



# Human-AI Collaborative Feedback in Improving EFL Writing Performance: An Analysis Based on Natural Language Processing Technology

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## Abstract

A perfect writing skill has been deemed instrumental to achieving competence in EFL, yet it is considered one of the most impressive learning domains. This study investigates the impact of human-AI collaborative feedback on the writing proficiency of EFL students. It examines key teaching domains, including the teaching environment, teacher knowledge and experience, and feedback quality and timeliness, focusing on language features such as accuracy, complexity, and fluency. This study employed a mixed-methods approach, integrating both quantitative and qualitative data. A stratified random sampling technique was utilised to select 260 EFL students from tertiary institutions for the survey, while purposive sampling was employed to recruit five participants for semi-structured interviews. Quantitative data were analysed using regression and mediation tests to examine the relationships between feedback and writing performance. In contrast, qualitative data were subjected to thematic analysis to explore participants' perceptions of the human-AI feedback mechanism. The findings indicate that human-AI collaborative feedback significantly enhances writing performance by delivering timely and detailed insights, thereby fostering improvements in language accuracy, complexity, and fluency. Additionally, writing enjoyment and cognitive competencies were identified as mediators in the relationship between feedback and writing improvement. The study highlights the potential of integrating AI into EFL feedback systems to complement existing approaches and foster more comprehensive improvements in EFL writing. The study acknowledges certain limitations, including its reliance on self-reported data, which may introduce biases in students' perceptions of their writing improvement.

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**Keywords:** Human-AI Combined Feedback; EFL Writing Performance; Collaborative Learning Engagement, Feedback Mechanism.

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## Introduction

Effective writing skills are regarded as essential for achieving competence in EFL and are recognised as one of the most complex learning domains. Many EFL learners encounter challenges in grammar, syntax, vocabulary, and overall proficiency in written language (Ferris, 2014). Traditional assessment methods rely

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on teacher-generated feedback, which, although beneficial, can be time-consuming, subjective, and inconsistent (Lee, 2017). The growing interest in enhanced feedback systems has led to the integration of AI to complement human input, making feedback more comprehensive and efficient (Chang et al., 2021). Human-AI collaborative feedback models combine the expertise of teachers with the capabilities of Artificial Intelligence to deliver timely, accurate, and highly personalised feedback (Hutson & Plate, 2023). These systems leverage Natural Language Processing (NLP), a branch of Artificial Intelligence focused on analysing and generating human language (Lashkarian & Sayadian, 2015).

Writing proficiency is a fundamental aspect of language acquisition, particularly for EFL learners who frequently face challenges in mastering grammar, syntax, vocabulary, and overall coherence. Beyond linguistic competence, effective writing also involves understanding cultural contexts and conventions specific to the English language (Hyland, 2019). Through these complex processes, learners can identify errors, refine their ideas, and ultimately improve their writing skills (Lee, 2017). Effective feedback has been identified as a crucial factor in this process. Mandouit & Hattie (2023) define feedback as information provided by an agent regarding aspects of one's performance or understanding. In EFL writing, feedback can either be form-focused, addressing grammatical accuracy, or meaning-focused, targeting coherence, structure, and argumentation (Ferris, 2014). Traditional teacher-led feedback methods are often criticised for being time-consuming, subjective, and inconsistent (Hyland, 2019). As a result, there is growing interest in integrating Artificial Intelligence (AI) into feedback processes to enhance efficiency and objectivity (Chang et al., 2021).

The integration of human instructors' nuanced insights with the speed and precision of AI systems creates a more comprehensive feedback experience, known as Human-AI collaborative feedback (Hutson, Plate, & Berry, 2024). NLP, a branch of AI, enables the development of systems capable of evaluating grammar, style, and even the logical structure of student writing (Lashkarian & Sayadian, 2015). These systems promise real-time, personalised feedback, easing teacher workloads and providing students with prompt, actionable insights (Oktarina et al., 2024). However, challenges persist in the implementation of AI-enhanced feedback. AI systems often struggle to recognise contextual and cultural nuances essential for effective communication (Song & Song, 2023). Additionally, AI-generated feedback tends to focus on surface-level corrections, such as grammar and spelling, rather than addressing higher-order skills like argument development and critical thinking (Woo & Choi, 2021). In contrast, human feedback offers personalisation and empathy, crucial elements in fostering student motivation and creating a supportive learning environment (Hyland, 2019).

Optimising the feedback process can incorporate cognitive and affective factors, such as writing enjoyment and self-regulation. Positive Psychology highlights how positive emotions like enjoyment can boost student engagement and motivation (Edwards & Cooper, 2024). Social Cognitive Theory (Schunk & DiBenedetto, 2020) and Sociocultural Theory (Glăveanu, 2021) emphasise the importance of self-regulation and metacognitive skills for using feedback effectively (Zimmerman & Schunk, 2013). Integrating AI into conventional feedback systems aligns with Constructivist Learning Theory, which advocates active, student-centred learning (Alessandroni, 2021). AI tools provide immediate, objective feedback, fostering self-directed learning and bridging the gap between mechanical accuracy and creative expression (Self, 2021). Therefore, this collaborative feedback system has the capability of closing the gap between mechanical accuracy and creative expression to encourage more integral language development.

### *The Rationale of the Study*

The growing reliance on AI in education has raised questions about its role in feedback mechanisms, particularly in EFL writing instruction. Traditionally, teacher-generated feedback has guided students in improving their writing but faces limitations such as subjectivity, inconsistency, and time constraints (Lee, 2017). As a result, there is increasing interest in AI-based feedback systems to meet the demand for scalable and efficient personalised feedback (Chang et al., 2021). AI-powered feedback using NLP offers real-time, objective insights on grammar, structure, and coherence (Lashkarian & Sayadian, 2015). However, research indicates that AI feedback alone is insufficient, as it primarily focuses on surface-level corrections and lacks contextual and pedagogical judgment (Song & Song, 2023). Combining AI with human feedback presents a promising approach, merging AI's efficiency with the depth and personalisation of human insight (Hutson & Plate, 2023).

### *Problem Statement*

Despite the positive implications of integrating AI with human feedback in EFL writing instruction, limited research has explored its efficacy. While studies have demonstrated that human-AI collaborative feedback enhances EFL writing performance, insufficient attention has been given to the influence of specific factors such as the teaching environment, teacher expertise, and the quality and timeliness of AI-generated feedback (Hyland, 2019). Additionally, there is a lack of research on the mediating role of EFL students' cognitive assets, such as writing enjoyment and self-regulation, in the feedback-writing performance relationship. These gaps in the literature underscore the need for a more systematic investigation into how human-AI feedback mechanisms can be optimally utilised to enhance EFL writing outcomes.

### *Aim and Research Objectives/Questions*

The aim of this study are:

- To evaluate the influence of key factors of human-AI collaborative feedback, including teaching environment, teacher knowledge, and feedback quality and timelines, on improving EFL students' writing performance.
- To investigate the mediation effects of writing enjoyment and cognitive competencies in the relationship between human-AI feedback and EFL writing performance factors.
- To explore the perceptions of teachers and students regarding the implementation of human-AI combined feedback mechanisms to improve EFL writing performance.

Based on the research objectives, there are the following research questions that this study answered.

- What is the influence of the key factors of human-AI collaborative feedback (including teaching environment, teacher knowledge and experience, and feedback quality and timelines) on the improvement of EFL students' writing performance?
- What is the mediation impact of writing enjoyment and cognitive competencies in the relationship between the EFL writing performance factors and human-AI feedback?
- What are the perceptions of the teachers and students related to the implementation of human-AI combined feedback mechanisms in improving EFL writing performance?

