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"An AI-Based Adaptive Feedback Learning Environment: Effects on Cognitive Anxiety During Academic Writing Among University Students"

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Abstract:

This study aimed to investigate the effect of an Artificial Intelligence (AI)-based adaptive feedback learning environment on reducing cognitive anxiety during academic writing among university students. The study population consisted of university students enrolled at Ono Academic College during the 2025/2026 academic year. A quasi-experimental pre-measurement/post-measurement control group design was used with an accessible sample of 46 students selected from two intact class sections taught by the same lecturer. The participants were divided into two non-randomized equal groups: an experimental group (n = 23) that received AI-based adaptive feedback and a control group (n = 23) that received conventional lecturer-provided feedback.

The study used a 22-item adapted Writing Anxiety Inventory focusing on cognitive anxiety during academic writing. The instrument demonstrated strong internal consistency validity and excellent reliability, with Cronbach's alpha reaching $\alpha = 0.92$. Data were collected through pre-intervention and post-intervention measurements. The results showed that the two groups were equivalent at the baseline stage ($p = 0.360$). One-Way Analysis of Covariance (ANCOVA) revealed a statistically significant effect of the instructional environment after controlling for pre-measurement scores, $F(1, 43) = 52.724$, $p < 0.001$.

The experimental group recorded a lower adjusted post-measurement mean score (M adj = 2.46) compared with the control group (M adj = 4.01). In addition, the partial eta-squared value ($\eta p^2 = 0.551$) indicated a large effect size, showing that the type of feedback accounted for 55.1% of the variance in post-measurement cognitive anxiety scores. Within-group analysis also showed a statistically significant reduction in cognitive anxiety among the experimental group from pre-measurement to post-measurement, $t(22) = 3.493$, $p = 0.002$. The study concluded that the AI-based adaptive feedback learning environment was effective in reducing cognitive anxiety during academic writing among university students.

Keywords: AI adaptive feedback, academic writing, cognitive anxiety, higher education.

How to Cite This Article

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1. Introduction

Higher education is witnessing significant transformation as artificial intelligence increasingly reshapes teaching and learning toward more personalized, responsive, and data-informed instructional models. Within this transformation, AI-supported adaptive learning environments have gained increasing attention because they can provide instructional support that responds to learners' performance, needs, and difficulties during the learning process. Such environments are particularly relevant in cognitively demanding tasks such as academic writing, where students are required to manage several mental processes simultaneously.

Academic writing is widely regarded as one of the most complex tasks in higher education. It requires students to plan ideas, organize arguments, revise content, edit language, respond to feedback, and monitor the quality of their written work. When these processes occur under evaluative conditions, they may increase students' cognitive burden and generate cognitive anxiety during writing. In the present study, cognitive anxiety refers to the mental tension and cognitive difficulty that students may experience while writing, including difficulty organizing thoughts, fear of evaluation, hesitation in beginning the task, uncertainty about revision, and increased cognitive load.

In response to these challenges, AI-supported adaptive feedback may offer a promising instructional approach. Unlike general feedback that provides similar comments to all learners, adaptive feedback can offer immediate, personalized, and staged guidance according to students' needs during the writing process. By clarifying task expectations, directing learners' attention to relevant aspects of writing, and supporting revision through manageable steps, such feedback may reduce unnecessary cognitive load and help students experience academic writing as a more controllable and less anxiety-provoking task.

Although recent studies have shown the potential of AI-supported feedback in improving writing support, revision, learner autonomy, and confidence, less attention has been given to its role in reducing cognitive anxiety during academic writing. Much of the existing literature has focused either on general AI tools or on writing-related outcomes, while cognitive anxiety has often been treated as a secondary issue rather than as a central research outcome. Moreover, relatively few studies have examined AI-supported adaptive feedback as an organized learning environment designed to respond to learners' ongoing needs and reduce the cognitive strain associated with academic writing.

Accordingly, the present study seeks to examine the effect of an AI-based adaptive feedback learning environment on reducing cognitive anxiety during academic writing among university students, compared with conventional lecturer-provided feedback. By focusing on cognitive anxiety as the primary outcome, the study aims to contribute to a deeper understanding of how adaptive AI-supported feedback can create a more supportive, responsive, and less cognitively stressful academic writing experience.

2. Problem Statement

Academic writing is one of the most cognitively demanding tasks in higher education because it requires students to manage several mental processes at the same time, including planning, organizing ideas, revising, editing, responding to feedback, and monitoring the quality of their written work. When these processes occur under evaluative conditions, students may experience increased cognitive pressure, uncertainty, and difficulty in maintaining control over the writing process (Cheng, 2004).

This cognitive pressure may appear in the form of cognitive anxiety during academic writing. In the present study, cognitive anxiety refers to the mental tension students experience while writing, including difficulty organizing thoughts, hesitation in beginning the task, uncertainty about how to revise, fear of evaluation, and increased cognitive load. Such anxiety may negatively affect students' willingness to engage in writing tasks and their ability to respond effectively to feedback (Vermeiren et al., 2025).

Although AI-supported feedback has shown potential in supporting academic writing, much of the existing research has focused on general AI tools, automated feedback, generative chatbots, or writing-related outcomes such as revision and text

improvement. Less attention has been given to AI-supported adaptive feedback as a structured learning environment designed to respond to students' ongoing needs during the writing process (Alawad, 2025).

Moreover, previous studies have often examined writing anxiety, autonomy, or self-efficacy as related outcomes, while cognitive anxiety during academic writing has received limited attention as a primary research variable. This creates a need to investigate whether an AI-based adaptive feedback learning environment can reduce students' cognitive anxiety by clarifying expectations, reducing uncertainty, and strengthening their perceived control during writing (Cho, 2025).

