration showed a more significant improvement. These findings revealed that the use of AI, such as ChatGPT, QuillBot, Grammarly, and DeepL, can act as a digital scaffold that helps students develop ideas, improve grammar, and increase writing fluency more effectively. Practically, this study provides evidence that AI integration in collaborative learning can improve quality and efficiency of writing learning process in higher education. The findings also suggest that combining technological tools with collaborative strategies creates a more supportive and interactive learning environment for EFL students. Therefore, AI-integrated collaborative writing can be considered an innovative pedagogical approach to enhance writing fluency in higher education contexts.
Keywords: *AI-integrated, collaborative writing; EFL students; writing fluency; writing skill.*

INTRODUCTION

Writing is a fundamental productive skill in English as a Foreign Language (EFL) learning, particularly in higher education contexts. It serves as a primary medium through which students demonstrate conceptual understanding, critical thinking, and language proficiency (Hou et al., 2026). However, many university students still encounter difficulties in organizing and expressing ideas coherently in academic texts (Putri & Cahyono, 2020; Yulandari & Suryadi, 2025). These challenges indicate that effective writing requires not only linguistic competence but also higher-order cognitive abilities. As a result, students often struggle to meet academic expectations in written communication. Therefore, identifying key aspects that require pedagogical attention is essential.

Writing fluency represents a crucial component of effective academic writing. It refers to the ability to produce text continuously with minimal interruption during the writing process (Latif, 2013). In EFL contexts, fluency includes not only writing speed but also the smooth development and logical progression of ideas. Limited fluency can hinder students from constructing coherent arguments and maintaining textual continuity. Studies show that EFL learners often face issues in idea development and cohesion despite having adequate grammatical

knowledge (Putri & Cahyono, 2020). Consequently, writing fluency plays a central role in determining overall writing quality.

Despite its importance, many EFL students still experience difficulties in achieving adequate writing fluency. Their texts often show weak organization, limited cohesion, and lack of continuity, which reduces communicative effectiveness (Latif, 2013; Putri & Cahyono, 2020). These challenges also influence students' confidence and motivation, particularly when writing is perceived as difficult and unengaging (Rosdiana, 2019). In addition, limited exposure to meaningful writing practice further constrains fluency development. Such conditions suggest that both cognitive and affective factors influence writing performance. Therefore, improving writing fluency requires comprehensive instructional approaches.

Traditional writing instruction tends to emphasize final products rather than the writing process. This approach often limits students' opportunities to explore and develop ideas freely. In contrast, collaborative writing promotes interaction and shared responsibility in constructing texts. Research shows that collaborative writing supports idea generation, reduces cognitive load, and enhances writing fluency (Pham, 2021; Rezeki & Rahmani, 2021). It also increases engagement, creativity, and confidence among students (Andanty et al., 2025; Sappaile et al., 2025). However, its effectiveness depends on appropriate task design and instructional support (Sundgren & Jaldemark, 2020).

Technological developments, particularly in artificial intelligence (AI), have introduced new possibilities for writing instruction. AI tools can provide automated feedback, language suggestions, and support for idea development (Pan, 2024; N. Yang et al., 2025). These features help students revise their work more efficiently and improve writing quality (Mahdi et al., 2025; Rahmi et al., 2024; Wale & Kassahun, 2024). In addition, AI has been linked to innovative approaches such as flipped learning, which enhances engagement and metacognitive awareness (Namaziandost, 2025; Yan et al., 2024). Nevertheless, students still face challenges such as limited vocabulary and difficulty structuring ideas (Aldayel et al., 2026; Sulaiman et al., 2023). Therefore, both technological and individual factors must be considered in writing instruction.

Recent studies highlight the growing importance of integrating collaboration with AI in writing instruction. AI-supported collaborative writing has been shown to improve engagement, knowledge construction, and learner autonomy (Cheng et al., 2026; Hu et al., 2025; Michel et al., 2025). It also encourages reflection and self-directed learning during the writing process (Aladini et al., 2025; Wiboolyasarin et al., 2024). Furthermore, collaboration combined with AI helps students develop a stronger authorial voice through interaction (Khuder & Petric, 2026). AI tools such as ChatGPT also support idea generation and confidence in writing (Song & Song, 2023). However, most studies still treat AI as an individual tool rather than integrating it into collaborative practices (Fauziah et al., 2025; Munawaroh, 2025).