### *Research Significance*

This research is significant as it addresses existing gaps in both the theoretical and practical aspects of feedback within EFL writing instruction. It contributes to the literature on AI in education, particularly focusing on the unresolved issue of human-AI interaction in language acquisition (Haswani, 2014). Practically, it offers valuable insights for language educators by demonstrating how NLP-based AI tools can be integrated into traditional educational frameworks to enhance writing proficiency. Additionally, examining the mediating effects of writing enjoyment and cognitive competencies may inform more effective feedback strategies that not only improve the quality of written work but also foster greater student engagement in writing activities (Ellis & Shintani, 2013).

## **Literature Review**

The literature review in this study begins by establishing an operational definition of human-AI feedback systems and their components. It then examines previous research on the use of AI-based feedback in learning. The discussion subsequently focuses on EFL writing performance, highlighting factors that contribute to writing proficiency and the critical role of feedback in enhancing writing skills.

### *EFL Writing Challenges and the Role of Feedback*

EFL writing presents learners with various complexities, including grammar, vocabulary, coherence, cohesion, and idea development (Hyland, 2019). Writing in a second language requires students to work within the constraints of the target language, necessitating not only the application of first-language writing conventions but also the reorganisation and monitoring of their thoughts (Ferris, 2014). Feedback is a critical intervention, enabling learners to identify errors, reflect on their writing, and make necessary corrections (Lee, 2017). However, traditional teacher-initiated feedback is often limited by time, resources, and subjectivity (Hyland, 2019). Feedback plays a pivotal role in enhancing EFL writing skills by fostering self-regulation and enabling learners to transition from form-focused feedback (addressing grammatical issues) to meaning-focused feedback, which emphasises organisation and cohesion (Ferris, 2014).

### *Human-AI Collaborative Feedback Mechanisms in EFL Writing*

Recent advancements in NLP and AI technologies have introduced innovative approaches to feedback provision in EFL writing instruction. NLP-based AI tools enable grammar checks, style recommendations, and feedback on content and cohesiveness (Oktarina, 2023). When combined with the expertise of human teachers, these tools create a mixed feedback approach that addresses both local (e.g., grammar and vocabulary) and global (e.g., coherence and argument structure) aspects of students' writing (Hutson et al., 2024). Notable advantages of AI in feedback systems include real-time feedback and the opportunity for iterative learning, allowing students to correct their work continuously (Chang et al., 2021).

### *Key Factors Influencing the Effectiveness of Human-AI Collaborative Feedback*

Several factors influence the effectiveness of human and AI feedback in enhancing EFL students' writing quality, including the teaching environment, teacher expertise, and the quality and promptness of feedback provided. The context and setting in which feedback is delivered significantly impact its effectiveness. Technologically supported classrooms are better equipped to integrate AI applications and implement seamless human-AI feedback systems (Zhang & Cheung, 2018). Moreover, classroom climate and the

perceptions of both teachers and students towards AI technology can influence how these tools are utilised (Oktarina et al., 2024). Communities that view AI as an assistant to human instruction are more likely to engage with and apply feedback during composition tasks. The effectiveness of feedback, whether generated by a human or AI, positively correlates with the teacher's ability level. Teachers with advanced skills are better equipped to provide high-quality, meaningful feedback (Bitchener & Storch, 2016).

### *The Mediating Role of Writing Enjoyment and Cognitive Competencies*

The current analysis also examines the mediating effects of writing enjoyment and cognitive competencies as intermediate variables in the feedback loop between human-AI feedback and writing performance. Robertson (2015) highlighted the importance of affective factors in shaping students' reception of feedback and their approach to writing. When students are engaged in revising and implementing suggestions, their writing performance tends to improve (Ellis & Shintani, 2013). Cognitive skills, including self-regulation, play a crucial role in the feedback process. High writing-related engagement enhances the alignment between feedback perception and regulation, fostering deeper levels of metacognition during revision (Zimmerman & Schunk, 2013).

### *Limitations of AI Feedback Systems in EFL Writing*

Although AI feedback systems offer advantages such as scalability and quick response times, they also have notable drawbacks in EFL writing instruction. One significant limitation is AI's inability to grasp cultural and contextual nuances, which are essential in language use and particularly critical in EFL settings (Guo et al., 2024). Human instructors, by contrast, can interpret subtle cultural cues and understand learners' contexts, while AI may produce ambiguous interpretations or overlook these aspects, leading to unhelpful or even confusing feedback (Song & Song, 2023). Additionally, AI feedback is generally more effective at addressing surface-level lexical features but falls short when dealing with higher-order elements, such as argument structure, critical evaluation, and the generation of ideas (Woo & Choi, 2021).

### *Theoretical Frameworks*

#### *Positive Psychological Theory*

In Positive Psychological Theory, Edwards & Cooper (2024) argue that well-being should be enhanced, while weaknesses should be addressed. In the context of education, this theory emphasises fostering positive emotions, interests, and motivation to improve students' performance. Writing enjoyment, a key feature of this study, aligns with the positive psychological perspective, particularly the idea that students' emotional experiences can significantly influence their learning and performance outcomes (Robertson, 2015).

#### *Social Cognitive Theory*

Schunk & DiBenedetto (2020) suggest that the study can also be examined through the lens of Social Cognitive Theory, which emphasises self-efficacy, knowledge, and learning experiences as key determinants of learning behaviours. Consistent with the development of this theory, individuals learn by observing others, evaluating the consequences of observed performances, and engaging in modelling. This process helps learners develop approach and avoidance behaviours, as well as self-regulation and metacognitive skills (Wootton, 2024).

#### *Sociocultural Theory and the Role of AI in Learning*

The Sociocultural Approach, grounded in Vygotsky's theory, posits that learning is an interactive process where participation and cooperation drive essential developmental changes (Zavershneva & van der Veer, 2019). In the context of human-AI collaborative feedback, Sociocultural Theory provides a useful framework, as AI tools can act as mediators, scaffolding learners' development within the "zone of proximal development." Current research highlights that AI feedback can function as a scaffold by providing regular, iterative feedback, thereby facilitating the improvement of written tasks (Oktarina, 2023).

#### *Constructivist Learning Theory*

Constructivist Learning Theory, as outlined by Alessandrini (2021), Self (2021), and Barnes & Todd (2021), asserts that knowledge is built through learners' experiences and reflections. In the context of human-AI co-authoring feedback, this theory suggests that learners engage in writing by integrating AI proposals into their work, fostering iterative knowledge construction. AI feedback aligns with the active learning model, where learners are proactive builders of knowledge. Additionally, AI tools can promote personalised feedback, targeting specific learners' abilities and needs, thereby fostering deeper cognitive processes and enhanced writing skills (Ren et al., 2024). The literature highlights the potential of the student-AI feedback loop to enhance EFL students' writing abilities. By combining the instant and consistent nature of AI with teacher expertise, this integrated system can address many limitations of traditional feedback methods.



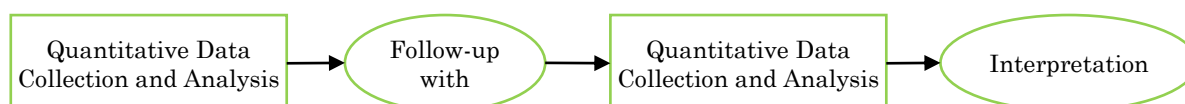
## Research Methodology

### Research Method

This study adopted a mixed-methods research approach to gain comprehensive insights into the effects of the cooperative human–AI feedback system on EFL writing performance. Initially driven by a purely quantitative focus, the research was enriched with qualitative insights obtained through interviews. As [Creswell & Creswell \(2017\)](#) suggest, employing mixed methods is appropriate when aiming to achieve convergence between data collection approaches. Quantitative data were gathered through a survey that examined factors such as the teaching environment, teacher expertise, and feedback quality. The qualitative component involved structured interviews with EFL teachers and students. The combination of these approaches allowed for a more thorough exploration and understanding of the research problem.