Accordingly, the problem of the present study lies in the need to examine the effect of an AI-based adaptive feedback learning environment on reducing cognitive anxiety during academic writing among university students, compared with conventional lecturer-provided feedback. This study therefore addresses an important gap by focusing on cognitive anxiety as the central outcome within a structured, responsive, and AI-supported adaptive learning environment (Zhan et al., 2025).

3. Research Questions and Hypotheses

Main Research Question

What is the effect of an AI-based adaptive feedback learning environment, compared with conventional lecturer-provided feedback, on reducing cognitive anxiety during academic writing among university students?

3.1 Sub-Questions

Sub-Question 1: Pre-test Equivalence

Is there a statistically significant difference at the level of $\alpha \leq 0.05$ between the mean scores of the experimental group and the control group in the pre-measurement of cognitive anxiety during academic writing?

Sub-Question 2: Post-test Comparison

Is there a statistically significant difference at the level of $\alpha \leq 0.05$ between the adjusted post-measurement mean scores of the experimental group and the control group in cognitive anxiety during academic writing after controlling for pre-measurement scores?

Sub-Question 3: Experimental Group Progress

Is there a statistically significant difference at the level of $\alpha \leq 0.05$ between the pre-measurement and post-measurement mean scores of the experimental group in cognitive anxiety during academic writing?

3.2 Null Hypotheses of the study:

H01: Pre-test Equivalence

There is no statistically significant difference at the level of $\alpha \leq 0.05$ between the mean scores of the experimental group and the control group in the pre-measurement of cognitive anxiety during academic writing.

H02: Post-Measurement Comparison

There is no statistically significant difference at the level of $\alpha \leq 0.05$ between the adjusted post-measurement mean scores of the experimental group and the control group in cognitive anxiety during academic writing after controlling for pre-measurement scores.

H03: Experimental Group Progress

There is no statistically significant difference at the level of $\alpha \leq 0.05$ between the pre-measurement and post-measurement mean scores of the experimental group in cognitive anxiety during academic writing.

4. Objectives of the Study

The main objective of this study is to investigate the effect of an AI-based adaptive feedback learning environment, compared with conventional lecturer-provided feedback, on reducing cognitive anxiety during academic writing among university students.

The specific objectives are:

1. To determine whether the experimental and control groups are equivalent in cognitive anxiety during academic writing before the intervention.
2. To examine whether there is a statistically significant difference between the experimental group and the control group in post-test cognitive anxiety during academic writing after controlling for pre-test scores.
3. To determine whether the experimental group shows a statistically significant reduction in cognitive anxiety during academic writing between the pre-test and the post-test.

5. Significance of the Study

Theoretically, the study contributes to the literature on AI-supported learning, academic writing, cognitive anxiety, adaptive feedback, and self-regulated learning. Unlike prior research that often treats writing anxiety as a secondary or general issue, this study focuses on cognitive anxiety during academic writing as a central outcome. By examining cognitive anxiety directly, it offers a more precise understanding of the specific psychological and cognitive difficulties students experience while writing.

Practically, the findings may directly benefit university students by identifying an adaptive feedback model that helps them manage academic writing tasks with less tension and greater confidence. By examining AI-supported adaptive feedback as a structured learning environment—rather than merely a technical writing tool—this study clarifies how personalized, immediate, and staged feedback can alleviate students' uncertainty, cognitive pressure, and fear of evaluation.

Pedagogically, the study provides actionable insights for university lecturers and curriculum designers. It supports them in integrating AI-based adaptive feedback into academic writing instruction in a responsible, structured, and effective manner, thereby fostering more supportive institutional feedback practices.

6. Delimitations of the Study

This study is delimited to the following parameters:

1. **Subject Delimitation:** The study is strictly confined to its title, "An AI-Based Adaptive Feedback Learning Environment: Effects on Cognitive Anxiety During Academic Writing Among University Students." It focuses specifically on examining the effects on **cognitive anxiety** during academic writing, rather than investigating general anxiety types or overall writing performance.
2. **Human Delimitation:** The target population is limited to Arab students studying at Ono Academic College within the green line. Participants are divided into two distinct groups: an experimental group that receives AI-based adaptive feedback and a control group that receives conventional, lecturer-provided feedback.
3. **Temporal Delimitation:** The empirical study and intervention are conducted during the academic year 2025/2026.
4. **Spatial Delimitation:** The study is conducted at Ono Academic College, targeting the campuses and learning environments that serve the Arab student community within the green line.

7. Definition of Terms

AI-Based Adaptive Feedback Learning Environment

Conceptual Definition: AI-based adaptive feedback refers to an instructional feedback mechanism powered by artificial intelligence that dynamically adjusts its support, complexity, and guidance in real time according to individual students' specific needs, ongoing performance, and learning progress (Alawad, 2025).

Operational Definition: In this study, it refers to the specialized digital learning environment deployed for the experimental group (n = 23) during the academic writing course at Ono Academic College. Within this environment, students received automated, real-time feedback tailored to their writing phases (planning, organizing, and drafting) to systematically mitigate their writing-related cognitive anxiety, contrasting with the conventional, lecturer-provided feedback received by the control group.

Academic Writing

Conceptual Definition: Academic writing refers to a complex, situated social and cognitive practice in higher education through which students engage with disciplinary knowledge, construct formal arguments, and negotiate their scholarly identities using evolving digital and text-production technologies (Bailey, 2011).