From a theoretical perspective, research on writing fluency, collaborative writing, and AI-assisted learning reflects different yet complementary orientations. Writing fluency studies focus on individual cognitive processes and sustained idea generation (Putri & Cahyono, 2020). Collaborative writing emphasizes social interaction and shared knowledge construction (Pham, 2021; Rezeki & Rahmani, 2021). Meanwhile, AI research highlights technological mediation and scaffolding in learning (Meniado et al., 2024; Wang & Wang, 2025). Despite these differences, all approaches aim to reduce cognitive load and enhance idea continuity. Thus, integrating these perspectives offers a more comprehensive understanding of writing development.

Recent developments position AI as an active participant in the learning process rather than merely a support tool. Generative AI enables iterative writing, adaptive feedback, and improved metacognitive awareness (Guan et al., 2025; Wang & Wang, 2025). It also expands interaction into more complex human–AI–human dynamics (Goswami & Krushna, 2026). These developments create new opportunities for enhancing collaborative learning environments. However, empirical research focusing specifically on writing fluency within this integration remains limited. Therefore, further investigation is needed to examine its effectiveness.

Based on the gaps identified in previous studies, this research focuses on AI-integrated collaborative writing. It seeks to examine whether integrating AI into collaborative writing improves students' writing outcomes. Most previous studies have not explicitly addressed writing fluency as a

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distinct construct. In addition, limited research employs rigorous quasi-experimental designs in EFL higher education contexts. This study addresses these limitations by focusing on writing fluency as a measurable outcome. The research question is: "Do students taught using AI-integrated collaborative writing achieve better results than those taught without AI integration?"

To support this investigation, the literature review focuses on three key areas. These include writing fluency, collaborative writing, and AI integration in writing instruction. Each area provides a theoretical foundation for understanding the research problem. Previous studies are examined to identify key findings and limitations. The review also highlights gaps that justify the need for this study. Thus, it establishes a clear framework for the research.

Writing fluency refers to the ability to produce coherent and meaningful text continuously within a limited time. It involves maintaining idea flow and cohesion rather than focusing solely on writing speed (Latif, 2013). In the Indonesian EFL context, students often face limitations in vocabulary and writing practice (Putri & Cahyono, 2020). They also tend to focus excessively on grammar, which interrupts idea development (Rosdiana, 2019). As a result, their writing may appear fragmented and underdeveloped. Therefore, improving fluency is essential for effective academic writing.

Low writing fluency significantly affects students' ability to communicate ideas clearly. It often leads to weak organization and reduced coherence in academic texts (Yulandari & Suryadi, 2025). Students may struggle to sustain arguments and connect ideas logically. These issues can limit their academic performance and confidence. A process-oriented approach can help address these challenges (Latif, 2013; Putri & Cahyono, 2020). Thus, writing instruction should emphasize idea development and continuity.

Collaborative writing is an approach where learners jointly produce texts through shared processes. It is grounded in sociocultural theory, which highlights interaction as a key factor in learning. Through collaboration, students can exchange ideas and negotiate meaning (Pham, 2021; Rezeki & Rahmani, 2021). This interaction supports deeper cognitive processing and improves writing fluency. It also allows students to learn alternative expressions from peers. Therefore, collaborative writing enhances both linguistic and cognitive development.

In addition, collaborative writing improves engagement and motivation in learning. Students become more confident as they receive feedback and support from peers (Andanty et al., 2025; Sappaile et al., 2025). It also promotes creativity and shared responsibility for learning outcomes (Sundgren & Jaldemark, 2020). However, its success depends on effective task design and facilitation. Poorly structured tasks may limit meaningful interaction (Rezeki & Rahmani, 2021). Thus, careful instructional planning is necessary.

AI-integrated collaborative writing represents an emerging approach in EFL instruction. AI tools provide feedback, vocabulary suggestions, and support for idea development (Ekizoğlu & Demir, 2025; N. Yang et al., 2025). These features help students revise their writing more effectively (Andriyanti et al., 2025; Riviyanti & Pratolo, 2025). In collaborative settings, AI feedback can stimulate discussion and peer interaction. This process enhances both revision and fluency development. Therefore, AI functions as both a cognitive and social scaffold.

