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# Comparative Effects of Adaptive and Generative AI-Supported Mind Mapping on EFL Writing Cohesion, Fluency, and Anxiety

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A B S T R A C T

**Purpose:** This study aimed to compare the effects of traditional instruction, conventional mind mapping, generative AI-supported mind mapping (GenAI), and adaptive AI-supported mind mapping (AdaptAI) on EFL learners' writing cohesion, writing fluency, and writing anxiety.

**Methods and Materials:** This quasi-experimental study employed a pretest–posttest design with 140 intermediate adult EFL learners enrolled in writing courses at a private language institute in Kerman, Iran, during spring 2025. Participants were selected through purposive sampling and assigned by intact classes to four instructional conditions: traditional instruction, conventional mind mapping, GenAI-supported mind mapping, and AdaptAI-supported mind mapping, with 35 learners in each group. The intervention lasted eight weeks and included 16 ninety-minute sessions. Writing cohesion was assessed using an analytical rubric adapted from McNamara et al. (2010), writing fluency was measured through scaled word-count scores, and writing anxiety was assessed using Cheng's Second Language Writing Anxiety Inventory. Gain scores were analyzed using one-way analysis of variance and Tukey HSD post hoc comparisons.

**Findings:** One-way ANOVA showed significant between-group differences in writing cohesion, $F(3, 136) = 53.11$, $p < .001$; writing fluency, $F(3, 136) = 48.02$, $p < .001$; and anxiety reduction, $F(3, 136) = 30.38$, $p < .001$. Tukey tests indicated that AdaptAI significantly outperformed GenAI in cohesion ($p = .048$) and anxiety reduction ($p = .025$), whereas their difference in fluency was nonsignificant ($p = .164$). Both AI-supported groups significantly outperformed the conventional mind-mapping and traditional groups across all outcomes. Conventional mind mapping also produced significantly greater gains than traditional instruction in cohesion and fluency (both $p < .001$), but not in anxiety reduction ($p = .160$).

**Conclusion:** AI-supported mind mapping, particularly adaptive AI-supported mind mapping, appears to provide an effective instructional scaffold for improving EFL learners' writing cohesion and fluency while reducing writing anxiety. Adaptive, personalized feedback may offer additional advantages over generative AI for higher-order textual organization and affective outcomes, although both AI approaches appear similarly effective for improving fluency.

***Keywords:*** *adaptive AI; generative AI; mind mapping; writing cohesion; writing fluency; writing anxiety.*

## 1. Introduction

Writing in English as a Foreign Language (EFL) is a cognitively demanding process that requires learners to coordinate idea generation, organization, linguistic formulation, revision, and monitoring while simultaneously maintaining coherence across sentences and paragraphs. For many EFL learners, these demands become particularly challenging because limited linguistic resources can interfere with the effective translation of ideas into well-organized written discourse. Writing quality therefore depends not only on grammatical accuracy or lexical knowledge, but also on learners' ability to plan content, construct logical relationships among ideas, sustain textual cohesion, and produce written language with sufficient fluency. In addition, affective variables such as writing anxiety can substantially shape the writing process by reducing learners' willingness to experiment with language, limiting cognitive engagement, and increasing hesitation during planning and composition. Consequently, contemporary EFL writing instruction increasingly emphasizes instructional approaches that simultaneously support cognitive organization, linguistic production, and learners' emotional engagement with writing tasks.

The growing integration of digital technologies into language education has substantially altered how these instructional challenges are approached. Artificial intelligence (AI), in particular, has emerged as a major development in educational technology because of its capacity to analyze learner performance, generate content, provide feedback, and adapt instructional support to individual needs. Earlier reviews of AI applications in education showed that intelligent systems could facilitate personalization, assessment, learner profiling, and automated support, although much early research concentrated on technological development rather than teacher–learner interaction or pedagogical implementation (Zawacki-Richter et al., 2019). Subsequent conceptual work emphasized that AI in education should not merely automate existing instructional practices but should support learning through adaptive interaction, timely feedback, and learner-centered instructional design (Hwang et al., 2020). These developments are especially relevant to language learning because language production requires repeated cycles of practice, feedback, revision, and reflection that can potentially be supported by intelligent technologies.

Research on intelligent computer-assisted language learning has accordingly demonstrated increasing attention to personalized instruction, automated feedback, learner modeling, and adaptive support. A systematic review by Weng and Chiu showed that intelligent language-learning environments can contribute to learning outcomes when technological functions are meaningfully aligned with instructional design and learner needs (Weng & Chiu, 2023). Similarly, research mapping the applications of AI in language education has identified writing, automated assessment, feedback, adaptive learning, and conversational support as prominent areas of development (Huang et al., 2023). Chatbot-supported language learning has also attracted considerable interest because conversational agents can provide interactive opportunities, immediate responses, and individualized practice outside the limitations of conventional classroom time (Huang et al., 2022). Nevertheless, the pedagogical value of such technologies depends on how learners interact with them and whether AI functions as a genuine scaffold rather than a substitute for cognitive engagement.

The recent emergence of generative AI has accelerated this transformation. Large language models can rapidly generate ideas, suggest vocabulary, restructure sentences, offer feedback, and produce extended text in response to user prompts. Such capabilities have created new possibilities for EFL writing instruction, especially during brainstorming, drafting, and revision. AI-based writing assistants were already being used before the widespread adoption of generative systems, with evidence suggesting that intelligent writing support could contribute to language learners' writing processes by providing accessible feedback and language-related assistance (Gayed et al., 2022). Wang likewise demonstrated the potential of AI-based computer-assisted writing and evaluation to support EFL writing through automated analysis and feedback mechanisms (Wang, 2020). More recent tools such as Wordtune illustrate how AI can function as a digital writing assistant by helping EFL learners reformulate expressions and explore alternative linguistic choices (Zhao, 2023). These technologies therefore have the potential to reduce some of the linguistic barriers that interfere with fluent written expression.

The instructional relevance of generative AI extends beyond sentence-level correction. ChatGPT and related large language models can support idea generation, organization, revision, and metalinguistic reflection, thereby potentially transforming AI from a corrective tool into an interactive writing partner. Song and Song reported that AI-assisted language learning using ChatGPT could support


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academic writing development and learner motivation, suggesting that generative systems may contribute to both performance and engagement (Song & Song, 2023). Ghafouri and colleagues similarly examined a ChatGPT-based writing instruction protocol and demonstrated the broader potential of generative AI to function as a writing mentor rather than merely an automated editing application (Ghafouri et al., 2024). More recently, Mekheimer found that generative AI-assisted feedback was associated with EFL writing development, with its effects linked to proficiency, revision frequency, and writing quality (Mekheimer, 2025). Yang also emphasized the importance of knowledge capture and feedback mechanisms in generative AI writing assistants, indicating that their educational value depends on how AI-generated information is integrated into students' writing processes rather than simply on content generation itself (Yang, 2025).