Operational Definition: In this study, it refers to the specific academic writing tasks and essays completed by university students within the target **Academic Writing Course** during the intervention phases.

Cognitive Anxiety

Conceptual Definition: Cognitive anxiety refers to the mental component of anxiety, characterized by worry, disorganized thoughts, fear of negative evaluation, and diminished concentration during the writing process (Cheng, 2004).

Operational Definition: In this study, it refers to the operationalized levels of mental tension measured via students' scores on the **adopted Cognitive Anxiety Subscale** of the Writing Anxiety Inventory, administered during the **pre-intervention and post-intervention measurements**.

Higher Education

Operational Definition: In this study, it refers specifically to the undergraduate university context of **Ono Academic College** during the academic year **2025/2026**.

8. Theoretical Framework

The present study conceptualizes AI-supported adaptive feedback as a personalized instructional environment rather than a simple mechanism for immediate correction. In this study, AI-supported adaptive feedback refers to a structured learning environment that provides immediate, personalized, and staged guidance according to students' writing performance, progress, difficulties, and revision needs. Its pedagogical significance lies in its ability to support learners during academic writing by clarifying expectations, guiding revision, reducing uncertainty, and helping students monitor and improve their writing through manageable steps. This view is consistent with recent research suggesting that AI-based writing tools can function as pedagogically meaningful resources that support learners' engagement with academic writing tasks (Lee et al., 2025).

The study adopts an integrative theoretical framework to explain how AI-supported adaptive feedback may reduce cognitive anxiety during academic writing. This framework is based on three complementary perspectives: Cognitive Load Theory, Social Constructivist Theory, and Self-Regulated Learning Theory. Cognitive Load Theory explains how adaptive feedback may reduce unnecessary cognitive burden by decreasing extraneous demands on working memory (Sweller, 1988).

Social Constructivist Theory provides a second explanatory perspective by emphasizing the role of support, mediation, and gradual guidance in learning. From this view, students can perform beyond their current independent level when they receive appropriate support that helps them move through challenging tasks. This perspective is relevant to academic writing because adaptive feedback may function as a scaffold that helps students organize their ideas, revise their writing, and continue the task with less uncertainty (Vygotsky, 1978).

Self-Regulated Learning Theory provides a third perspective for understanding the relationship between adaptive feedback and cognitive anxiety. This theory views learners as active agents who plan, monitor, evaluate, and adjust their learning in relation to academic goals. In academic writing, adaptive feedback may strengthen students' ability to monitor their progress, identify weaknesses, and make informed decisions during revision (Zimmerman, 2002).

AI-Supported Adaptive Feedback as a Personalized Learning Environment

AI-supported adaptive feedback environments are based on the principle that learners do not all need the same type, amount, or timing of feedback. Instead of providing uniform feedback to all students, adaptive feedback responds to learners' actual needs during the writing process. In academic writing, such feedback may address idea organization, coherence, clarity, structure, revision, and self-monitoring. This makes adaptive feedback different from general AI tools that may provide broad or non-specific responses (Alawad, 2025).

From this perspective, AI-supported feedback is not merely a technical tool that corrects errors or produces linguistic alternatives. Rather, it functions as an organized instructional environment that structures students' engagement with writing. By offering repeated opportunities for feedback, revision, and self-correction, the adaptive environment may help students perceive academic writing as a more manageable and less threatening task (Lee et al., 2025).

This understanding is particularly important in relation to cognitive anxiety. Students may experience cognitive anxiety when they are uncertain about how to begin writing, how to organize ideas, how to respond to feedback, or how to revise their work effectively. Adaptive feedback can reduce this uncertainty by providing timely and task-related guidance that helps students move from confusion to action (Cho, 2025).

Cognitive Load Theory and the Cognitive Complexity of Academic Writing

Cognitive Load Theory provides a relevant theoretical basis for understanding the relationship between adaptive feedback and cognitive anxiety. The theory assumes that working memory has limited capacity and that learning becomes more effective when unnecessary cognitive demands are reduced. Academic writing places considerable pressure on working memory because students must plan ideas, organize arguments, revise content, edit language, respond to feedback, and monitor the quality of their writing at the same time (Sweller, 1988).

When students face these demands without sufficient guidance, the writing process may become cognitively overwhelming. This may lead to cognitive anxiety, especially when students write under evaluative conditions or feel uncertain about how to begin, organize, revise, or respond to feedback. From this perspective, AI-supported adaptive feedback may reduce extraneous cognitive load by breaking the writing task into smaller and clearer steps (Vermeiren et al., 2025).

The expected value of adaptive feedback is therefore not limited to improving the final written product. Its deeper pedagogical value lies in reducing the mental pressure associated with managing the writing process. When students receive immediate and staged support, cognitive resources may be freed for higher-order writing processes such as idea development, organization, and critical revision (Sweller, 1988).

In this sense, adaptive feedback may help students experience greater clarity, confidence, and emotional control during academic writing. Instead of facing the entire writing task as one complex demand, students can deal with the task gradually through clearer steps and more focused feedback. This may reduce the cognitive tension that often accompanies academic writing tasks (Vermeiren et al., 2025).

Social Constructivist Theory and Scaffolded Support in Writing Tasks

The second theoretical foundation is Social Constructivist Theory, particularly the concept of the Zone of Proximal Development. According to this perspective, learners can perform beyond their current independent ability when they receive appropriate, timely, and gradually adjusted support. In the context of academic writing, AI-supported adaptive feedback can be understood as a mediating tool that provides scaffolded support during different stages of the writing process (Vygotsky, 1978).