Research also shows that AI reduces students' overfocus on technical accuracy. It enables them to concentrate more on idea expression and organization (Munawaroh, 2025; Song & Song, 2023). In higher education, AI integration supports digital literacy and autonomous learning (Fauziah et al., 2025; Pan, 2024). However, most studies still examine AI as an individual tool rather than a collaborative component (Ranalli et al., 2016; Steiss et al., 2024). As a result, its impact on writing fluency remains underexplored. Therefore, further research is needed to address this gap.

METHOD

The method used in the study was quantitative method to investigate the effectiveness of AI-integrated collaborative writing in improving the writing fluency of EFL students in higher education. A quantitative method was chosen for numerical measurement and analysis of changes in writing ability resulting from the treatment and facilitates empirical comparisons between groups (Mills & Gay, 2019). The research design employed was a quasi-experimental. There were two groups, an experimental group and a control group (Creswell, 2014; Sugiyono, 2018). Both groups were given a pretest to measure initial writing fluency. Next, the experimental group received treatment in the form of AI-incorporated into collaborative writing, while the control group

underwent conventional method in writing instruction. After the treatment period, both groups were given a posttest in determining changes in writing skill. This design allowed researchers to identify the effect of the treatment by comparing pretest and posttest scores within and between groups (Creswell & Creswell, 2018).

The research participants consisted of 40 students in the first year of English Language Education Study Program at Universitas Lancang Kuning, separated into two groups. Each group consisted of 20 students. Participant selection was conducted using purposive sampling, with the criteria being that students had completed the Writing I course and possessed relatively balanced basic writing skills (Sugiyono, 2017). This approach is commonly used in quasi-experimental research in higher education to ensure equivalence of initial abilities between groups (Mills & Gay, 2019). The two groups were assigned as the experimental group and the control group to compare the effectiveness of different instructional treatments. The experimental group received AI-integrated collaborative writing instruction, while the control group participated in collaborative writing without AI integration. The participants were within a similar age range and had relatively homogeneous academic backgrounds.

Data were collected through writing tests. The primary instrument was an essay writing test consist of 1000-1200 words to measure writing fluency. The pretest and posttest topics were different but of equal difficulty. Assessment was conducted using a rubric that assessed text fluency, the connectedness of ideas, and the number of words produced within a specified time (Mills & Gay, 2019). The treatment was given in four sessions and each session took two hours. Students worked in pairs or small groups, using AI-integrated collaborative writing as scaffolding, including assistance with idea development and text revision. The control group followed conventional individual writing methods for the same period (Creswell & Creswell, 2018). The research instrument was validated by two English language experts and one lecturer in charge of the Writing course to ensure content validity and suitability to the research context (Mills & Gay, 2019).

The collected data were analyzed using statistical procedures to determine the effectiveness of the treatment. First, descriptive statistics were calculated to identify the mean scores, standard deviations, and overall distribution of pretest and posttest results in both groups. Next, a normality and homogeneity test were conducted to ensure that the data met the assumptions required for parametric testing. An independent samples t-test was used to compare the posttest scores between the experimental and control groups, while a paired samples t-test was applied to examine the improvement within each group. The level of significance was set at 0.05 to determine whether the differences were statistically significant (Mills & Gay, 2019). The results of the statistical analysis were then interpreted to determine whether AI-integrated collaborative writing had a significant effect on students' writing fluency.

RESULTS AND DISCUSSION

In this part, it shows the results of quantitative analysis to answer the sim of research about the effectiveness of AI-integrated collaborative writing on EFL students' writing fluency. The analysis includes descriptive statistics, assumption tests (normality and homogeneity), and hypothesis testing using parametric analysis. The result of SPSS analysis is presented in tabular form to facilitate data interpretation. The presentation of the results begins with a comparison of pretest and posttest scores to identify the overall improvement in each group.