Despite these benefits, the pedagogical implications of generative AI are complex. Large language models can provide sophisticated responses, but they can also generate inaccurate, overly general, or contextually inappropriate information. Kasneci and colleagues highlighted both the opportunities and challenges associated with large language models in education, including their capacity for personalized support alongside concerns regarding reliability, dependency, bias, and inappropriate replacement of learner effort (Kasneci et al., 2023). Hockly similarly argued that AI in English language teaching should be approached critically because its apparent efficiency may coexist with pedagogical, ethical, and practical limitations (Hockly, 2023). A broader critical review by Bearman and colleagues showed that educational discourse surrounding AI frequently oscillates between narratives of transformation and concern, particularly regarding human agency, assessment, and the changing nature of expertise (Bearman et al., 2023). These concerns reinforce the need to investigate not only whether AI improves writing outcomes, but also which form of AI support is pedagogically most effective.

Ethical and practical challenges further complicate the adoption of generative AI in educational contexts. Yan and colleagues identified several concerns surrounding large language models, including hallucinated information, transparency, privacy, academic integrity, bias, and possible overreliance by learners (Yan et al., 2023). Crompton and colleagues similarly noted that AI offers considerable affordances for English language teaching while simultaneously creating challenges related to teacher preparedness, learner autonomy, ethical use, and appropriate pedagogical integration (Crompton et al., 2024). Accordingly, the question is not simply whether AI should be used in EFL writing instruction, but how it can be structured to support meaningful learning while preserving learners' active role in planning and composing text.

Feedback is one of the areas in which AI may offer particularly important benefits. Writing development depends heavily on learners' ability to identify weaknesses, interpret feedback, and revise their texts strategically. Automated written corrective feedback has been shown to provide useful information, although learners do not always interpret or apply automated suggestions effectively (Ranalli, 2018). Link and colleagues found that automated writing evaluation feedback can influence revision behavior and writing quality, highlighting the potential of technology-mediated feedback to support iterative improvement (Link et al., 2020). The growing literature on technology-mediated feedback in second-language writing likewise demonstrates an expanding range of digital tools and feedback sources, while also emphasizing variability in feedback quality, learner uptake, and instructional implementation (Loncar et al., 2021). These findings suggest that the effectiveness of AI feedback depends substantially on its specificity, timing, personalization, and integration into the writing process.

Learner perceptions of AI feedback also appear to influence whether such support becomes educationally meaningful. Escalante and colleagues compared EFL learners' perceptions of AI-generated and teacher feedback and showed that students evaluate feedback not only according to correctness but also according to perceived usefulness and responsiveness to their writing needs (Escalante et al., 2023). Kim and Lee further demonstrated the importance of feedback specificity, showing that EFL learners distinguish between actionable AI-generated guidance and generic comments that provide limited support for revision (Kim & Lee, 2024). Guo and Wang likewise examined ChatGPT's potential to support teacher feedback and highlighted the possibility of incorporating generative AI into feedback processes rather than treating it as a replacement for pedagogical judgment (Guo & Wang, 2024). Evmenova and colleagues focused specifically on struggling writers and suggested that generative AI may enhance feedback accessibility when used carefully as part of an instructional support system (Evmenova et al., 2024). Thus, the quality of AI-supported writing instruction may depend less on the mere availability of generative output


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than on the extent to which feedback is individualized, actionable, and responsive to learners' developing texts.

This distinction is particularly important when comparing generative AI with adaptive AI. Generative AI primarily produces new linguistic or conceptual content in response to prompts, whereas adaptive AI can modify its support according to learner performance, needs, or behavior. From a pedagogical perspective, adaptive systems may therefore provide a more individualized form of scaffolding. Learning-theory perspectives on AI emphasize that technology becomes educationally meaningful when its functions are connected to established mechanisms such as scaffolding, self-regulation, feedback, cognitive support, and learner agency (Gibson et al., 2023). Whereas generative tools can reduce the burden of idea generation by supplying content directly, adaptive systems may instead guide learners toward discovering organizational weaknesses, elaborating ideas, and making decisions independently. This distinction may be especially consequential in writing, where excessive reliance on generated content could increase output without necessarily strengthening underlying organizational skills.

Recent work also indicates that individual learner characteristics influence the effectiveness of AI-supported writing. Shi and colleagues showed that AI literacy and self-regulated learning are related to both writing performance and student well-being in generative AI-supported educational environments (Shi et al., 2025). This finding is important because productive use of AI requires learners to evaluate suggestions, monitor their own goals, and decide how generated information should be incorporated into a developing text. Similarly, research on learner engagement with ChatGPT-generated automated written corrective feedback indicates that students do not passively receive AI feedback; instead, engagement varies across cognitive, behavioral, and affective dimensions (Yan & Zhang, 2024). Therefore, AI systems that respond to learners' individual progress may be particularly useful for supporting active engagement and self-regulated learning.

At the same time, the expansion of generative AI into educational contexts beyond conventional language instruction suggests that perceptions of AI-mediated creativity and authorship are becoming increasingly important. Song and colleagues examined students' and teachers' perceptions of creative mathematical writing with generative AI and showed that educational stakeholders may recognize both supportive and problematic dimensions of AI-assisted composition (Song et al., 2025). Although mathematical writing differs from EFL composition, this work reinforces a broader educational concern: AI can facilitate idea development and expression, but its contribution should be structured so that learners remain cognitively responsible for the final product. Adaptive support may offer one way of maintaining this balance because it can guide rather than simply generate.

Alongside AI, mind mapping represents a well-established pre-writing strategy for supporting the cognitive organization of written discourse. Mind maps allow learners to represent ideas visually, identify relationships among concepts, establish hierarchical structures, and organize content before beginning linear composition. This process is particularly useful in EFL writing because learners frequently struggle to manage idea generation and linguistic formulation simultaneously. Al-Zyoud and colleagues reported that mind mapping can improve students' writing performance by helping them structure ideas before composing (Al-Zyoud et al., 2017). Tran similarly found that mind-mapping strategies can improve EFL writing quality, demonstrating the value of visual planning for organizing content and developing more effective texts (Tran, 2021). These findings indicate that mind mapping can serve as a cognitive scaffold during the pre-writing stage by externalizing information that would otherwise place demands on working memory.