Scaffolding does not mean giving students ready-made answers. Rather, it involves helping them move gradually through the task by clarifying what needs to be improved, suggesting possible directions, and supporting revision without removing the learner's active role. In this sense, adaptive feedback may reorganize the writing task into clearer and more manageable stages (Urzúa et al., 2025).

This is directly related to cognitive anxiety. When students feel that the writing task is too difficult, unclear, or beyond their current ability, they may experience hesitation, confusion, or avoidance. However, when feedback is gradual, responsive, and aligned with their needs, the task may become less intimidating and more manageable (Vygotsky, 1978).

Through scaffolded feedback, students are not left to face the writing process alone. Instead, they receive structured guidance that helps transform uncertainty into manageable action. This may encourage students to engage with academic writing progressively rather than avoid the task because of fear, confusion, or perceived inability (Urzúa et al., 2025).

Self-Regulated Learning Theory, Autonomy, and Self-Efficacy

The third theoretical foundation is Self-Regulated Learning Theory, which views learners as active agents who plan, monitor, evaluate, and adjust their learning according to academic goals. This theory is especially relevant to academic writing because successful writing requires continuous decision-making about ideas, organization, revision, language, and feedback use (Zimmerman, 2002).

In AI-supported writing contexts, feedback can serve as a regulatory resource. It may help students identify weaknesses in their writing, understand what needs to be revised, evaluate their progress, and decide on the next step. When students receive immediate and personalized feedback, they may feel more capable of controlling the writing process and less dependent on delayed or general comments (Panadero, 2017).

This sense of control is important for reducing cognitive anxiety. Students who feel unable to manage the writing task may experience mental tension, hesitation, and fear of evaluation. By contrast, students who can monitor their progress and understand how to improve may develop stronger autonomy and greater confidence during writing (Cho, 2025).

Self-efficacy also plays an important role in this process. When students believe that they can understand feedback, revise their writing, and improve their performance, they are more likely to continue engaging with the task. In this way, adaptive feedback may reduce cognitive anxiety by strengthening students' belief in their ability to manage academic writing successfully (Zhou & Wang, 2026).

At the same time, AI-supported feedback should not be understood as a replacement for the teacher's role. While AI may provide immediate, structured, and individualized guidance, teacher presence remains important for emotional reassurance, ethical guidance, and helping students interpret feedback in meaningful and responsible ways (Maleki, 2026).

An Integrated Model Explaining the Effect of Adaptive Feedback on Cognitive Anxiety During Academic Writing

Taken together, these theoretical perspectives suggest that AI-supported adaptive feedback may reduce cognitive anxiety during academic writing through three interrelated pathways. First, it may reduce extraneous cognitive load by clarifying task expectations, simplifying complex writing demands, and guiding students' attention toward manageable steps (Sweller, 1988).

Second, adaptive feedback may provide scaffolded support that helps students move gradually through the writing process with less uncertainty and greater confidence. This support is important because writing anxiety often increases when learners perceive the task as unclear, difficult, or beyond their current ability (Vygotsky, 1978).

Third, adaptive feedback may strengthen self-regulated learning by enhancing students' autonomy, self-monitoring, self-efficacy, and perceived control over the writing task. When students are able to monitor their progress and understand how to improve their writing, they may experience less hesitation and greater confidence during the writing process (Zimmerman, 2002).

Accordingly, the present study assumes that AI-supported adaptive feedback can reduce cognitive anxiety during academic writing by making the writing process less ambiguous, less cognitively overwhelming, and less emotionally threatening. Through the combined effects of cognitive load reduction, scaffolded support, and self-regulated learning, such an environment may create a more supportive and responsive writing experience for university students (Lee et al., 2025).

The conceptual pathway guiding the present study can therefore be expressed as follows: AI-supported adaptive feedback may reduce ambiguity and cognitive load, increase scaffolded support and self-regulation, strengthen students' perceived control, and ultimately reduce cognitive anxiety during academic writing (Cho, 2025).

9. Literature Review

Recent scholarship has increasingly emphasized the role of AI-supported feedback in academic writing contexts, especially with the growing use of generative and adaptive tools that can provide immediate, iterative, and personalized support during the writing process. AI-based writing tools are no longer viewed only as systems for linguistic correction, but also as pedagogical resources that may support students' engagement with academic writing tasks and help them manage writing-related demands (Lee et al., 2025).

Academic writing is considered a cognitively demanding activity because it requires students to coordinate several processes at the same time, including planning, organizing ideas, revising, editing, and responding to feedback. When these processes occur under evaluative conditions, they may increase students' cognitive load and contribute to writing-related anxiety during academic writing tasks (Vermeiren et al., 2025).

Previous studies have examined AI-supported feedback from different perspectives. Some studies have focused on its role in improving writing performance and revision, whereas others have examined its relationship with anxiety, autonomy, self-efficacy, and students' engagement with writing. However, relatively limited attention has been given to AI-supported adaptive feedback environments specifically designed to reduce cognitive anxiety during academic writing (Cho, 2025).

Against this background, the literature reviewed in the present study is organized around two related areas. The first area addresses AI-supported feedback in academic writing contexts, while the second area focuses on AI-supported feedback in relation to cognitive anxiety during academic writing. This organization helps clarify how previous studies support the present research and where the remaining gap is located (Alawad, 2025).

First: AI-Supported Feedback in Academic Writing Contexts

AI-supported feedback has become an important instructional resource in academic writing because it provides students with immediate responses during the writing process. Its value lies not only in correcting errors, but also in helping learners revise, reorganize, and improve their written work through repeated opportunities for feedback and self-correction (Lee et al., 2025).