Descriptive statistics

The descriptive statistical analysis focused on students' writing skills before and after the intervention in both the experimental and control groups. Prior to the treatment, the mean pretest scores of the two groups were relatively comparable. The experimental group recorded a mean score of 77.75 (SD = 6.41), while the control group achieved a mean score of 76.90 (SD = 5.63).

Following the treatment, writing fluency scores increased in both groups; however, the improvement was more pronounced in the experimental group. The experimental group's mean posttest score rose to 82.20 (SD = 6.35), whereas the control group's mean score increased to 78.40 (SD = 5.12). A summary of the mean scores and standard deviations for both the pretest and posttest is presented in Table 1.

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Table 1. *Descriptive statistics*

	N	Min	Max	Mean	Std. Deviation
Pretest Experimental	20	65	90	77.75	6.414
Posttest Experimental	20	70	95	82.20	6.346
Pretest Control	20	65	88	76.90	5.628
Posttest Control	20	70	88	78.40	5.124
Valid N	20				

(Source: SPSS version 23, 2026)

Before further analysis, a normality test was performed to confirm that the data satisfied the assumption of normal distribution. Given that the sample size was fewer than 50 participants, the Shapiro–Wilk test was applied. The significance (Sig.) values obtained from the Shapiro–Wilk test for all groups in both the pre-test and post-test exceeded 0.05, specifically: experimental pre-test (0.151), experimental post-test (0.623), control pre-test (0.725), and control post-test (0.286). These findings suggest that the data are normally distributed and do not show significant deviations from normality. Consequently, the assumption of normality is fulfilled, allowing the use of parametric statistical analyses, including the paired-sample t-test and independent-sample t-test, to examine differences in writing performance within and between groups. The detailed results of the normality test are shown in Table 2.

Table 2. *Normality test*

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.
Writing Achievement	Pretest Experimental	0.187	20	0.065	0.929	20	0.151
	Posttest Experimental	0.164	20	0.161	0.964	20	0.623
	Pretest Control	0.150	20	0.200*	0.969	20	0.725
	Posttest Control	0.173	20	0.121	0.944	20	0.286

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

(Source: SPSS version 23, 2026)

The homogeneity of variance was examined using Levene's test to assess whether the experimental and control groups had comparable variances. The results of this test are presented in Table 3. This analysis was carried out to confirm that the variances of learning outcome scores between the two groups were equal, thereby meeting the requirements for parametric testing. The significance value (Sig.) obtained from Levene's test based on the mean was 0.684, which exceeds the 0.05 threshold. This result indicates that there is no statistically significant difference in variance between the experimental and control groups. Therefore, the assumption of homogeneity of variance is satisfied, and the independent-samples t-test is appropriate for comparing post-test scores between the two groups. A summary of the homogeneity test findings can be found in Table 3.

Table 3. *Test of homogeneity of variance*

		Levene Statistic	df1	df2	Sig.
Writing Achievement	Based on Mean	0.168	1	38	0.684
	Based on Median	0.225	1	38	0.638
	Based on Median and with adjusted df	0.225	1	36.678	0.638
	Based on trimmed mean	0.158	1	38	0.693

(Source: SPSS version 23, 2026)

Writing fluency improvement with AI-integrated collaborative writing in each group

Table 4 displays the findings of the paired-samples t-test conducted to examine changes in writing fluency scores within each group before and after the treatment. In the experimental group, the analysis revealed a t-value of −8.902 with a two-tailed significance level of 0.000, demonstrating a highly significant improvement in post-test scores compared to pre-test scores. This result suggests that the application of AI-integrated collaborative writing had a substantial positive effect on enhancing students' writing fluency.

Table 4. *Paired sample t-test*

No.		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Devt	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Pre-Test Experiment - Post-Test Experiment	-4.450	2.235	.500	-5.496	-3.404	-8.902	19	0.000
Pair 2	Pre-Test Control - Post-Test Control	-1.500	1.701	.380	-2.296	-.704	-3.943	19	0.001

(Source: SPSS version 23, 2026)

Meanwhile, the control group also showed a significant improvement, with a t-value of −3.943 and a two-tailed significance level of 0.001, although the magnitude of improvement was smaller than that observed in the experimental group. These results indicate that while traditional writing instruction contributes to students' writing development, incorporating AI into collaborative writing leads to greater and more pronounced gains. The detailed paired-samples t-test results for both groups are provided in Table 4.