The transition from conventional to digital mind mapping has further expanded its pedagogical possibilities. Pribadi and Susilana demonstrated that mind mapping can facilitate writing instruction in distance-learning environments, indicating that visual planning remains useful even when instruction is mediated through technology (Pribadi & Susilana, 2021). Mekhafi and colleagues reported that digital mind mapping positively influenced EFL learners' essay-writing performance and attitudes, suggesting that digital visualization can support both the cognitive and motivational dimensions of writing (Mekhafi et al., 2021). Digital mind maps are particularly compatible with AI because they provide structured spaces in which intelligent systems can generate suggestions, identify missing relationships, prompt elaboration, or personalize organizational feedback.

The integration of AI with mind mapping therefore represents a potentially powerful instructional approach. Mind mapping can provide a visual structure for externalizing and organizing ideas, while AI can supply immediate guidance or content during the planning process. However, the type of AI incorporated into the mind map may


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lead to different learning outcomes. Generative AI may facilitate rapid brainstorming by suggesting keywords, arguments, examples, or conceptual branches, thereby increasing the amount of material available for subsequent writing. Adaptive AI, by contrast, may monitor learners' developing maps and provide targeted prompts based on individual weaknesses or patterns. Such personalized guidance may be particularly beneficial for cohesion because learners must understand how ideas relate to one another rather than simply accumulate additional content. It may also influence fluency by reducing planning demands and making ideas more readily accessible during drafting.

The affective consequences of these instructional approaches warrant equal attention. Writing anxiety can emerge from concerns about linguistic accuracy, difficulty generating ideas, uncertainty about organization, limited confidence, or fear of evaluation. AI-based writing tools may reduce some of these pressures by providing immediate, private, and nonjudgmental support. Positive experiences with AI-assisted writing may consequently improve learner confidence and willingness to engage in revision (Gayed et al., 2022; Song & Song, 2023). At the same time, poorly calibrated or generic AI feedback may create uncertainty or cognitive overload, particularly when learners cannot determine which suggestions are appropriate (Kim & Lee, 2024; Yan & Zhang, 2024). Adaptive AI may therefore have particular potential for reducing writing anxiety because individualized prompts can limit uncertainty while preserving learners' responsibility for organizing and expressing their ideas.

Despite rapid growth in research on AI-assisted writing, several gaps remain. Much existing research has examined AI writing assistants, automated feedback, ChatGPT-supported instruction, or mind mapping as separate interventions. Studies have demonstrated the benefits of automated feedback for revision (Link et al., 2020), generative AI for writing development (Ghafouri et al., 2024; Mekheimer, 2025), and digital mind mapping for EFL writing (Mekhafi et al., 2021; Tran, 2021), yet comparatively little evidence is available regarding the combined use of AI and mind mapping. More importantly, studies have rarely distinguished between generative and adaptive AI when these systems are embedded within the same pre-writing strategy. This distinction is theoretically and pedagogically consequential because generative AI primarily contributes content, whereas adaptive AI can provide personalized scaffolding in response to learners' ongoing performance.

Another limitation is that many studies of AI-supported writing emphasize overall writing quality, feedback uptake, or perceptions rather than simultaneously investigating cohesion, fluency, and writing anxiety. These outcomes represent different yet interconnected dimensions of writing development. Cohesion reflects learners' capacity to establish meaningful linguistic and conceptual relationships across the text; fluency reflects the ability to produce written language with reduced interruption and greater output; and writing anxiety captures the affective burden associated with composition. Examining these three outcomes together can provide a more comprehensive understanding of whether AI-supported mind mapping improves not merely the quantity or surface quality of writing, but the broader cognitive and affective writing experience. Such comparative evidence is particularly important as educators increasingly face decisions about whether to adopt conventional digital tools, generative AI systems, or more sophisticated adaptive technologies.

The present study therefore addresses an emerging instructional problem at the intersection of EFL writing pedagogy, visual planning, personalized feedback, and generative artificial intelligence. By directly comparing traditional writing instruction, conventional mind mapping, generative AI-supported mind mapping, and adaptive AI-supported mind mapping, the study is designed to clarify whether incorporating AI into pre-writing activities produces additional benefits beyond mind mapping alone and whether adaptive personalization provides advantages over generative content support. This comparison responds to calls for stronger pedagogical grounding of AI use in education (Bearman et al., 2023; Crompton et al., 2024; Gibson et al., 2023), while also addressing concerns that AI effectiveness depends on the nature of learner engagement and the design of feedback mechanisms (Shi et al., 2025; Yan et al., 2023). Accordingly, the aim of this study was to compare the effects of traditional instruction, conventional mind mapping, generative AI-supported mind mapping, and adaptive AI-supported mind mapping on EFL learners' writing cohesion, writing fluency, and writing anxiety.

## 2. Methods and Materials

### *2.1. Study Design and Participants*

This study employed a quasi-experimental pretest–posttest design to examine the comparative effects of four instructional approaches on English as a Foreign Language (EFL) learners' writing cohesion, writing fluency, and


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writing anxiety. The study was conducted during the spring semester of 2025 at a private language institute in Kerman, Iran, where intermediate-level adult learners attended English writing courses twice weekly, with each instructional session lasting 90 minutes. The instructional context followed a blended-learning format combining conventional face-to-face teaching with technology-supported learning activities. During the intervention, learners assigned to the technology-based conditions used AI-supported mind-mapping tools in the institute's computer laboratory, which was equipped with desktop computers and internet access. A purposive sampling method was used to recruit 140 adult EFL learners from intermediate-level writing classes. Participants were between 18 and 35 years of age (M = 24.3, SD = 4.1) and had studied English for an average of 6.5 years (SD = 2.2). All participants were classified as B1–B2 English users according to the Common European Framework of Reference for Languages, based on the institute's standardized placement assessment. Because individual random assignment was not feasible within the institutional setting, four intact classes were allocated to four instructional conditions: traditional writing instruction, conventional mind mapping, generative AI-supported mind mapping (GenAI), and adaptive AI-supported mind mapping (AdaptAI). Each instructional condition included 35 learners. To reduce initial group differences, the intact classes were matched according to learners' English proficiency levels and previous writing performance. The instructional condition constituted the independent variable, whereas writing cohesion, writing fluency, and writing anxiety constituted the dependent variables.