### Research Design

This study employed a mixed research design, with quantitative data collection and analysis preceding the qualitative phase. The findings from the quantitative analysis informed the design of interview questions for the qualitative phase. Online self-administered cross-sectional surveys were used to gather quantitative data, measuring variables such as the teaching environment, teacher knowledge and experience, feedback quality, and delivery. In the qualitative phase, interviews were conducted with teachers and learners to gain deeper insights into their experiences and attitudes towards human–AI feedback. The interview guide mirrored the objectives of the questionnaire but approached them from an interpretative perspective, focusing on the operation of variables within the human–AI feedback system. Following research by [Song & Song \(2023\)](#) and [Oktarina et al. \(2024\)](#), the survey included validated scales assessing writing enjoyment and cognitive competencies, as outlined by [Robertson \(2015\)](#) and [Zimmerman & Schunk \(2013\)](#). The interviews were audio-recorded, transcribed, and thematically analysed using a coding frame developed from the transcriptions ([Braun & Clarke, 2023](#)).



**Figure 1:** *Sequential Methodology Design.*

[Figure 1](#) represents a sequential explanatory research design used in this study and it is commonly used in mixed-methods research. It illustrates a process of this study where quantitative data collection and analysis are conducted first, followed by a follow-up qualitative phase, which then leads to a second quantitative data collection and analysis, culminating in interpretation.

### Data Collection Method

The study adopted a mixed-methods approach, with data collection conducted in two stages. This method was selected for its efficiency in managing data and reaching a large student population, as recommended by [Wu, Zhao, & Fils-Aime \(2022\)](#). The questionnaire was available for four weeks, allowing respondents ample time to participate. Structured writing assignments were a core component of the evaluation, with students completing pre-tests and post-tests via Automated Content Feedback to assess initial abilities and subsequent improvements. Rough drafts, rewritten work, and supplementary assignments were completed within a 60-minute timeframe, yielding a total of 260 writing samples. Approximately five EFL teachers and students were selected for interviews based on availability and relevance to the study objectives. Interviews were conducted in a semi-structured format, either live or via Skype, following the approach recommended by [Groves et al. \(2011\)](#). This format allowed for both standardised questions and in-depth participant responses, facilitating a detailed exploration of the educational context, teaching quality, and the timeliness and effectiveness of feedback.

### Writing Performance and Its Measurement

Language production is essential for evaluating proficiency in second-language (L2) instruction. [Hyland \(2019\)](#) argues that EFL writing integrates grammar and vocabulary with broader writing competencies. [Luangkrajang \(2022\)](#) underscores the use of the Complexity, Accuracy, and Fluency (CAF) framework to assess EFL learners' language production, identifying these as key dimensions of language ability. Complexity involves sophisticated language processing, such as diverse sentence structures and syntactic development ([Kuiken & Vedder, 2019](#); [Schmitt, Nation, & Kremmel, 2020](#); [Suzuki & Kormos, 2020](#)). Accuracy focuses on adherence to grammatical rules and minimisation of errors ([Liu & McManus, 2023](#); [Pallotti, 2020](#)). Fluency refers to the smoothness and speed of language production, encompassing semantic, lexical, and syntactic fluency ([Duve, 2020](#); [Hijuelos-Cruz, Medina-Carballosa, & Pérez-Almaguer, 2020](#); [Rose et al., 2020](#)). The CAF framework provides a comprehensive approach to assessing writing performance and effectively tracking learners' progress.

### Measurement of Complexity, Accuracy and Fluency

Researchers have extensively examined measures of complexity, accuracy, and fluency in EFL writing, focusing on syntactic complexity as a crucial dimension. Syntactic complexity encompasses categories related to sentences, T-units, and phrases. Within the sentence category, terms such as clauses and dependent clauses are often used. The ratio of dependent clauses in T-units and clauses (DC/T and DC/C) is a significant metric for evaluating learners' writing proficiency, with studies suggesting a negative relationship between these ratios and advanced language development (Lu, 2011).

Li et al. (2020) demonstrated that T-unit length effectively distinguishes EFL learners at different proficiency levels. Kumar (2021) extended this concept by introducing complex T-units, defined as T-units containing at least one independent sentence. Liu & McManus (2023) highlighted the mean length of T-units (MLT), mean length of clauses (MLC), and the ratio of clauses to T-units (C/T) as ideal measures of sentence complexity. Spada (2022) proposed that syntactic complexity should be assessed through five dimensions: the number of subordinate structures, overall sentence complexity, phrase extension within clauses, the number of parallel structures, and the diversity, complexity, and acquisition sequence of sentence structures. These insights provide valuable frameworks for analysing and enhancing EFL learners' writing abilities.

### Sampling Technique

In the quantitative survey, stratified random sampling was employed, considering factors such as gender, year of study, and English language proficiency. This approach minimises sample bias and enhances the generalisability of findings, as recommended by Sekaran (2016). For the qualitative phase, purposive sampling was applied to select participants for interviews, targeting individuals who had experience with both AI and human feedback in EFL writing contexts, either as receivers or providers.

### Sample Size

The quantitative survey required a minimum of 260 participants based on the sample size formula proposed by Serdar et al. (2021). This sample size ensures adequate coverage for advanced statistical analyses, including regression and structural equation modelling. In the qualitative phase, a purposive sample of five respondents was selected, as this number is sufficient for thematic analysis when the focus is on achieving depth rather than breadth (Braun & Clarke, 2023).

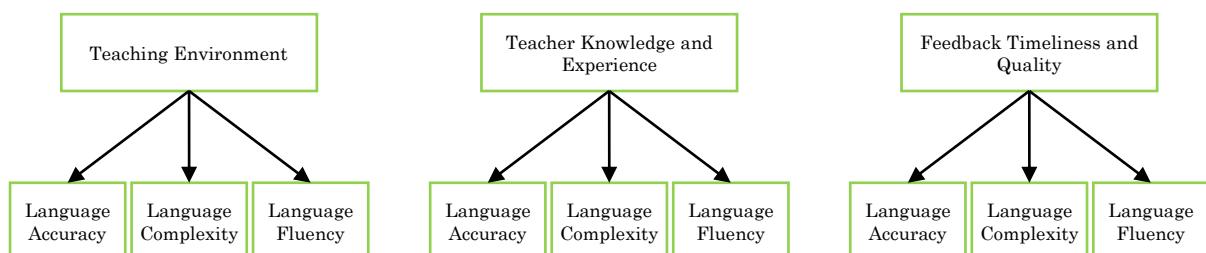
### Target Population

The target population comprised tertiary-level EFL students from various institutions of higher learning. Participants were selected based on this criterion to ensure a diverse sample of learners. The sample size of 260 students was deemed sufficiently large to generalise the findings to the broader population of EFL learners, as recommended by Serdar et al. (2021).

### Data Analysis Techniques

This study employed a mixed-methods approach to analyse feedback mechanisms involving human and AI collaboration in enhancing EFL writing performance. Quantitative analyses included descriptive statistics, reliability tests (Cronbach's alpha), Pearson's correlation, multiple regression, and Partial Least Squares Structural Equation Modelling (PLS-SEM) to validate constructs such as human-AI feedback, writing enjoyment, cognitive competencies, and EFL writing performance. These methods facilitated the assessment of demographic data, structural relationships, and mediating effects within the model (Field, 2018; Hair, Ringle, & Sarstedt, 2011; Hallquist, Wright, & Molenaar, 2021; Sarstedt, Ringle, & Hair, 2022). The qualitative analysis involved thematic coding based on Braun and Clarke's (2023) framework, enabling the identification of patterns and distinctions in participants' perceptions of the human-AI feedback system. This comprehensive approach provided valuable insights into the challenges and advantages of integrating AI-driven feedback in EFL contexts (Pallant, 2020).