Effectiveness of AI-integrated collaborative writing on writing fluency

Table 5 presents the results of the independent-samples t-test conducted to compare post-test writing fluency scores between the experimental and control groups. The analysis yielded a two-tailed significance value of 0.044, which is lower than the α level of 0.05, indicating a statistically significant difference between the two groups. The findings reveal that students in the experimental group, who engaged in AI-integrated collaborative writing, achieved higher writing fluency scores than those in the control group.

Therefore, this result supports the effectiveness of incorporating AI into collaborative writing instruction over conventional teaching methods in enhancing EFL students' writing skills. Overall, students exposed to AI-assisted collaborative writing demonstrated significantly better writing fluency than those who received traditional instruction. The complete results of the independent-samples t-test are provided in Table 5.

Table 5. *Independent sample t-test*

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Writing Achievement	Equal variances assumed	0.168	0.684	2.084	38	0.044	3.800	1.824	0.108	7.492
	Equal variances not assumed			2.084	36.384	0.044	3.800	1.824	0.102	7.498

(Source: SPSS version 23, 2026)

Overall, the analysis indicated that students in both groups began with relatively comparable levels of writing fluency. The data also met the assumptions of normality and homogeneity, confirming the appropriateness of using parametric statistical analyses. The results of the statistical tests revealed improvements in writing performance in both groups following the treatment; however, the gains achieved by the experimental group, which implemented AI-integrated collaborative writing, were notably greater than those of the control group. These

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findings offer empirical support for the effectiveness of integrating AI into collaborative writing instruction to enhance the writing fluency of EFL students in higher education.

Discussion

This section discusses the meaning and implications of the research findings regarding the effectiveness of AI-integrated collaborative writing in improving EFL students' writing fluency. The main findings indicate that students who received AI-based collaborative writing instruction experienced significantly greater writing improvement than the group that participated in collaborative writing without AI. Both groups experienced writing improvement, but the magnitude of the improvement varied.

Writing fluency improvement with AI-integrated collaborative writing in each group

Paired sample t-test analysis showed that experimental and control groups was significantly improved in writing fluency, but the experimental group with AI-integrated collaborative writing demonstrated greater improvement. This finding suggests that the combination of collaborative interaction and AI support creates a more conducive learning environment for fluent, consistent, and meaningful writing (Pham, 2021; Sappaile et al., 2025). The statistical results indicate that although collaboration alone contributes to improvement, the integration of AI strengthens the overall effect of the treatment. Students in the experimental group were able to generate ideas more continuously and organize them more coherently. This demonstrates that AI integration provides additional benefits beyond traditional collaborative strategies.

This improvement can be explained through a sociocultural perspective, where social interaction and scaffolding support more effective language development (Latif, 2013). In this context, AI functions as a digital scaffold that helps students focus on developing ideas and writing flow, without being unduly distracted by linguistic errors or structural difficulties (Riviyanti & Pratolo, 2025; Song & Song, 2023). The collaborative setting enables students to negotiate meaning and refine ideas together, while AI offers immediate linguistic assistance. As a result, students experience reduced anxiety and greater confidence during the writing process. This combination of peer interaction and technological support fosters a balanced cognitive and social learning environment.

Munawaroh (2025) demonstrated that the use of AI allows students to reduce cognitive barriers when writing, such as difficulty starting sentences or choosing vocabulary. With AI, students can more quickly develop ideas and formulate arguments, resulting in more consistent improvement in writing fluency compared to learning without AI. The availability of vocabulary suggestions and sentence restructuring features enables smoother text production. Students are therefore less likely to experience writer's block during collaborative activities. This emphasizes AI's role in supporting critical thinking and student expression in collaborative learning contexts.

Effectiveness of AI-integrated collaborative writing on writing fluency

Independent sample t-test results showed that the experimental group achieved posttest scores that were significantly higher than those of the control group.The finding confirms that AI-integrated collaborative writing is more effective in improving EFL students' writing fluency than conventional collaborative writing. The statistical difference between the two groups indicates that AI integration has a measurable impact on students' writing performance. This suggests that technology-enhanced collaboration offers a stronger instructional effect. Therefore, AI integration can be considered a valuable enhancement to collaborative writing pedagogy.