### *2.2. Instruments*

Data were collected using two argumentative writing tasks, an analytical writing cohesion rubric, a quantitative writing fluency measure, and the Second Language Writing Anxiety Inventory. The writing tasks were administered at the pretest and posttest stages and were selected from TOEFL iBT independent writing prompts. Participants were given 40 minutes to complete each argumentative essay. The pretest writing prompt concerned the influence of technology on people's lives, whereas the posttest prompt asked learners to discuss whether students should take courses outside their primary field of study. Writing cohesion was assessed using an analytical rubric adapted from McNamara et al. (2010). The rubric evaluated five dimensions of textual cohesion, namely the appropriate use of cohesive devices, logical organization of ideas, paragraph unity, information flow, and overall connectedness of the text. Each dimension was rated on a five-point scale ranging from 1, indicating poor performance, to 5, indicating excellent performance. Writing fluency was operationalized as the number of words produced within the 40-minute writing period. Essay titles and references were excluded from the total word count, and the raw number of words was calculated using the built-in word-count function of the word-processing software. To provide a standardized fluency index, the total word count was divided by 10, meaning that one unit on the resulting index represented approximately ten written words. Fluency gain scores were subsequently calculated by subtracting pretest fluency scores from corresponding posttest scores. Writing anxiety was assessed using the Second Language Writing Anxiety Inventory developed by Cheng (2004). The instrument contains 22 items assessing cognitive anxiety, somatic anxiety, and avoidance-related behavioral manifestations of anxiety in second-language writing. Participants responded to each item using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), with higher scores reflecting greater writing anxiety. For the analysis of intervention effects, anxiety change scores were calculated so that positive values represented reductions in writing anxiety from pretest to posttest.

### *2.3. Interventions*

The study was implemented over a ten-week period comprising a pretest phase, an eight-week instructional intervention, and a posttest phase. During the first week, all participants completed the pretest argumentative writing task in the institute's computer laboratory under standardized conditions and were not permitted to use external resources, mind-mapping applications, or AI tools; immediately afterward, they completed the writing anxiety questionnaire. The intervention was then conducted over eight consecutive weeks and consisted of 16 instructional sessions, each lasting 90 minutes. All four groups followed the same general argumentative-writing syllabus, while the mode of instructional support differed according to group allocation. Learners in the traditional instruction condition received conventional process-writing instruction involving brainstorming, outlining, drafting, and revision without the use of mind maps or artificial intelligence. Learners in the conventional mind-mapping condition used manually


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constructed paper-based mind maps during the pre-writing stage to generate, categorize, and organize ideas before composing their essays. Participants in the GenAI-supported condition used an online mind-mapping platform enhanced with generative artificial intelligence; after entering a writing topic, the system generated possible branches, keywords, concepts, and arguments that learners could incorporate into and reorganize within their mind maps. Learners assigned to the AdaptAI-supported condition used the same general technological platform, but the artificial intelligence system dynamically adjusted its guidance according to each learner's developing performance. In this condition, the system monitored aspects of the learner's planning process, including idea development, logical organization, and vocabulary use, and subsequently generated personalized prompts intended to improve the structure and quality of the learner's mind map. During the final week, all groups completed the posttest argumentative writing task under conditions equivalent to those of the pretest and without access to mind-mapping tools or AI assistance. Participants then completed the writing anxiety inventory again, allowing changes in writing cohesion, fluency, and anxiety to be evaluated across the four instructional conditions.

### *2.4. Data Analysis*

The collected data were analyzed using descriptive and inferential statistical procedures designed to determine whether the four instructional conditions differed significantly in their effects on writing cohesion, writing fluency, and writing anxiety. Initially, descriptive statistics were calculated for the outcome variables to summarize group performance and changes from pretest to posttest. Gain scores were calculated for writing cohesion and writing fluency by subtracting pretest scores from posttest scores, whereas writing-anxiety change scores were coded so that higher positive values indicated larger reductions in anxiety. Before evaluating intervention effects, a one-way analysis of variance was conducted on the pretest scores to determine whether the four groups were comparable before the intervention; no statistically significant baseline differences were found ($p > .05$). Subsequently, three separate one-way analyses of variance were performed on the gain scores, with instructional condition as the between-group factor and writing cohesion, writing fluency, and writing-anxiety reduction as the respective dependent variables. Where statistically significant omnibus differences were identified, Tukey's Honestly Significant Difference post hoc test was applied to determine which specific instructional groups differed from one another. Statistical significance was evaluated at the conventional alpha level of .05, with exact p values reported where appropriate and values below .001 reported as $p < .001$.

## 3. Findings and Results

This section presents the quantitative findings from the experimental study. The results are organized around three dependent variables: writing cohesion, writing fluency, and writing anxiety. Descriptive statistics are first reported for each group, followed by inferential analyses to determine whether the observed differences are statistically significant. A one-way ANOVA conducted on the pretest scores indicated no statistically significant differences among the four groups ($p > .05$), suggesting that the groups were comparable prior to the intervention.

Table 1 displays the mean gain scores (post-test minus pre-test) and standard deviations for all four instructional groups across the three outcome measures. As shown in Table 1, the AdaptAI group achieved the highest mean improvement in cohesion ($M = 5.92$, $SD = 2.14$), followed by the GenAI group ($M = 4.71$, $SD = 1.83$), the Mind Mapping group ($M = 2.70$, $SD = 1.69$), and the Traditional group ($M = 0.49$, $SD = 2.03$). For fluency, a similar pattern emerged: the AdaptAI group showed the largest gain ($M = 5.83$, $SD = 1.65$), followed by GenAI ($M = 4.92$, $SD = 2.17$), Mind Mapping ($M = 3.22$, $SD = 1.72$), and Traditional instruction ($M = 0.98$, $SD = 1.69$). Regarding anxiety reduction, the AdaptAI group again demonstrated the greatest improvement ($M = 6.34$, $SD = 2.20$), with GenAI ($M = 4.92$, $SD = 2.04$), Mind Mapping ($M = 3.05$, $SD = 1.65$), and Traditional ($M = 2.01$, $SD = 2.32$) following in descending order.