### Conceptual Framework

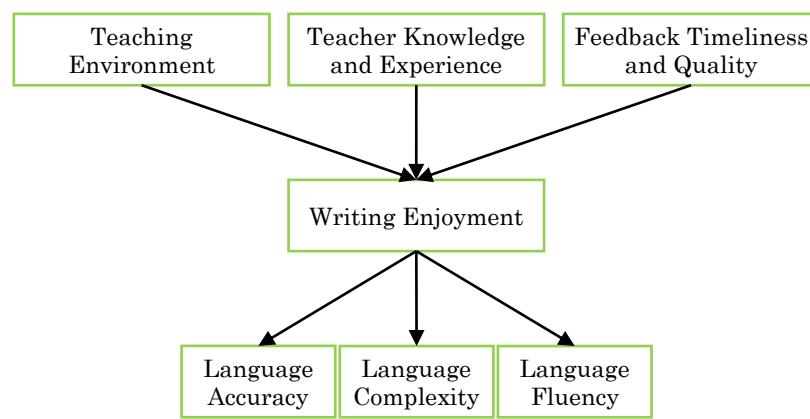


**Figure 2:** Human-AI Collaborative Feedback to EFL Writing Performance.

The framework illustrates the impact of 'human-AI co-feedback' on EFL writing performance,

highlighting key factors such as the teaching environment, teachers' content knowledge, and classroom experience. It underscores the importance of the quality and timeliness of feedback provided to learners. Additionally, the model demonstrates how mediating variables like writing enjoyment and cognitive operations influence writing performance, offering insights into the dynamic interactions within this feedback system. Figure 2 illustrates how the teaching environment, teacher knowledge and experience, and the timeliness and quality of feedback directly influence EFL writing performance. This performance is evaluated across three dimensions: language accuracy, language complexity, and language fluency. These metrics serve as essential indicators for assessing learners' writing abilities, capturing both surface-level and deeper linguistic competencies.

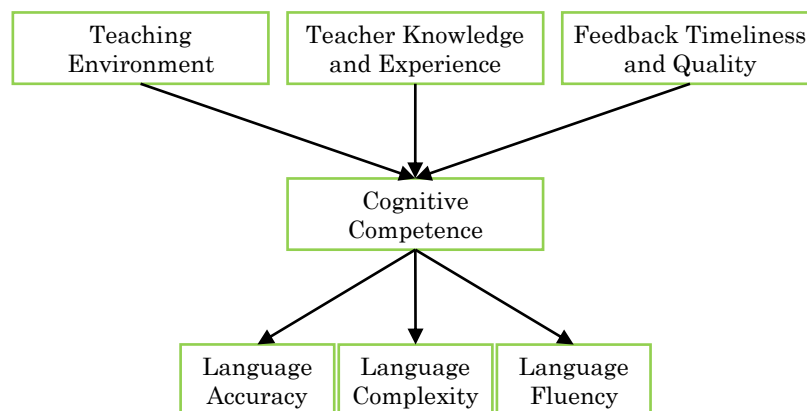
IV-1: The teaching environment plays a critical role in shaping EFL writing performance by providing the context for language learning and writing practice. Teacher knowledge and teaching experience influence writing outcomes through effective content delivery and teaching strategies. Timeliness and quality of feedback significantly affect learners' ability to improve their writing by offering actionable insights when needed. These independent variables collectively impact three primary dimensions of writing performance: language accuracy (correctness in grammar and vocabulary), language complexity (use of varied and sophisticated sentence structures), and language fluency (ease and coherence of expression).



**Figure 3:** Human-AI Collaborative Feedback to EFL Writing Performance Through Writing Enjoyment.

Figure 3 highlights writing enjoyment as a mediating variable between the teaching environment, teacher knowledge, feedback quality, and writing performance. A supportive teaching environment, well-informed and experienced teachers, and high-quality feedback foster positive emotional engagement with writing. This enjoyment subsequently enhances the three dimensions of writing performance: language accuracy, complexity, and fluency, by motivating learners to engage more deeply and consistently with the writing process.

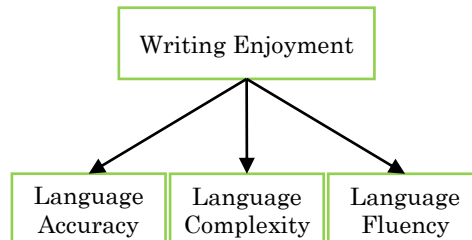
IV-1 to IV-3: Same as in Figure 1. MV-1: Writing enjoyment mediates the influence of the teaching environment, teacher knowledge, and feedback quality on writing performance outcomes. This mediator strengthens the relationship between these independent variables and the three dependent variables: language accuracy, complexity, and fluency. Writing enjoyment encourages greater learner engagement, fostering improved performance across these key dimensions.



**Figure 4:** Human-AI Collaborative Feedback to EFL Writing Performance Through Cognitive Competences.

Figure 4 illustrates the role of cognitive competencies as a mediating factor. It shows how the teaching environment, teacher knowledge, and feedback quality shape learners' cognitive abilities, which in turn positively influence their writing performance in terms of language accuracy, complexity, and fluency. The figure highlights the interconnected pathways between these variables and underscores the importance of cognitive development in EFL writing enhancement.

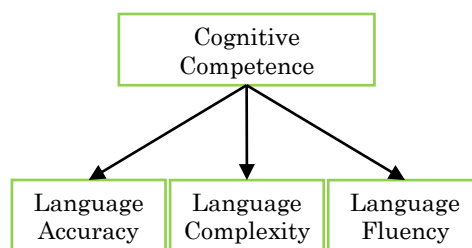
IV-1 to IV-3: Same as in Figure 1. MV-1: Cognitive competencies, serving as an additional mediating variable, represent the cognitive abilities learners acquire and develop within the teaching context, shaped by teacher knowledge and the quality of feedback. These competencies significantly influence the criteria for writing performance. DV-1 to DV-3: As illustrated in Figure 1, these interactions are mediated by the cognitive competencies discussed in this study.



**Figure 5:** *Writing Enjoyment to Human-AI Collaborative Feedback.*

Figure 5 highlights the isolated relationship between writing enjoyment and writing performance, demonstrating that writing enjoyment directly impacts language accuracy, complexity, and fluency.

IV-1: Writing Enjoyment serves as an independent variable in this model, directly prompting changes in writing outcomes. DV-1 to DV-3 represent the writing performance dimensions influenced by writing enjoyment, namely Language Accuracy, Language Complexity, and Language Fluency.



**Figure 6:** *Cognitive to Human-AI Collaborative Feedback.*

Similarly, Figure 6 illustrates how cognitive competencies function as an independent variable, directly impacting the writing performance dimensions of language accuracy, complexity, and fluency.

IV-1: Writing performance is directly influenced by cognitive competencies, which act as the independent variable. DV-1 to DV-3: Language Accuracy, Language Complexity, and Language Fluency are primarily shaped by cognitive competencies in response to writing production.

### *Ethical Considerations*

This research adhered to ethical standards essential for protecting participants' rights. Participants were adequately informed about the study's objectives, data confidentiality, and their right to withdraw at any time. Consent was obtained from all participants following ethical guidelines (Bryman, 2016). To ensure privacy, individual identification data were anonymised, and responses were securely stored to protect participants' identities. Furthermore, institutional ethical committee approval was secured before data collection commenced.