Andriyanti et al. (2025) emphasize that AI provides structural and linguistic support, allowing students to focus on developing text content and cohesion. Pan (2024) adds that AI helps maintain academic integrity while improving writing efficiency, while Pawestri & Pratolo (2024) states that AI integration facilitates a more adaptive writing learning process. These perspectives highlight the multifaceted benefits of AI in writing instruction. By offering real-time feedback, AI helps students make immediate revisions and improvements. Consequently, students can produce more coherent and fluent texts within a limited time.

These findings align with the studies of Rezeki & Rahmani, (2021) showed that collaboration improves writing skills, then, Khusnul et al. (2025) confirmed that collaborative methods effectively increase student engagement. With AI, the collaborative process becomes faster and more accurate, as students receive real-time feedback and automated correction suggestions, which strengthen their understanding of text structure,

cohesion, and writing fluency. The integration of AI also reduces delays in the revision process. Students can immediately identify and correct weaknesses in their drafts. This synergy between collaboration and AI enhances both efficiency and learning outcomes.

AI functions as a cognitive and pedagogical facilitator, enabling students to write faster and more fluently, for example by providing vocabulary suggestions, checking grammar, and assisting with brainstorming (Song & Song, 2023; Steiss et al., 2024). Ekizoğlu & Demir (2025) emphasize that automated feedback from AI can reduce linguistic errors that typically limit writing fluency, while Riviyanti & Pratolo (2025) highlight the role of AI in enhancing peer-to-peer collaboration through real-time collaborative revision. Through these features, AI minimizes interruptions in the writing process. Students can maintain the flow of ideas without excessive concern about technical mistakes. As a result, writing fluency improves both quantitatively and qualitatively.

Fauziah et al. (2025) show that students who use AI such as Grammarly, QuillBot, and DeepL report significant improvements in writing speed and language accuracy. AI not only supports technical aspects but also enhances students' creativity and engagement in the discussion of ideas. The presence of AI tools encourages students to experiment with vocabulary and sentence structures. This expands on previous literature emphasizing that writing fluency can be improved through collaboration. It confirms that AI integration provides additional pedagogical effects that strengthen students' writing skills.

Based on these findings, AI-integrated collaborative writing can be considered a relevant pedagogical innovation in the digital education era. Examples of AI that can be used in writing learning include ChatGPT, QuillBot, Grammarly, and DeepL. These tools function as digital scaffolds that help students brainstorm ideas, organize their writing flow, check grammar, and provide automated feedback. Their accessibility also allows students to practice writing beyond classroom sessions. Therefore, AI supports continuous and independent learning alongside collaborative instruction.

Rosdiana (2019) emphasized that AI supports students in becoming more engaged participants in the writing learning process, increasing motivation and minimizing frustration caused by language errors. Steiss et al. (2024) also found that AI provides rapid formative feedback, enabling lecturers to monitor student progress more effectively. The integration of AI thus benefits both students and instructors. It facilitates more efficient feedback cycles and promotes adaptive instruction. This innovation demonstrates that AI integration not only simplifies the technical aspects of writing but also enhances adaptive, personalized, and interactive collaborative learning experiences.

Overall, this research confirms that AI-integrated collaborative writing is an effective and cutting-edge strategy for improving the writing fluency of EFL students in higher education. AI support provides significant improvements compared to conventional methods, enriching pedagogical, cognitive, and motivational aspects. The findings offer empirical evidence that technology-enhanced collaboration strengthens writing performance. Furthermore, the study highlights the importance of integrating digital tools thoughtfully within collaborative frameworks. Therefore, AI-integrated collaborative writing represents a promising direction for future EFL writing instruction in the digital era.