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**Table 1**

*Descriptive Statistics for Gain Scores by Group*

| Group | Cohesion M | Cohesion SD | Fluency M | Fluency SD | Anxiety M | Anxiety SD |
|---|---|---|---|---|---|---|
| Traditional | 0.49 | 2.03 | 0.98 | 1.69 | 2.01 | 2.32 |
| Mind Mapping | 2.70 | 1.69 | 3.22 | 1.72 | 3.05 | 1.65 |
| GenAI | 4.71 | 1.83 | 4.92 | 2.17 | 4.92 | 2.04 |
| AdaptAI | 5.92 | 2.14 | 5.83 | 1.65 | 6.34 | 2.20 |

To provide a clearer visual comparison of the group differences, Figures 1, 2, and 3 display the mean gain scores with standard deviation error bars for cohesion, fluency, and anxiety reduction, respectively.

**Figure 1**

*Mean Gain Scores in Writing Cohesion by Instructional Group*

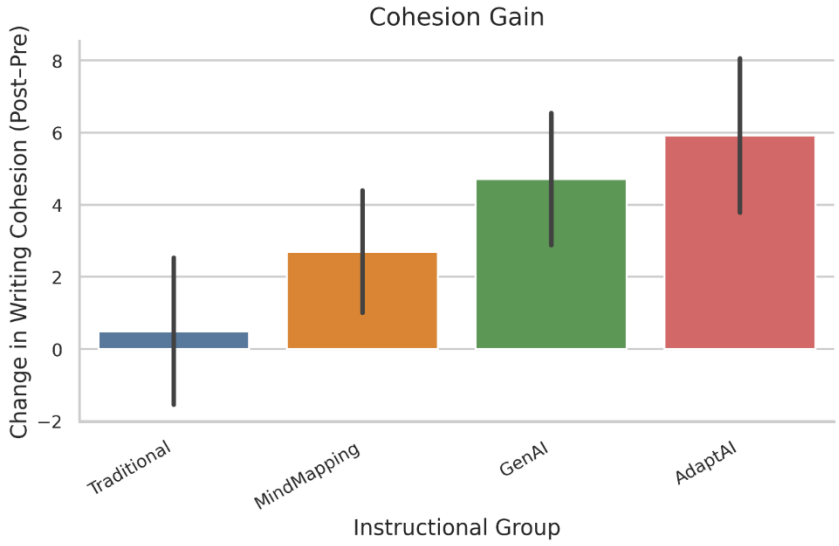


**Figure 2**

*Mean Gain Scores in Writing Fluency by Instructional Group*

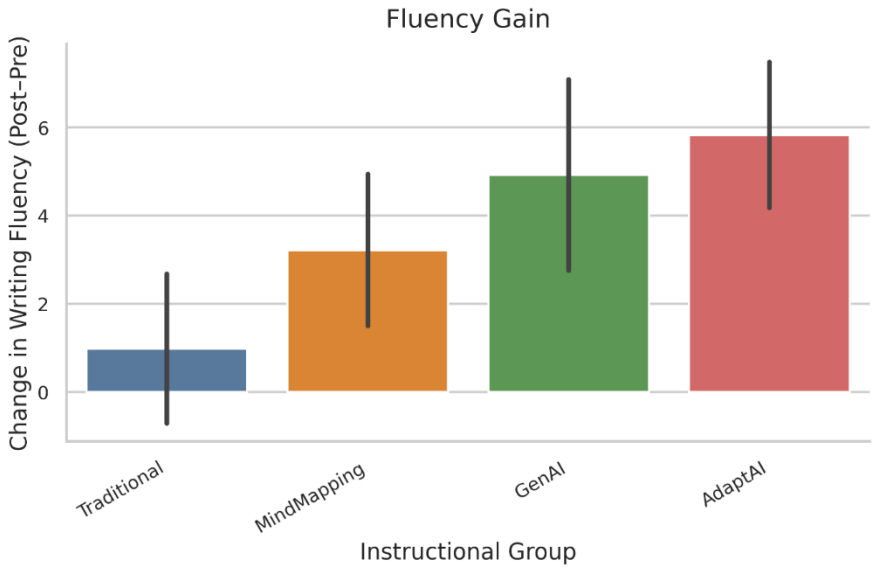




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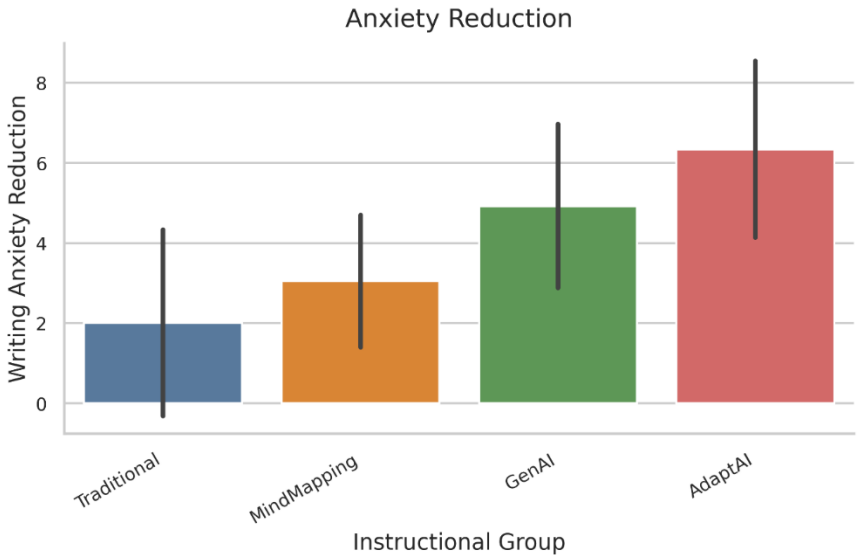
**Figure 3**

*Mean Gain Scores in Writing Anxiety Reduction by Instructional Group*




As the figures illustrate, a consistent ascending pattern is visible across all three outcomes, with the Traditional group showing the smallest gains and the AdaptAI group showing the largest. The two AI-supported conditions (GenAI and AdaptAI) clearly outperformed the non-AI conditions in all three measures, while the difference between GenAI and AdaptAI was relatively smaller and more variable.

To determine whether these observed differences were statistically significant, three separate one-way ANOVAs were conducted one for each outcome variable. Table 2 summarizes the results of these analyses.

**Table 2**

*One-Way ANOVA Results for Gain Scores*

| Outcome Variable | F(3, 136) | p |
|---|---|---|
| Cohesion | 53.11 | < .001 |
| Fluency | 48.02 | < .001 |
| Anxiety Reduction | 30.38 | < .001 |

As demonstrated in Table 2, all three ANOVAs yielded statistically significant results. For cohesion, the effect of instructional group was significant, $F(3, 136) = 53.11$, $p < .001$. Similarly, the effect on fluency was significant, $F(3, 136) = 48.02$, $p < .001$. Finally, the effect on anxiety reduction was also significant, $F(3, 136) = 30.38$, $p < .001$.