Alawad (2025) examined the role of AI-supported adaptive assessment criteria in academic writing instruction. The study showed that integrating AI-supported criteria into writing tasks provided students with clearer, more structured, and more goal-oriented feedback. The relevance of this study to the present research lies in showing that AI feedback becomes more pedagogically meaningful when it is guided by clear criteria and aligned with learners' writing needs (Alawad, 2025).

Zhang et al. (2025) investigated different modes of feedback in writing instruction. The findings indicated that automated feedback was more useful for basic linguistic features, whereas hybrid feedback was more effective in supporting higher-order aspects of writing. This study is relevant to the present research because it shows that AI feedback is not a uniform instructional tool; rather, its effectiveness depends on how it is designed, delivered, and integrated into the learning process (Zhang et al., 2025).

Urzúa et al. (2025) indicated that AI-supported feedback can support students during the writing process by helping them generate ideas, reorganize their work, and revise their texts more effectively. This finding is important for the present study because it confirms that AI-supported feedback may assist students not only at the level of language correction, but also at the level of idea development and writing organization (Urzúa et al., 2025).

Lee et al. (2025) emphasized that AI-based writing tools may function as pedagogical resources that support learners' engagement with academic writing tasks. This is relevant to the present study because it supports the idea that AI feedback should be understood as part of a learning environment rather than as a separate technical tool used only for editing or correction (Lee et al., 2025).

Despite the usefulness of these studies, much of the existing research has treated AI tools as general-purpose systems that provide broad forms of support to learners. Less attention has been given to adaptive feedback environments that respond to individual learner needs during the writing process and reduce the cognitive strain associated with academic writing. This limitation highlights the need to examine AI-supported feedback as a structured learning environment that may make academic writing less overwhelming and less anxiety-provoking (Alawad, 2025).

Second: AI-Supported Feedback and Cognitive Anxiety During Academic Writing

A growing body of research has examined the affective dimensions associated with the use of artificial intelligence in writing contexts. These studies suggest that AI-supported feedback may help reduce writing-related anxiety by providing students with immediate, low-pressure, and repeated opportunities to revise and improve their work. This is particularly important in academic writing, where students may experience uncertainty, fear of evaluation, difficulty initiating writing, and anxiety about making mistakes (Cho, 2025).

Almusharraf (2026) examined the role of generative chatbots in supporting university students during writing tasks. The findings indicated that chatbots helped students overcome difficulty in starting writing, reduce apprehension toward writing, and strengthen their sense of capability to engage with the task. This study is relevant to the present research because cognitive anxiety during writing often begins at the moment of task initiation, especially when students feel uncertain about how to begin (Almusharraf, 2026).

Maleki (2026) found that AI-generated feedback enhanced learner autonomy and supported students' engagement with writing. The study also emphasized that technological feedback does not fully replace the emotional reassurance provided by teachers. This finding is important for the present study because it shows that reducing anxiety depends not only on receiving corrective information, but also on how feedback is emotionally experienced and interpreted by students (Maleki, 2026).

Cho (2025) used a quantitative structural model to examine the relationship between AI-supported writing tools, learner autonomy, and writing anxiety. The findings showed that learners' perceived effectiveness of AI tools enhanced learner autonomy, and that autonomy contributed to reducing writing anxiety. This study provides an important explanatory link for the present research because it suggests that AI-supported feedback may reduce cognitive anxiety by strengthening students' sense of control over the writing process (Cho, 2025).

Aydın-Yıldız (2025) reported that AI-enhanced writing instruction can reduce students' fear of making mistakes and help them overcome affective barriers associated with writing. This finding is relevant to the present study because fear of mistakes may increase hesitation, mental tension, and avoidance during academic writing. Therefore, supportive AI feedback may encourage students to engage with writing tasks rather than avoid them (Aydın-Yıldız, 2025).

Zhan et al. (2025) proposed that feedback awareness plays an important role in improving learners' engagement with feedback and reducing anxiety. This perspective is useful for the present study because it highlights that the effect of feedback depends not only on its content, but also on students' ability to understand, interpret, and use it constructively. In this sense, adaptive feedback may reduce cognitive anxiety when students become more aware of how to respond to feedback during writing (Zhan et al., 2025).

Zhou and Wang (2026) found that acceptance of artificial intelligence positively predicts self-efficacy and negatively predicts writing anxiety. This finding indicates that students' psychological readiness and confidence in using AI tools are important factors in explaining how AI-supported feedback may reduce anxiety. It is directly relevant to the present study because cognitive anxiety may decrease when students believe that they can use feedback effectively to improve their writing (Zhou & Wang, 2026).

Taken together, these studies suggest that AI-supported feedback may reduce anxiety during academic writing by clarifying expectations, lowering fear of mistakes, increasing autonomy, strengthening self-efficacy, and creating a less judgmental writing environment. However, although these studies are relevant, many of them examine writing anxiety, autonomy, or self-efficacy rather than cognitive anxiety as a distinct primary variable. This indicates the need for further research that focuses directly on cognitive anxiety during academic writing (Cho, 2025).

Although previous studies provide valuable evidence regarding the affective benefits of AI-supported feedback, cognitive anxiety has often been examined as a secondary outcome of AI tool use rather than as the central focus of an adaptive instructional environment. This limitation is important because cognitive anxiety is closely related to the mental effort, uncertainty, and cognitive pressure students experience while writing. Therefore, the present study addresses this limitation by examining cognitive anxiety as the primary outcome within an AI-supported adaptive feedback learning environment (Zhan et al., 2025).