## **Results**

### *Demographic Statistics*

Table 1 shows the demographic summary of the respondents. The demographic data indicate that 53.5% of the sample is male, and 46.5% is female, with a total of 260 participants. In terms of age distribution, the largest groups are employees aged 31-35 and 36 or older, each representing 25.8% of the sample, followed by those aged 25-30 (25%) and 18-24 (23.5%). Regarding educational attainment, 51.5% of respondents are undergraduates, while 48.5% are postgraduates, reflecting a sample characterised by a relatively high level of education.



**Table 1: Demographic Statistics.**

Category	Sub-Category	Frequency	Percent
<b>Gender</b>	Male	139	53.5
	Female	121	46.5
<b>Total</b>		260	100
<b>Age</b>	18-24	61	23.5
	25-30	65	25
	31-35	67	25.8
	36 and Above	67	25.8
<b>Total</b>		260	100
<b>Education</b>	Undergraduate	134	51.5
	Postgraduate	126	48.5
<b>Total</b>		260	100

*Data Statistics*

**Table 2** shows the descriptive summary of the variables, used in this study. Different statistics has been used to summarise the data, which includes the mean, median and mode for central tendency, skewness and kurtoses for data distribution, minimum, maximum, range, standard deviation and variance for measures of dispersion.

**Table 2: Data Summary.**

Statistics	Teaching Environment	Teacher Knowledge and Experience	Feedback Quality and Timeliness	Writing Enjoyment	Cognitive Competencies	Language Accuracy	Language Complexity	Language Fluency
<b>N Valid</b>	260	260	260	260	260	260	260	260
<b>N Missing</b>	0	0	0	0	0	0	0	0
<b>Mean</b>	3.06	3.008	3.029	3.018	3.002	3.029	3.038	2.989
<b>Median</b>	3	3	3	3	3	3	3	3
<b>Mode</b>	4.6	1.6	4.4	4.6	4.6	4.4	1.4	4.6
<b>Skewness</b>	-0.071	0.044	-0.063	-0.014	0	-0.005	-0.077	0.064
<b>Std. Error of Skewness</b>	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151
<b>Kurtosis</b>	-1.235	-1.318	-1.266	-1.266	-1.226	-1.319	-1.257	-1.266
<b>Std. Error of Kurtosis</b>	0.301	0.301	0.301	0.301	0.301	0.301	0.301	0.301
<b>Minimum</b>	1	1.2	1	1	1	1.2	1	1
<b>Maximum</b>	5	4.8	5	5	5	5	5	5

*Reliability Analysis*

**Table 3** shows reliability analysis which confirmed acceptable reliability coefficients for all eight measured variables, with Cronbach's Alpha values ranging from 0.802 to 0.831. Specifically, "Teaching Environment" ( $\alpha = 0.813$ ), "Teacher Knowledge and Experience" ( $\alpha = 0.825$ ), "Feedback Quality and Timeliness" ( $\alpha = 0.824$ ), "Writing Enjoyment" ( $\alpha = 0.826$ ), and "Cognitive Competencies" ( $\alpha = 0.827$ ) all exceed the acceptable threshold of 0.7, demonstrating good reliability for each scale.

**Table 3: Reliability and Validity Analysis.**

Scale	Items	Source	Reliability Statistics	CR	AVE
Teaching Environment	The classroom environment supports the effective use of AI tools for providing feedback.	<a href="#">Chang et al., (2021)</a>	0.813	0.753	0.867
Teacher Knowledge and Experience	My teachers are knowledgeable about AI tools used for writing feedback.	<a href="#">Ferris (2014)</a> , <a href="#">Hutson and Plate (2023)</a>	0.825	0.769	0.835
Feedback Quality and Timeliness	AI tools provide feedback on my writing on time.	<a href="#">Ferris (2014)</a> , <a href="#">Hutson and Plate (2023)</a>	0.824	0.793	0.892
Writing Enjoyment	I enjoy the process of writing in English.	<a href="#">Hutson and Plate (2023)</a>	0.826	0.801	0.883
Cognitive Competencies	I use feedback from AI and teachers to reflect on my writing process.	<a href="#">Chang et al., (2021)</a>	0.827	0.732	0.845

### Regression Analysis

#### *Impact of Human-AI Collaborative Feedback (Teaching Environment) on EFL Writing Performance (Language Accuracy) Mediating by Writing Enjoyment and Cognitive Competencies*

The findings indicate that the Teaching Environment (TE) significantly enhances Language Accuracy (LA), with Writing Enjoyment (WE) and Cognitive Competencies (CC) acting as mediators. In Table 4, TE demonstrates a strong positive relationship with both WE (Coeff = 0.8450,  $p < 0.001$ ) and CC (Coeff = 0.8393,  $p < 0.001$ ), accounting for 71.67% of the variance in WE and 70.20% in CC. Additionally, the correlations reveal that LA and CC are positively associated, and WE also correlates positively with LA (Coeff = 0.1627,  $p < 0.01$ ) and CC (Coeff = 0.3704,  $p < 0.001$ ). Table 5 shows the direct effect of TE on LA is substantial (Coeff = 0.3751,  $p < 0.001$ ). The total indirect effect of TE through both mediators is statistically significant (total = 0.4484), with a stronger effect via CC (Coeff = 0.3109) compared to WE (Coeff = 0.1375). In conclusion, the findings suggest that both WE and CC partially mediate the influence of TE on LA, contributing to improved EFL writing performance.

**Table 4: Regression Results.**

Outcome Variable	Predictor	Coeff.	SE	t	p	LLCI	ULCI	R	R <sup>2</sup>	F	df1	df2
WE	Constant	0.4320	0.1081	3.9969	0.0001	0.2192	0.6449	0.8466	0.7167	652.57	1	258
	TE	0.8450	0.0331	25.5455	0.0000	0.7799	0.9101					
CC	Constant	0.4333	0.1112	3.8950	0.0001	0.2142	0.6524	0.8379	0.7020	607.75	1	258
	TE	0.8393	0.0340	24.6527	0.0000	0.7722	0.9063					
LA	Constant	0.2785	0.1023	2.7227	0.0069	0.0771	0.4799	0.8731	0.7624	273.79	3	256
	TE	0.3751	0.0637	5.8903	0.0000	0.2497	0.5005					
	WE	0.1627	0.0616	2.6424	0.0087	0.0415	0.2840					
	CC	0.3704	0.0598	6.1910	0.0000	0.2526	0.4883					

**Table 5: Direct and Indirect Effects.**

Effect Type	Effect	SE	LLCI	ULCI
Direct Effect (TE → LA)	0.3751	0.0637	0.2497	0.5005
Total Indirect Effect (TE → WE, CC → LA)	0.4484	0.0717	0.3143	0.5997
Indirect Effect via WE (TE → WE → LA)	0.1375	0.0612	0.0181	0.2656
Indirect Effect via CC (TE → CC → LA)	0.3109	0.0599	0.1936	0.4319

#### *Impact of Human-AI Collaborative Feedback (Teacher Knowledge and Experience) on EFL Writing Performance (Language Accuracy) Mediating by Writing Enjoyment and Cognitive Competencies*

The findings reveal that Teacher Knowledge and Experience (TKE) has a direct positive effect on LA, with WE and CC acting as mediators. In Table 6, TKE shows a strong association with WE (Coeff = 0.8092,  $p < 0.001$ ) and CC (Coeff = 0.8497,  $p < 0.001$ ), accounting for 65.04% and 71.21% of the variance in WE and CC, respectively. Both mediators positively influence LA, with WE (Coeff = 0.2384,  $p < 0.001$ ) and CC (Coeff = 0.3613,  $p < 0.001$ ) demonstrating significant effects. TKE's direct impact on LA is highly substantial (Coeff = 0.3111,  $t = 17.28$ ,  $p < 0.001$ ). Table 7 shows the total indirect effect of TKE on LA through both mediators is significant ( $\text{Chi}^2 = 43.259$ ,  $p < 0.001$ ). CC shows a slightly stronger mediating effect ( $\text{Chi}^2 = 25.204$ ,  $p < 0.001$ ) than WE ( $\text{Chi}^2 = 18.055$ ,  $p < 0.001$ ). In summary, WE and CC partially mediate the relationship between TKE and LA, contributing to enhanced EFL writing performance.