Because the ANOVAs indicated significant overall group differences, Tukey HSD post hoc tests were performed to identify which specific pairs of groups differed from one another. Table 3 presents the pairwise comparisons for all three outcome measures.

**Table 3**

*Tukey HSD Post Hoc Comparisons*

| Comparison | Cohesion | Fluency | Anxiety Reduction |
|---|---|---|---|
| AdaptAI vs. GenAI | p = .048 | p = .164 | p = .025 |
| AdaptAI vs. Mind Mapping | p < .001 | p < .001 | p < .001 |
| AdaptAI vs. Traditional | p < .001 | p < .001 | p < .001 |
| GenAI vs. Mind Mapping | p < .001 | p = .001 | p = .001 |
| GenAI vs. Traditional | p < .001 | p < .001 | p < .001 |
| Mind Mapping vs. Traditional | p < .001 | p < .001 | p = .160 |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As shown in Table 3, the AdaptAI group significantly outperformed the GenAI group in cohesion ($p = .048$) and anxiety reduction ($p = .025$), but not in fluency ($p = .164$), suggesting that both AI-supported conditions improved writing fluency to a similar extent. Both AI-supported conditions produced significantly greater gains than the Mind Mapping and Traditional instruction groups across all three outcomes. The Mind Mapping group showed significantly higher cohesion and fluency gains than the Traditional group ($p < .001$ for both), but the difference in anxiety reduction between these two groups was not significant ($p = .160$). the results indicate that AI-supported mind mapping led to the greatest improvements in writing cohesion, fluency, and anxiety reduction. Among the AI conditions, AdaptAI was superior to GenAI in cohesion and anxiety reduction, though both performed similarly in fluency. Conventional mind mapping was more effective than traditional instruction for cohesion and fluency, but not for anxiety reduction.

## 4. Discussion and Conclusion

The present study compared the effects of traditional writing instruction, conventional mind mapping, generative AI-supported mind mapping (GenAI), and adaptive AI-supported mind mapping (AdaptAI) on EFL learners' writing cohesion, writing fluency, and writing anxiety. The inferential findings demonstrated statistically significant differences among the four instructional conditions for all three outcomes. Specifically, the instructional-group effect was significant for writing cohesion, $F(3, 136) = 53.11$, $p < .001$, for writing fluency, $F(3, 136) = 48.02$, $p < .001$, and for anxiety reduction, $F(3, 136) = 30.38$, $p < .001$. Post hoc comparisons further showed that AdaptAI significantly outperformed GenAI in cohesion and anxiety reduction, whereas the two AI-supported conditions did not differ significantly in fluency. Both AI-supported groups performed significantly better than the conventional mind-mapping and traditional-instruction groups across the three outcomes. Conventional mind mapping also significantly surpassed traditional instruction in cohesion and fluency, although the two non-AI conditions did not differ significantly in anxiety reduction. Taken together, these results indicate a graded pattern in which progressively more individualized and technologically enhanced pre-writing support was associated with stronger writing outcomes, with adaptive AI providing the most pronounced benefits for textual cohesion and anxiety reduction.

The significant superiority of the AdaptAI condition in writing cohesion suggests that personalized, responsive scaffolding may be particularly effective for helping learners organize and connect ideas across a text. Cohesion requires more than the generation of relevant content; learners must establish logical relationships between propositions, maintain paragraph unity, control information flow, and use cohesive devices appropriately. Adaptive AI may support these processes because it responds to learners' developing performance rather than offering the same form of assistance to all users. This interpretation aligns with research emphasizing that AI becomes educationally valuable when it provides individualized, actionable, and context-sensitive feedback rather than generic suggestions (Kim & Lee, 2024; Weng & Chiu, 2023). It is also compatible with broader learning-theory perspectives in AI-supported education, which stress the importance of scaffolding, learner modeling, and responsive instructional support in promoting deeper cognitive engagement (Gibson et al., 2023; Hwang et al., 2020). In the present study, the adaptive system monitored aspects such as idea development, logical organization, and vocabulary use and then generated personalized prompts. Such support likely directed learners' attention toward structural weaknesses in their mind maps before those weaknesses were reproduced in the written text.

The significant difference between AdaptAI and GenAI in cohesion is also theoretically meaningful. Generative AI can provide rapid suggestions, possible arguments, vocabulary, or conceptual branches, but the generation of more content does not necessarily ensure better organization. Learners may receive useful ideas without being guided to evaluate the relationships among those ideas or determine how they should be sequenced in the final composition. This distinction reflects concerns raised in the literature regarding the pedagogical limitations of generative systems when learners rely too heavily on ready-made responses (Hockly, 2023; Kasneci et al., 2023). Research has also emphasized that the effectiveness of AI-generated feedback depends on specificity, relevance, and learner engagement with suggestions (Escalante et al., 2023; Yan & Zhang, 2024). Thus, the stronger cohesion gains observed in the AdaptAI condition may have resulted from a more dialogic and individualized interaction in which learners were prompted to reconsider their own organization rather than merely incorporating externally generated material.

The current findings also support previous research demonstrating beneficial effects of AI-assisted writing environments on EFL writing performance. Gayed and


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colleagues reported that AI-based writing assistants can facilitate English learners' writing development by providing accessible language support and feedback (Gayed et al., 2022). Similarly, Wang showed that artificial-intelligence-based computer-assisted writing and evaluation can contribute to EFL writing development through automated analysis and instructional support (Wang, 2020). More recent studies have extended these findings to generative AI. Ghafouri and colleagues demonstrated the potential of ChatGPT-based writing instruction to function as a writing mentor and enhance learners' writing skills (Ghafouri et al., 2024), while Mekheimer reported that generative AI-assisted feedback contributed to EFL writing quality and revision processes (Mekheimer, 2025). The present study extends this body of evidence by indicating that the form of AI assistance matters: although both generative and adaptive support were effective, personalized adaptive support yielded additional benefits for higher-order textual organization.