9.1 Commentary on Previous Studies

Previous studies converge in showing that artificial intelligence has become an influential resource in academic writing contexts. They indicate that AI-supported feedback can provide immediate guidance, facilitate revision, increase learner autonomy, and help students engage more confidently with writing tasks. This supports the present study's assumption that AI-supported feedback can be examined as a pedagogical mechanism within academic writing instruction (Lee et al., 2025).

The reviewed studies also show that AI-supported feedback becomes more effective when it is structured, responsive, and aligned with learners' needs. This is important because the present study does not examine general AI use, but rather an adaptive feedback learning environment designed to respond to students' difficulties during academic writing (Alawad, 2025).

At the same time, the reviewed studies differ in the type of AI support examined. Some studies focused on generative chatbots, while others examined automated feedback, hybrid feedback, adaptive criteria, or AI-enhanced instruction. This diversity shows that AI-supported feedback is not a single uniform tool, but a broad instructional field that varies according to design, purpose, and level of integration into teaching (Zhang et al., 2025).

The reviewed studies also differ in their methodological approaches. Some used quantitative models, others used mixed-methods designs, while some were theoretical or review-based. This methodological diversity enriches the field, but it also shows that more focused intervention-based studies are still needed to examine the direct effect of adaptive feedback environments on specific learning and affective outcomes (Almusharraf, 2026).

In relation to outcomes, previous studies have focused on writing support, revision, autonomy, self-efficacy, engagement, and writing anxiety. However, fewer studies have examined cognitive anxiety during academic writing as the central outcome. This distinction is important because cognitive anxiety refers specifically to the mental tension and cognitive difficulty students experience while managing the writing process (Cho, 2025).

Another important observation is that some studies discuss anxiety in general terms, while the present study focuses specifically on cognitive anxiety. Although writing anxiety and cognitive anxiety are related, they are not identical. Cognitive anxiety is more directly connected to mental overload, difficulty organizing thoughts, hesitation, uncertainty, and fear of evaluation during the writing process (Vermeiren et al., 2025).

Therefore, the gap in the existing literature is not related to the absence of studies on AI-supported writing feedback. Rather, the gap lies in the limited examination of cognitive anxiety as a primary outcome within a structured AI-supported adaptive feedback learning environment. This gap provides a clear justification for the present study and supports its contribution to the field of academic writing in higher education (Zhan et al., 2025).

10. Methodology

10.1 Research Design

The study employed a quasi-experimental pre-test/post-test control group design, with pre- and post-administration of the Writing Anxiety Inventory. This design was considered appropriate because the study aimed to examine the effect of an AI-based adaptive feedback learning environment on cognitive anxiety during academic writing among university students.

The design involved two non-randomized groups: an experimental group and a control group. To enhance internal validity and reduce the influence of extraneous variables, both groups covered the same academic writing content, engaged in the same learning tasks, and followed the same instructional timeframe. The main difference between the two groups was the type of feedback provided. The experimental group received AI-based adaptive feedback, whereas the control group received conventional lecturer-provided feedback.

To measure changes in students' cognitive anxiety, an adapted Writing Anxiety Inventory focusing on the cognitive anxiety dimension was administered to both groups before and after the intervention. The pre-test was used to examine the initial level of cognitive anxiety and the equivalence of the two groups, while the post-test was used to assess changes in cognitive anxiety after the intervention. This design allowed the researcher to compare the effectiveness of the two feedback modes by examining differences in cognitive anxiety scores before and after the intervention.

10.2 Population and Sample

The target population of this study consisted of university students enrolled at Ono Academic College during the academic year 2025/2026. The accessible study sample comprised 46 students selected from two intact class sections enrolled in the same academic writing course and taught by the same lecturer. Due to the administrative constraints of educational settings, these two sections were assigned via non-randomized allocation into two equal groups: an experimental group (n = 23) and a control group (n = 23).

The control group received conventional, lecturer-provided feedback, whereas the experimental group received AI-based adaptive feedback. To maintain strict experimental control and minimize confounding variables, both groups operated within the same instructional setting, covered identical course content, engaged in the same learning tasks, and followed the same general timeframe under the instruction of the same lecturer. Consequently, the distinct mode of feedback provided during the writing process constituted the sole variance between the two groups.

Demographic Characteristics of the Study Sample

The final sample for this study comprised 46 university students, equally distributed into an experimental group (n=23) and a control group (n=23). Table 1 delineates the demographic profile of the participants categorized by gender and geographical location.

Table 1

Demographic Distribution of the Study Sample (N = 46)

Demographic Variable	Category	Control Group (n=23)	Experimental Group (n=23)	Total (n=46)
Gender	Male	6 (26.1%)	4 (17.4%)	10 (21.7%)
	Female	17 (73.9%)	19 (82.6%)	36 (78.3%)
Place of Living	Recognized Village	23 (100.0%)	21 (91.3%)	44 (95.7%)
	Unrecognized Village	0 (0.0%)	2 (8.7%)	2 (4.3%)

A preliminary review of the demographic data in Table 1 reveals a pronounced concentration of female participants across both groups, accounting for 78.3% of the total sample. In terms of geographical distribution, the vast majority of the participants (95.7%) resided in recognized villages, whereas representation from unrecognized villages was minimal, restricted to only two instances (4.3%) within the experimental group.

10.3 Study Instruments

The study relied on one main instrument:

Writing Anxiety Inventory — Cognitive Anxiety Subscale The study utilized the Cognitive Anxiety Subscale of the Writing Anxiety Inventory to measure cognitive anxiety associated with academic writing. This instrument is adopted from Cheng's (2004) Second Language Writing Anxiety Inventory (SLWAI), which was originally developed to assess writing anxiety in second or foreign language writing contexts. In the present study, this subscale was employed to fit the context of academic writing among university students, focusing exclusively on operationalizing indicators of cognitive anxiety experienced during the writing process.