**Table 6: Regression Results.**

Outcome Variable	Predictor	Coeff.	SE	t	p	LLCI	ULCI	R	R <sup>2</sup>	F	df1	df2
WE	Constant	0.5839	0.1188	4.9145	0.0000	0.3500	0.8179	0.8064	0.6504	479.90	1	258
	TKE	0.8092	0.0369	21.9067	0.0000	0.7364	0.8819					
CC	Constant	0.4458	0.1082	4.1201	0.0001	0.2327	0.6589	0.8438	0.7121	638.02	1	258
	TKE	0.8497	0.0336	25.2590	0.0000	0.7835	0.9160					
LA	Constant	0.2897	0.1040	2.7864	0.0057	0.0850	0.4944	0.8688	0.7548	262.68	3	256
	TKE	0.3111	0.0614	5.0700	0.0000	0.1903	0.4319					
	WE	0.2384	0.0580	4.1086	0.0001	0.1241	0.3526					
	CC	0.3613	0.0637	5.6717	0.0000	0.2359	0.4868					

**Table 7: Direct and Indirect Effects.**

Effect Type	Effect	SE	LLCI	ULCI
Direct Effect (TKE → LA)	0.3111	0.0614	0.1903	0.4319
Total Indirect Effect (TKE → WE, CC → LA)	0.4999	0.0562	0.3890	0.6092
Indirect Effect via WE (TKE → WE → LA)	0.1929	0.0570	0.0814	0.3011
Indirect Effect via CC (TKE → CC → LA)	0.3070	0.0616	0.1821	0.4266

*Impact of Human-AI Collaborative Feedback (Feedback Quality and Timeliness) on EFL Writing Performance (Language Accuracy) Mediating by Writing Enjoyment and Cognitive Competencies*

The findings indicate that Feedback Quality and Timeliness (FQT) has a moderate to strong positive correlation with LA, with WE and CC mediating this relationship. In Table 8, FQT shows a strong association with WE (Coeff = 0.8027,  $p < 0.001$ ), accounting for 62.97% of the variance in WE, and an even stronger correlation with CC (Coeff = 0.8369,  $p < 0.001$ ), accounting for 67.98% of the variance in CC. Model analysis confirms a significant effect of both mediators on LA. The Weibull coefficient for WE (0.2598,  $p < 0.001$ ) indicates that WE positively influences LA, while the coefficient for CC (0.4062,  $p < 0.001$ ) provides evidence for a stronger effect of CC on LA. The direct effect of FQT on LA is also statistically significant (Coeff = 0.2441,  $p < 0.001$ ). Table 9 shows the total indirect effect of FQT on LA is significant (effect = 0.5485), with CC having a stronger mediating effect (effect = 0.3399) compared to WE (effect = 0.2085). In conclusion, both WE and CC partially mediate the relationship between FQT and LA, enhancing EFL writing performance.

**Table 8: Regression Results.**

Outcome Variable	Predictor	Coeff.	SE	t	p	LLCI	ULCI	R	R <sup>2</sup>	F	df1	df2
WE	Constant	0.5862	0.1239	4.7308	0.0000	0.3422	0.8302	0.7935	0.6297	438.77	1	258
	FQT	0.8027	0.0383	20.9469	0.0000	0.7272	0.8781					
CC	Constant	0.4663	0.1156	4.0317	0.0001	0.2385	0.6940	0.8245	0.6798	547.63	1	258
	FQT	0.8369	0.0358	23.4015	0.0000	0.7665	0.9074					
LA	Constant	0.2867	0.1066	2.6901	0.0076	0.0768	0.4966	0.8642	0.7469	251.81	3	256
	FQT	0.2441	0.0594	4.1118	0.0001	0.1272	0.3610					
	WE	0.2598	0.0587	4.4244	0.0000	0.1442	0.3755					
	CC	0.4062	0.0629	6.4553	0.0000	0.2823	0.5301					

**Table 9: Direct and Indirect Effects.**

Effect Type	Effect	SE	LLCI	ULCI
Direct Effect (FQT → LA)	0.2441	0.0594	0.1272	0.3610
Total Indirect Effect (FQT → WE, CC → LA)	0.5485	0.0646	0.4261	0.6796
Indirect Effect via WE (FQT → WE → LA)	0.2085	0.0616	0.0879	0.3284
Indirect Effect via CC (FQT → CC → LA)	0.3399	0.0569	0.2319	0.4559

*Impact of Human-AI Collaborative Feedback (Teaching Environment) on EFL Writing Performance (Language Complexity) Mediating by Writing Enjoyment and Cognitive Competencies*

The findings reveal that the Teaching Environment (TE) significantly influences LC, with WE and CC serving as mediators. In Table 10, TE strongly predicts both WE (Coeff = 0.8450,  $p < 0.001$ ) and CC (Coeff = 0.8393,  $p < 0.001$ ), accounting for 71.67% and 70.20% of the variance in WE and CC, respectively. Both WE (Coeff = 0.2667,  $p < 0.001$ ) and CC (Coeff = 0.2883,  $p < 0.001$ ) demonstrate significant positive relationships with LC. Additionally, the direct effect of TE on LC is substantial (Coeff = 0.3580,  $p < 0.001$ ). Table 11 shows the total indirect effect of TE on LC is also significant (effect = 0.4673). When comparing the size of the total indirect effects, the mediation by CC (effect = 0.2420) and WE (effect = 0.2253) is fairly balanced. These findings suggest that both WE and CC partially mediate the relationship between TE and LC, contributing to enhanced EFL writing complexity.

**Table 10: Regression Results.**

Outcome Variable	Predictor	Coeff.	SE	t	p	LLCI	ULCI	R	R <sup>2</sup>	F	df1	df2
WE	Constant	0.4320	0.1081	3.9969	0.0001	0.2192	0.6449	0.8466	0.7167	652.57	1	258
	TE	0.8450	0.0331	25.5455	0.0000	0.7799	0.9101					
CC	Constant	0.4333	0.1112	3.8950	0.0001	0.2142	0.6524	0.8379	0.7020	607.75	1	258
	TE	0.8393	0.0340	24.6527	0.0000	0.7722	0.9063					
LC	Constant	0.2720	0.1025	2.6543	0.0084	0.0702	0.4737	0.8732	0.7625	274.00	3	256
	TE	0.3580	0.0638	5.6116	0.0000	0.2324	0.4837					
	WE	0.2667	0.0617	4.3224	0.0000	0.1452	0.3882					
	CC	0.2883	0.0599	4.8102	0.0000	0.1703	0.4064					

**Table 11: Direct and Indirect Effects.**

Effect Type	Effect	SE	LLCI	ULCI
Direct Effect (TE → LC)	0.3580	0.0638	0.2324	0.4837
Total Indirect Effect (TE → WE, CC → LC)	0.4673	0.0641	0.3455	0.6001
Indirect Effect via WE (TE → WE → LC)	0.2253	0.0692	0.0929	0.3683
Indirect Effect via CC (TE → CC → LC)	0.2420	0.0639	0.1144	0.3670