The results concerning conventional mind mapping further reinforce the importance of pre-writing organization. The mind-mapping group significantly outperformed the traditional group in writing cohesion, indicating that even without AI, visually organizing ideas before drafting can improve textual connectedness. This finding is consistent with Al-Zyoud and colleagues, who demonstrated that mind mapping can enhance students' writing performance by helping them structure ideas before composition (Al-Zyoud et al., 2017). Similar findings were reported by Tran, who found that mind-mapping strategies improved EFL writing quality (Tran, 2021), and by Mekhafi and colleagues, who showed that digital mind mapping positively influenced EFL learners' essay writing and attitudes (Mekhafi et al., 2021). Pribadi and Susilana likewise demonstrated the usefulness of mind mapping as a writing-support strategy in technology-mediated learning contexts (Pribadi & Susilana, 2021). These studies support the interpretation that externalizing ideas in a visual format reduces organizational demands and makes conceptual relationships more explicit before learners begin drafting.

With respect to writing fluency, significant differences were again observed among the four conditions, and both AI-supported groups clearly surpassed the conventional mind-mapping and traditional groups. However, unlike cohesion, the difference between AdaptAI and GenAI was not statistically significant. This finding suggests that both forms of AI support may facilitate fluency through a shared mechanism: reducing the cognitive burden associated with idea generation and planning. When learners begin writing with a richer and more structured pool of ideas, they may spend less time hesitating, searching for content, or deciding what to write next. Generative AI can accelerate this process by directly offering keywords, arguments, and possible directions, while adaptive AI can facilitate it by guiding learners toward gaps in their plans. In both cases, the result may be smoother and more sustained written production.

This interpretation is consistent with research on AI-supported language learning showing that intelligent systems can provide immediate assistance that facilitates task completion and sustained engagement (Huang et al., 2022; Huang et al., 2023). Song and Song found that ChatGPT-assisted learning could enhance academic writing skills and motivation, illustrating how generative AI may help learners maintain momentum during composition (Song & Song, 2023). Zhao similarly described AI writing assistants as tools capable of supporting EFL writers through linguistic reformulation and readily available language alternatives (Zhao, 2023). Yang's work on generative AI writing assistants also emphasizes the importance of knowledge capture and feedback mechanisms in facilitating writing processes (Yang, 2025). These findings are compatible with the present result that both GenAI and AdaptAI produced strong gains in fluency.

The nonsignificant difference between the two AI groups in fluency may also indicate that personalized adaptation is less critical for increasing written output than for improving organizational quality. Fluency, operationalized in this study as scaled word production, may benefit substantially from any instructional support that reduces planning delays and expands the availability of content. Generative AI is particularly capable of supplying immediate material, which may be sufficient to increase writing output even without individualized feedback. In contrast, cohesion requires learners to make more precise decisions about relationships among ideas, where personalization becomes more consequential. This distinction is consistent with research showing that AI-assisted writing can increase revision activity and output but that the quality of feedback and learner engagement determine whether deeper improvements occur (Link et al., 2020; Loncar et al., 2021; Ranalli, 2018). Therefore, comparable fluency gains do not necessarily imply that generative and adaptive systems supported the writing process in the same way.

The conventional mind-mapping group also significantly exceeded the traditional group in writing fluency. This result provides additional support for the role of visual planning in


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reducing cognitive demands before composition. When learners organize their ideas spatially and hierarchically, they can enter the drafting stage with a clearer sequence of content and fewer interruptions caused by idea searching. Previous investigations of mind mapping have similarly reported improvements in writing performance and idea organization (Al-Zyoud et al., 2017; Tran, 2021). Digital mind mapping has also been shown to facilitate writing activities and improve learner attitudes (Mekhafi et al., 2021). The present findings therefore suggest that the basic cognitive benefits of mind mapping remain meaningful even without AI, although the addition of intelligent support substantially strengthens those benefits.

Writing anxiety showed a somewhat different pattern. AdaptAI produced the strongest anxiety reduction and significantly outperformed GenAI, while both AI-supported groups significantly exceeded the non-AI groups. In contrast, the difference between conventional mind mapping and traditional instruction was not statistically significant. This pattern suggests that reducing writing anxiety may require more than simply organizing ideas visually. Mind mapping can clarify content structure, but learners may still remain uncertain about whether their ideas are sufficient, logically connected, or linguistically appropriate. AI support, by contrast, can provide immediate confirmation, suggestions, and guidance during the planning process, potentially reducing uncertainty and perceived task difficulty.

The stronger anxiety reduction in the AdaptAI condition can be interpreted in relation to personalization and perceived control. Writing anxiety often intensifies when learners feel uncertain about how to proceed or fear that they lack adequate linguistic or organizational resources. A responsive AI system that monitors performance and offers tailored prompts may reduce this uncertainty by providing support precisely when it is needed. This explanation is consistent with research suggesting that learners value AI feedback when it is specific and actionable (Kim & Lee, 2024). It also aligns with studies showing that students' engagement with AI-generated feedback includes important affective dimensions and varies according to how useful and trustworthy they perceive the support to be (Yan & Zhang, 2024). Shi and colleagues further demonstrated that AI literacy and self-regulated learning are related not only to writing performance but also to student well-being in generative AI-supported environments (Shi et al., 2025). The present results suggest that adaptive personalization may strengthen this affective benefit by making assistance more predictable and relevant to individual needs.

The beneficial effect of GenAI on anxiety is also compatible with previous evidence. Generative systems can reduce the perceived difficulty of writing by providing brainstorming assistance, vocabulary, reformulations, and immediate feedback. Such support may help learners approach demanding writing tasks with greater confidence. Song and Song reported positive motivational consequences of ChatGPT-supported writing instruction (Song & Song, 2023), while Guo and Wang highlighted ChatGPT's potential to complement teacher feedback in EFL writing (Guo & Wang, 2024). Evmenova and colleagues likewise emphasized the potential of generative AI to improve feedback accessibility, particularly for writers who struggle with conventional writing demands (Evmenova et al., 2024). The present study adds to these findings by showing that although generative AI can reduce anxiety, adaptive AI may produce a stronger affective effect when support is individualized.

At the same time, these results should be interpreted within the broader concerns surrounding AI use in education. The educational literature consistently cautions that AI support can create risks of dependency, uncritical acceptance of suggestions, and reduced learner agency if it is used as a substitute for thinking rather than as a scaffold (Bearman et al., 2023; Yan et al., 2023). Crompton and colleagues similarly emphasize that the affordances of AI for English language teaching must be balanced against pedagogical and ethical challenges (Crompton et al., 2024). Hockly also notes that the benefits of AI in language teaching coexist with limitations that require critical teacher oversight (Hockly, 2023). The stronger outcomes observed for AdaptAI in the current study are therefore important because they suggest that AI may be most pedagogically productive when it guides learners' decision making rather than simply completing writing-related tasks for them.