Recent developments in AI-assisted language learning further support the findings of this study by emphasizing the evolving role of AI as both a cognitive and collaborative mediator in academic writing. For instance, AI co-writing systems powered by transformer-based models have been shown to enhance collaborative research writing by supporting idea generation, structural organization, and iterative revision processes (Goswami & Krushna, 2026). Similarly, studies on AI-based communication tools such as chatbots indicate that continuous interaction with AI systems can significantly improve learners' writing practice and linguistic awareness in EFL contexts (Mohammad et al., 2026). These findings align with the present study in that AI not only functions as a corrective tool but also as an active participant in the writing process, particularly when embedded in collaborative environments. Moreover, (Y. Wang, 2024) highlights that the use of generative AI and machine translation in academic writing reflects a complex interplay between cognitive regulation and sociocultural mediation, where learners strategically negotiate meaning with technological support. This supports the interpretation that AI in the current study operates as a form of distributed scaffolding that enhances both fluency and learner autonomy.

The findings show that AI has a positive impact on different stages of the writing process.

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It supports students in planning, drafting, and revising their work. Students can generate ideas more easily with the help of AI tools. They can also correct grammatical errors and improve text coherence (Mahdi et al., 2025; Rahmi et al., 2024). As a result, the overall quality of writing improves. In addition, combining AI with platforms like Google Docs makes writing more interactive and collaborative (Wale & Kassahun, 2024).

The study also finds that AI-supported flipped learning increases student engagement. It helps students become more aware of their own learning process. This leads to better metacognitive awareness in writing tasks (Namaziandost, 2025; Yan et al., 2024). However, the effectiveness of AI is influenced by internal factors. Motivation, mindset, and self-confidence play an important role in student success (Mohamed et al., 2026; Zhang, 2026). Therefore, technology should be supported by strong learner characteristics.

Furthermore, AI in collaborative writing improves both interaction and writing outcomes. Students can share ideas and receive feedback more effectively. AI also acts as a supportive partner in the writing process. It helps students develop and refine their ideas (Cheng et al., 2026; Hu et al., 2025). In addition, AI encourages deeper revision and reflection (Michel et al., 2025)(Michel et al., 2025). This process helps students produce more structured and complex writing (Aladini et al., 2025; Wiboolyasarin et al., 2024).

In addition, recent research emphasizes the human–AI collaborative dimension in academic writing, where learners' agency is shaped through continuous interaction with intelligent systems (Alyasin & Shah, 2026). This perspective is further reinforced by findings that AI writing tools are perceived not only as beneficial in improving efficiency and language quality but also as raising concerns regarding dependency and critical engagement (Akanda & Talukder, 2026). Such duality suggests that the effectiveness of AI-integrated writing is highly dependent on learners' digital literacy and critical AI awareness (Wang & Wang, 2025). Furthermore, motivational and affective dimensions play an essential role in determining the success of AI-supported writing environments, as AI use has been found to influence students' motivation, engagement, and self-efficacy in EFL writing tasks (Fraidan, 2025; Sun & Feng, 2009). Similarly, AI-enhanced learning environments have been shown to reduce anxiety and emotional barriers, thereby creating more supportive conditions for sustained writing development (Wu & Wu, 2026; H. Yang & Rui, 2025). Taken together, these studies strengthen the present findings by demonstrating that AI-integrated collaborative writing is not only a pedagogical innovation but also a multidimensional learning ecosystem involving cognitive, social, and affective interactions that collectively contribute to improved writing fluency.

CONCLUSION

This study aimed to investigate the effectiveness of AI-incorporated collaborative writing in improving the writing fluency of EFL students in higher education. The conclusion revealed that the implementation of AI-assisted collaborative writing, such as ChatGPT, QuillBot, Grammarly, and DeepL, significantly improved students' writing fluency compared to conventional individual writing methods. Both research groups experienced improved writing skills after the treatment, but the experimental group showed greater improvement. This suggests that AI-incorporated collaborative writing can help students focus more effectively on developing ideas, sentence flow, and connecting ideas. This approach can be considered a pedagogical innovation in writing instruction for the digital era. Nevertheless, this study has certain limitations, as the sample size was relatively small and drawn from a single university, which restricts the generalizability of the results. Furthermore, this study only measured short-term improvements in writing fluency, without assessing the long-term impact or transfer of writing skills to other text types, or other aspects such as accuracy, complexity, and creativity. For further research, it is recommended to use a larger and more diverse sample, examine the long-term effects of AI-integrated collaborative writing, and compare the effectiveness of various AI tools to support collaborative writing and improve EFL students' writing skills as a whole.

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