The subscale consisted of 22 items in English and was structured according to a five-point Likert scale ranging from Strongly Disagree to Strongly Agree. The items measured several indicators related to cognitive anxiety during academic writing, including disorganized thoughts, mental tension while writing, fear of evaluation, hesitation in initiating the writing task, uncertainty during revision, and task-related cognitive load.

The inventory was administered to both the experimental group and the control group prior to and following the intervention. The **pre-intervention administration** was used to establish students' initial levels of cognitive anxiety and to verify the equivalence between the two groups before the treatment. The **post-intervention administration** was used to assess changes in students' cognitive anxiety after the intervention.

This instrument allowed the researchers to compare changes in cognitive anxiety scores between the experimental group, which received AI-based adaptive feedback, and the control group, which received conventional lecturer-provided feedback. It also helped determine whether the AI-based adaptive feedback learning environment contributed to reducing students' cognitive anxiety during academic writing.

10.4 Psychometric Properties of the Instrument

Internal Consistency Validity

To establish the construct validity of the 22-item Cognitive Anxiety Scale, Pearson product-moment correlation coefficients (r) were computed between individual item scores and the overall scale score. The analysis yielded correlation coefficients ranging from ($r = 0.47$) to ($r = 0.81$). Given that all 22 items demonstrated statistically significant correlations at the ($p < 0.05$) and ($p < 0.01$) levels, the scale exhibits robust internal consistency validity, confirming that each item adequately measures the intended underlying construct.

Reliability

The internal reliability of the instrument was evaluated using Cronbach's alpha (α). The analysis yielded an overall alpha coefficient of alpha = 0.92 for the 22-item scale. This value indicates excellent internal consistency, substantially exceeding the conventional psychometric threshold of 0.70, thereby confirming the instrument's stability and reliability for experimental deployment.

11. Results

Hypotheses Testing

Baseline Equivalence: Testing Hypothesis 1 (H_01)

The first null hypothesis asserted that: There is no statistically significant difference at the level of ($\alpha \leq 0.05$) between the mean scores of the experimental group and the control group in the pre-measurement of cognitive anxiety during academic writing.

To ascertain whether the two groups were equivalent prior to introducing the independent variable, an independent samples t-test was performed on the pre-intervention measurement scores. The outcomes of this analysis are detailed in Table 2.

Table 2

Independent Samples t-test Results for Pre-test Cognitive Anxiety Scores

Variable	Group	n	M	SD	Levene's F	p-value	t	df	p (2-tailed)
Pre-test Anxiety	Control	23	2.76	0.53	0.353	0.555	-0.925	44	0.360
	Experimental	23	2.92	0.62					

As indicated in Table 2, Levene's test confirmed that the assumption of homogeneity of variances was satisfied, $F(44) = 0.353$, $p = 0.555$. The independent samples t-test revealed no statistically significant differences between the baseline scores of the control group ($M = 2.76$, $SD = 0.53$) and the experimental group ($M = 2.92$, $SD = 0.62$), $t(44) = -0.925$, $p = 0.360$. Because the p-value exceeds the designated significance level of 0.05, **the first null hypothesis (H_01) is accepted**, establishing that both groups were statistically equivalent in their cognitive anxiety levels prior to the intervention.

Inter-Group Post-test Differences: Testing Hypothesis 2 (H_02)

The second null hypothesis stated that: There is no statistically significant difference at the level of ($\alpha \leq 0.05$) between the adjusted post-measurement mean scores of the experimental group and the control group in cognitive anxiety during academic writing after controlling for pre-measurement scores.

To isolate the genuine effect of the instructional intervention and statistically control for minor baseline variations in the pre-intervention scores, a One-Way Analysis of Covariance (ANCOVA) was executed. In this model, the pre-intervention score served as the covariate, the instructional environment (Group) acted as the independent variable, and the post-intervention score was designated as the dependent variable. Tables 3 and 4 present the adjusted means and the ANCOVA summary, respectively.

Table 3

Observed and Estimated Marginal Means for Post-test Scores

Group	n	Observed Mean	SD	Adjusted Mean (EM Mean)[a]	Standard Error
Control Group	23	3.99	0.94	**4.01**	0.15
Experimental Group	23	2.48	0.38	**2.46**	0.15

Note. M adj= Adjusted Mean; SD = Standard Deviation.

a Covariates appearing in the model are evaluated at the following value: Pre-test Total = 2.8399.

Table 4

ANCOVA Summary Table for Group Differences on Post-test Cognitive Anxiety

Source	Sum of Squares	df	Mean Square	F	p-value (Sig.)	Partial η^2
Covariate (Pre-measure)	0.614	1	0.614	1.204	0.279	0.027
Group (Intervention)	26.895	1	26.895	**52.724**	**< 0.001**	**0.551**
Error	21.935	43	0.510			
Corrected Total	48.835	45				

Note. df = degrees of freedom; F = F-ratio; p = probability value; Partial eta^2 = Partial Eta Squared effect size.

The ANCOVA results presented in Table 4 demonstrate that the covariate (pre-test scores) did not significantly predict post-test cognitive anxiety, $F(1, 43) = 1.204$, $p = 0.279$. Crucially, after accounting for baseline scores, a highly significant main effect was observed for the instructional environment, $F(1, 43) = 52.724$, $p < 0.001$.