The findings also contribute to an emerging distinction between assistance that generates content and assistance that scaffolds learning. Generative systems are powerful because they can provide immediate linguistic and conceptual material, but adaptive systems may be better positioned to promote self-regulation by responding to individual performance. Learning-theory approaches to AI emphasize that educational technologies should support learner agency, feedback cycles, and meaningful cognitive activity rather than merely automate task completion (Gibson et al., 2023). Likewise, intelligent instructional systems are most effective


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when technological affordances are deliberately integrated into pedagogy (Weng & Chiu, 2023). This may explain why the adaptive condition produced the strongest improvements in cohesion and anxiety while offering no additional significant fluency advantage over generative AI. The adaptive system appears to have influenced dimensions requiring individualized guidance more strongly than a dimension such as output quantity that could benefit from either type of AI support.

Another important implication of the results concerns the interaction between AI literacy, self-regulation, and writing performance. As learners increasingly use AI-supported writing tools, effectiveness may depend on their capacity to critically evaluate, modify, and strategically apply AI suggestions. Shi and colleagues found relationships among AI literacy, self-regulated learning, writing performance, and well-being (Shi et al., 2025). Similarly, Song and colleagues' investigation of perceptions toward generative AI in creative writing contexts underscores that users evaluate AI not only as a productivity tool but also in relation to creativity, learning, and authorship (Song et al., 2025). These findings suggest that the superior performance of adaptive AI may partly reflect a better balance between external technological support and learner participation. Instead of delivering complete solutions, adaptive prompts can potentially encourage students to remain responsible for the decisions that shape their writing.

Overall, the findings support a layered understanding of technology-assisted EFL writing. Conventional mind mapping improved cohesion and fluency by externalizing the planning process, but its benefits were amplified substantially when AI was incorporated. Generative AI provided effective support for all three outcomes, particularly by facilitating rapid idea generation and reducing the burden of planning. Adaptive AI produced the strongest overall pattern, especially for cohesion and writing anxiety, suggesting that personalized scaffolding offers advantages beyond the availability of generated content. This pattern is compatible with the wider literature showing that AI-supported writing can enhance language production, revision, and feedback processes (Gayed et al., 2022; Ghafouri et al., 2024; Mekheimer, 2025), while also reinforcing the argument that educational value depends on feedback design, learner engagement, and personalization (Kim & Lee, 2024; Weng & Chiu, 2023; Yan & Zhang, 2024). The study therefore provides evidence that AI-supported mind mapping is most effective when technology functions as an adaptive instructional scaffold integrated into the learner's own planning process.

Several limitations should be considered when interpreting the findings. First, the study used a quasi-experimental design in which intact classes, rather than individual participants, were assigned to instructional conditions. Although the groups were matched according to English proficiency and prior writing performance and did not differ significantly at pretest, the absence of individual randomization limits the strength of causal inference. Second, the sample consisted of 140 intermediate-level adult EFL learners recruited from a single private language institute in Kerman, Iran, which may limit the generalizability of the findings to learners from other educational systems, proficiency levels, age groups, and sociocultural contexts. Third, writing fluency was operationalized primarily through word production within a fixed period, which captures output quantity but does not fully represent other dimensions of fluency such as lexical accessibility, syntactic productivity, pausing behavior, or the efficiency of idea formulation. Fourth, the study examined immediate pretest-to-posttest changes and did not include a delayed follow-up assessment, making it impossible to determine whether the observed improvements were maintained after learners no longer had access to AI-supported mind mapping. Fifth, the study did not directly measure participants' AI literacy, self-regulation, perceived usefulness, trust in AI feedback, or patterns of actual interaction with the AI systems, all of which may have contributed to individual differences in intervention response. Finally, the adaptive and generative tools were primarily incorporated into the pre-writing stage; therefore, the results cannot determine whether comparable effects would emerge if AI support were extended systematically across drafting, revision, and editing.

Future studies should replicate the present design using randomized controlled trials where institutional conditions permit and should recruit larger samples from multiple schools, universities, language institutes, and cultural settings to improve external validity. Research should also examine learners at different levels of English proficiency to determine whether adaptive and generative AI produce similar effects among beginning, advanced, adolescent, and academically oriented EFL writers. Longitudinal studies incorporating delayed posttests would be valuable for determining whether AI-supported mind-mapping strategies become internalized and continue to influence writing after technological support is withdrawn. Future research should


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also employ multidimensional measures of writing performance, including lexical diversity, grammatical accuracy, syntactic complexity, rhetorical organization, revision quality, and process-based indicators of fluency. Mixed-method designs could incorporate interviews, think-aloud protocols, screen recordings, interaction logs, and learner journals to clarify how students actually use AI prompts and why adaptive feedback may produce stronger outcomes for certain variables. Researchers should additionally investigate possible mediators and moderators, including AI literacy, self-regulated learning, digital competence, prior writing ability, feedback literacy, cognitive load, perceived control, and trust in AI. Direct comparisons among teacher feedback, peer feedback, generative AI, adaptive AI, and hybrid human–AI feedback systems could further establish which combinations provide the most sustainable educational benefits.

EFL instructors may consider integrating AI-supported mind mapping into pre-writing instruction as a structured planning tool rather than allowing AI to function as an unrestricted text-generation mechanism. Adaptive systems are especially suitable when the instructional objective involves improving organization, cohesion, and learner confidence because personalized prompts can guide students to evaluate the relationships among their own ideas before drafting. Generative AI can also be useful for brainstorming, vocabulary activation, and exploring alternative perspectives, but learners should be encouraged to evaluate and reorganize generated suggestions rather than copy them directly. Teachers should explicitly model how to construct effective mind maps, distinguish central from peripheral ideas, identify logical connections, and convert visual plans into coherent paragraphs. AI literacy should also become part of writing instruction so that students learn to question AI outputs, recognize inaccurate or irrelevant suggestions, preserve authorship, and make independent writing decisions. Institutions implementing AI-supported writing instruction should provide equitable access to appropriate tools and ensure that teachers receive sufficient professional development in pedagogical, ethical, and assessment-related aspects of AI use. Most importantly, AI should be incorporated as a scaffold that strengthens planning, reflection, and autonomy while preserving the learner's responsibility for the intellectual and linguistic construction of the final text.

## Authors' Contributions

Authors equally contributed to this article.

## Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

## Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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The authors report no conflict of interest.

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## Ethical Considerations

All procedures performed in studies involving human participants were under the ethical standards of the institutional and, or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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