*Impact of Human-AI Collaborative Feedback (Teacher Knowledge and Experience) on EFL Writing Performance (Language Complexity) Mediating by Writing Enjoyment and Cognitive Competencies*

The findings indicate that Teacher Knowledge and Experience (TKE) significantly influences LC, with WE and CC serving as mediators. The research hypotheses are validated, as in Table 12, TKE demonstrates a strong positive relationship with both WE (Coeff = 0.8092,  $p < 0.001$ ) and CC (Coeff = 0.8497,  $p < 0.001$ ), accounting for 65.04% of the variance in WE and 71.21% in CC. WE (Coeff = 0.3311,  $p < 0.001$ ) and CC (Coeff = 0.2671,  $p < 0.001$ ) both significantly influence LC. Table 13 shows the direct effect of TKE on LC is statistically substantial (Coeff = 0.3195,  $p < 0.001$ ). Furthermore, the total indirect effect of TKE on LC is meaningful (effect = 0.4949), with CC contributing slightly more (effect = 0.2679) than WE (effect = 0.2270). In conclusion, WE and CC partially mediate the relationship between TKE and LC, contributing to enhanced EFL writing complexity.

**Table 12: Regression Results.**

Outcome Variable	Predictor	Coeff.	SE	t	p	LLCI	ULCI	R	R <sup>2</sup>	F	df1	df2
WE	Constant	0.5839	0.1188	4.9145	0.0000	0.3500	0.8179	0.8064	0.6504	479.90	1	258
	TKE	0.8092	0.0369	21.9067	0.0000	0.7364	0.8819					
CC	Constant	0.4458	0.1082	4.1201	0.0001	0.2327	0.6589	0.8438	0.7121	638.02	1	258
	TKE	0.8497	0.0336	25.2590	0.0000	0.7835	0.9160					
LC	Constant	0.2759	0.1033	2.6716	0.0080	0.0725	0.4792	0.8713	0.7592	269.00	3	256
	TKE	0.3195	0.0609	5.2430	0.0000	0.1995	0.4395					
	WE	0.3311	0.0576	5.7460	0.0000	0.2176	0.4446					
	CC	0.2671	0.0633	4.2218	0.0000	0.1425	0.3917					

**Table 13: Direct and Indirect Effects.**

Effect Type	Effect	SE	LLCI	ULCI
Direct Effect (TKE → LC)	0.3195	0.0609	0.1995	0.4395
Total Indirect Effect (TKE → WE, CC → LC)	0.4949	0.0656	0.3723	0.6274
Indirect Effect via WE (TKE → WE → LC)	0.2679	0.0576	0.1559	0.3822
Indirect Effect via CC (TKE → CC → LC)	0.2270	0.0757	0.0804	0.3794

*Impact of Human-AI Collaborative Feedback (Feedback Quality and Timeliness) on EFL Writing Performance (Language Complexity) Mediating by Writing Enjoyment and Cognitive Competencies*

The findings indicate that Feedback Quality and Timeliness (FQT) significantly influence LC, with WE and CC as mediators. In Table 14, FQT exhibits a strong direct relationship with both WE (Coeff = 0.8027,  $p < 0.001$ ) and CC (Coeff = 0.8369,  $p < 0.001$ ), accounting for 62.97% and 67.98% of the variance in WE and CC, respectively. WE has a significant and positive impact on LC (Coeff = 0.3086,  $p < 0.001$ ), while CC also significantly affects LC, though with a slightly smaller effect (Coeff = 0.2468,  $p < 0.001$ ). FQT further demonstrates a substantial direct effect on LC (Coeff = 0.3774,  $p < 0.001$ ). Table 15 shows the total indirect effect of FQT on LC is statistically significant (effect = 0.4543), with WE contributing slightly more (effect = 0.2477) than CC (effect = 0.2066). Overall, WE and CC moderately mediate the relationship between FQT and LC, contributing to improvements in the complexity of EFL writing.

**Table 14: Regression Results.**

Outcome Variable	Predictor	Coeff.	SE	t	p	LLCI	ULCI	R	R <sup>2</sup>	F	df1	df2
WE	Constant	0.5862	0.1239	4.7308	0.0000	0.3422	0.8302	0.7935	0.6297	438.77	1	258
	FQT	0.8027	0.0383	20.9469	0.0000	0.7272	0.8781					
CC	Constant	0.4663	0.1156	4.0317	0.0001	0.2385	0.6940	0.8245	0.6798	547.63	1	258
	FQT	0.8369	0.0358	23.4015	0.0000	0.7665	0.9074					
LC	Constant	0.2224	0.1011	2.1991	0.0288	0.0232	0.4215	0.8793	0.7731	290.75	3	256
	FQT	0.3774	0.0563	6.6999	0.0000	0.2664	0.4883					
	WE	0.3086	0.0557	5.5391	0.0000	0.1989	0.4183					
	CC	0.2468	0.0597	4.1344	0.0000	0.1293	0.3644					

**Table 15: Direct and Indirect Effects.**

Effect Type	Effect	SE	LLCI	ULCI
Direct Effect (FQT → LC)	0.3774	0.0563	0.2664	0.4883
Total Indirect Effect (FQT → WE, CC → LC)	0.4543	0.0554	0.3454	0.5649
Indirect Effect via WE (FQT → WE → LC)	0.2477	0.0571	0.1346	0.3603
Indirect Effect via CC (FQT → CC → LC)	0.2066	0.0669	0.0772	0.3392

*Impact of Human-AI Collaborative Feedback (Teaching Environment) on EFL Writing Performance (Language Fluency) Mediating by Writing Enjoyment and Cognitive Competencies*

The study demonstrates that Teaching Environment (TE) positively impacts LF, mediated by WE and

CC. In Table 16, TE strongly correlates with WE (Coeff = 0.8450,  $p < 0.001$ ) and CC (Coeff = 0.8393,  $p < 0.001$ ), accounting for 71.67% and 70.20% of their variance, respectively. WE (Coeff = 0.2135,  $p < 0.001$ ) and CC (Coeff = 0.3197,  $p < 0.001$ ) significantly predict LF. The direct effect of TE on LF is also substantial (Coeff = 0.3585,  $p < 0.001$ ). Table 17 shows the total indirect effect (0.4487) is primarily mediated by CC (0.2683) rather than WE (0.1804), suggesting partial mediation by WE and CC in enhancing EFL writing fluency.

**Table 16: Regression Results.**

Outcome Variable	Predictor	Coeff.	SE	t	p	LLCI	ULCI	R	R <sup>2</sup>	F	df1	df2
WE	Constant	0.4320	0.1081	3.9969	0.0001	0.2192	0.6449	0.8466	0.7167	652.57	1	258
	TE	0.8450	0.0331	25.5455	0.0000	0.7799	0.9101					
CC	Constant	0.4333	0.1112	3.8950	0.0001	0.2142	0.6524	0.8379	0.7020	607.75	1	258
	TE	0.8393	0.0340	24.6527	0.0000	0.7722	0.9063					
LF	Constant	0.2884	0.1045	2.7595	0.0062	0.0826	0.4943	0.8641	0.7467	251.55	3	256
	TE	0.3585	0.0651	5.5081	0.0000	0.2303	0.4867					
	WE	0.2135	0.0629	3.3919	0.0008	0.0895	0.3374					
	CC	0.3197	0.0612	5.2278	0.0000	0.1993	0.4401					

**Table 17: Direct and Indirect Effects.**

Effect Type	Effect	SE	LLCI	ULCI
Direct Effect (TE → LF)	0.3585	0.0651	0.2303	0.4867
Total Indirect Effect (TE → WE, CC → LF)	0.4487	0.0689	0.3271	0.5933
Indirect Effect via WE (TE → WE → LF)	0.1804	0.0637	0.0636	0.3111
Indirect Effect via CC (TE → CC → LF)	0.2683	0.0613	0.1529	0.3951