The practical significance of this intervention is underscored by the partial eta-squared value ($eta^2 = 0.551$), which indicates that the AI-based adaptive feedback environment alone accounted for 55.1% of the variance in post-test cognitive anxiety. A comparison of the adjusted marginal means in Table 3 highlights a pronounced reduction in cognitive anxiety within the experimental group (M adj= 2.46) relative to the control group (M adj= 4.01). Consequently, **the second null hypothesis ($H_0$2) is rejected**.

Within-Group Progress: Testing Hypothesis 3 ($H_0$3):

The third null hypothesis stated that: There is no statistically significant difference at the level of ($\alpha \leq 0.05$) between the pre-measurement and post-measurement mean scores of the experimental group in cognitive anxiety during academic writing.

To track the longitudinal progression of the experimental group and determine whether their anxiety decreased significantly over time, a paired samples t-test was conducted (n = 23). The findings are presented in Table 5.

Table 5

Paired Samples t-test Results for the Experimental Group (n = 23)

Intervention Phase	Mean	SD	Mean Diff.	Standard Error Mean	t	df	p (2-tailed)
Pre-Intervention Total	2.92	0.62	0.44	0.13	**3.493**	22	**0.002**

Post-Intervention Total	2.48	0.38

Note. SD = Standard Deviation; df = degrees of freedom; t = computed t-statistic.

The data in Table 5 illustrate a clear downward trajectory in cognitive anxiety for the experimental group, with mean scores decreasing from 2.92 (SD = 0.62) at pre-test to 2.48 (SD = 0.38) at post-test. The paired samples t-test confirmed that this internal reduction was statistically highly significant, $t(22) = 3.493$, $p = 0.002$. Accordingly, **the third null hypothesis (H_03) is rejected**, proving that the experimental group achieved a genuine, independent mitigation of academic writing anxiety following exposure to the AI-driven adaptive feedback environment.

Synthesis and Direct Answer to the Main Research Question

To address the main research question concerning the effect of an AI-based adaptive feedback learning environment on reducing cognitive anxiety during academic writing among university students, the empirical findings indicate that the AI-based adaptive feedback learning environment had a statistically significant and practically meaningful effect on reducing cognitive anxiety.

The findings show that students in the experimental group, who received AI-based adaptive feedback, demonstrated lower levels of cognitive anxiety after the intervention compared with students in the control group, who received conventional lecturer-provided feedback. This suggests that the adaptive feedback environment helped reduce writing-related cognitive tension and provided students with a more supportive and less anxiety-provoking academic writing experience.

This overarching conclusion is firmly grounded in three core statistical milestones:

- **Substantial Adjusted Inter-Group Deviations:** Even after partialing out baseline variations using ANCOVA, the experimental group displayed a remarkably lower adjusted post-measurement mean ($M_{adj} = 2.46$) compared to the control group ($M_{adj} = 4.01$). This proves that the adaptive environment acted as a vital educational intervention, effectively mitigating anxiety, whereas conventional writing instruction was associated with an increase in students' cognitive tension.
- **High Explanatory Power (Effect Size):** The large effect size (partial $eta^2 = 0.551$) bridges statistical significance with practical field utility. Knowing that the technological intervention alone explains 55.1% of the variance in post-measurement anxiety emphasizes its viability as a primary pedagogical tool for academic writing contexts.
- **Significant Within-Group Progress:** The paired samples t-test confirms that the experimental group's drop in anxiety (from 2.92 to 2.48) was not a statistical anomaly, but rather a direct, significant ($p = 0.002$) outcome of the adaptive, real-time feedback loop over the course of the intervention.

Overall, the findings provide a clear and definitive answer to the main research question: the AI-based adaptive feedback learning environment was highly effective in reducing cognitive anxiety during academic writing among university students.

12. Recommendations

Based on the empirical findings of this study, the following practical recommendations are offered:

- **Curriculum Integration of AI-Based Adaptive Feedback:** Academic departments should systematically incorporate AI-based adaptive feedback environments into the design of university academic writing courses. This integration should target critical stages of the writing process—specifically during initial planning, cognitive organization of ideas, draft revision, and final text refinement—to actively alleviate students' writing-related cognitive anxiety and mental tension.
- **Pedagogical Training Programs for Lecturers:** Higher education institutions should design targeted professional development workshops and training seminars for faculty members. This training should equip lecturers with the pedagogical skills necessary to guide students in interacting with AI feedback systems responsibly. The focus should be on shifting the perception of AI from a substitute for student writing to a supportive cognitive tool that reduces evaluation anxiety and fosters independent self-regulation.

- **Development of Standardized Student Instructional Frameworks:** Academic writing centers and institutions should develop and distribute comprehensive instructional guidelines and practical handbooks for students. This guide should explicitly delineate when and how to leverage AI-supported feedback effectively, providing structured prompting techniques, systematic revision workflows, and clear ethical parameters to mitigate the risks of overdependence and academic dishonesty.

13. Conclusion

In conclusion, the findings of the present study indicate that the AI-based adaptive feedback learning environment was highly effective in reducing cognitive anxiety during academic writing among university students. The results demonstrated that students who received adaptive, AI-supported feedback experienced significantly lower levels of cognitive anxiety compared with those who received conventional, lecturer-provided feedback.

From **the researchers' perspective**, these outcomes suggest that academic writing difficulties should not be addressed merely by evaluating or correcting students' final written products. Instead, instructional interventions must actively support the intricate mental and cognitive processes that students navigate during the writing process. Consequently, **the researchers believe** that AI-based adaptive feedback can serve as a powerful pedagogical tool when integrated in a structured, ethical, and guided manner that complements—rather than replaces—the vital role of the university lecturer.

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