*Impact of Human-AI Collaborative Feedback (Teacher Knowledge and Experience) on EFL Writing Performance (Language Fluency) Mediating by Writing Enjoyment and Cognitive Competencies*

The findings reveal that Teacher Knowledge and Experience (TKE) positively correlates with Language Fluency (LF), with WE and CC as mediators. In Table 18, TKE significantly predicts WE (Coeff = 0.8092,  $p < 0.001$ ) and CC (Coeff = 0.8497,  $p < 0.001$ ), accounting for 65.04% and 71.21% of their variance, respectively. WE (Coeff = 0.2620,  $p < 0.001$ ) and CC (Coeff = 0.2727,  $p < 0.001$ ) significantly influence LF. Table 19 shows the direct effect of TKE on LF is also substantial (Coeff = 0.3664,  $p < 0.001$ ). WE mediates 47.7% and CC mediates 52.3% of the total indirect impact on LF, indicating partial mediation by both factors in enhancing EFL writing fluency.

**Table 18: Regression Results.**

Outcome Variable	Predictor	Coeff.	SE	t	p	LLCI	ULCI	R	R <sup>2</sup>	F	df1	df2
WE	Constant	0.5839	0.1188	4.9145	0.0000	0.3500	0.8179	0.8064	0.6504	479.90	1	258
	TKE	0.8092	0.0369	21.9067	0.0000	0.7364	0.8819					
CC	Constant	0.4458	0.1082	4.1201	0.0001	0.2327	0.6589	0.8438	0.7121	638.02	1	258
	TKE	0.8497	0.0336	25.2590	0.0000	0.7835	0.9160					
LF	Constant	0.2783	0.1036	2.6862	0.0077	0.0743	0.4823	0.8669	0.7515	258.10	3	256
	TKE	0.3664	0.0611	5.9923	0.0000	0.2460	0.4868					
	WE	0.2620	0.0578	4.5318	0.0000	0.1481	0.3759					
	CC	0.2727	0.0635	4.2952	0.0000	0.1476	0.3977					

**Table 19: Direct and Indirect Effects.**

Effect Type	Effect	SE	LLCI	ULCI
Direct Effect (TKE → LF)	0.3664	0.0611	0.2460	0.4868
Total Indirect Effect (TKE → WE, CC → LF)	0.4437	0.0588	0.3259	0.5603
Indirect Effect via WE (TKE → WE → LF)	0.2120	0.0555	0.1055	0.3208
Indirect Effect via CC (TKE → CC → LF)	0.2317	0.0647	0.0961	0.3551

*Impact of Human-AI Collaborative Feedback (Feedback Quality and Timeliness) on EFL Writing Performance (Language Fluency) Mediating by Writing Enjoyment and Cognitive Competencies*

With WE and CC as mediating variables, the study reveals that Feedback Quality and Timeliness (FQT) positively impact Language Fluency (LF). In Table 20, FQT demonstrates a strong positive correlation with both WE (Coeff = 0.8027,  $p < 0.001$ ) and CC (Coeff = 0.8369,  $p < 0.001$ ), accounting for 62.97% and 67.98% of their variance, respectively. The hypothesised main effects show that WE (Coeff = 0.2671,  $p < 0.001$ ) and CC (Coeff = 0.2954,  $p < 0.001$ ) significantly influence LF. Consistent with other FQT findings, the direct relationship between FQT and LF is positive and statistically significant (Coeff = 0.3448,  $p < 0.001$ ). Table 21 shows the total indirect effect of FQT on LF is also significant (effect = 0.4617), with CC exerting a greater indirect influence (0.2473) than WE (0.2144). These findings suggest that WE and CC partially mediate the relationship between FQT and LF, contributing to enhanced EFL writing fluency.



**Table 20: Regression Results.**

Outcome Variable	Predictor	Coeff.	SE	t	p	LLCI	ULCI	R	R <sup>2</sup>	F	df1	df2
WE	Constant	0.5862	0.1239	4.7308	0.0000	0.3422	0.8302	0.7935	0.6297	438.77	1	258
	FQT	0.8027	0.0383	20.9469	0.0000	0.7272	0.8781					
CC	Constant	0.4663	0.1156	4.0317	0.0001	0.2385	0.6940	0.8245	0.6798	547.63	1	258
	FQT	0.8369	0.0358	23.4015	0.0000	0.7665	0.9074					
LF	Constant	0.2520	0.1047	2.4065	0.0168	0.0458	0.4581	0.8664	0.7507	256.98	3	256
	FQT	0.3448	0.0583	5.9122	0.0000	0.2299	0.4596					
	WE	0.2671	0.0577	4.6305	0.0000	0.1535	0.3807					
	CC	0.2954	0.0618	4.7799	0.0000	0.1737	0.4172					

**Table 21: Direct and Indirect Effects.**

Effect Type	Effect	SE	LLCI	ULCI
Direct Effect (FQT → LF)	0.3448	0.0583	0.2299	0.4596
Total Indirect Effect (FQT → WE, CC → LF)	0.4617	0.0610	0.3397	0.5772
Indirect Effect via WE (FQT → WE → LF)	0.2144	0.0551	0.1077	0.3265
Indirect Effect via CC (FQT → CC → LF)	0.2473	0.0621	0.1268	0.3678

### Thematic Analysis

This study employed thematic analysis to categorise and examine qualitative data from closed-ended questionnaires. The systematic process involved several steps to organise the search, analysis, and assessment of patterns to achieve clear and objective outcomes. The research began with a careful review and coding of participant responses concerning their perceptions of AI and human feedback. Initial readings highlighted key concepts and preliminary impressions, such as the effectiveness and limitations of AI compared to human feedback. Specific codes, like "AI is efficient but limited," were manually assigned and grouped into broader themes, such as 'Perception of AI Feedback' and 'Difference between AI and Human Feedback.' These themes were refined iteratively to ensure accurate data representation. Further validation included re-examining the responses to confirm that all significant aspects were captured. The final step involved deriving interpretive conclusions from these themes. Participants recognised AI's utility but emphasised the advantages of a hybrid feedback model, combining AI's efficiency with the nuanced understanding of human feedback. This thematic analysis illuminated the complex interplay between AI and human feedback in educational contexts. Table 22 shows the developed themes, based on the responses.

**Table 22: Themes.**

Question	Theme	Code 1
How do you feel about the role of AI in providing feedback on students' EFL writing assignments?	Perception of AI feedback	AI is efficient but limited. AI lacks personalization
In your experience, how does human feedback differ from AI-generated feedback in terms of usefulness and clarity?	Difference between AI and human feedback	AI is fast but generic Human feedback is deeper and clearer.
Do you think a combination of AI and human feedback can enhance the writing skills of EFL students? Why or why not?	Perceived benefits of combined feedback	Complements each other Enhances both technical and creative skills
What challenges do you perceive in implementing a human-AI combined feedback mechanism in the classroom?	Challenges in implementation	Difficulty interpreting AI feedback Balancing AI and Human Feedback

### Perception of AI Feedback

*Respondent 1: "I think AI can help with grammar and structure, but it lacks the human touch for nuanced feedback."*

*Respondent 3: "I see AI as a supportive tool, but it can't replace human insight in writing development."*

#### AI is Efficient but Limited

Interview findings reveal that participants recognise AI's role in enhancing efficiency by providing quick and precise feedback, particularly on grammar and structure. Respondent 1 (teacher) noted that AI effectively corrects simple errors such as grammatical mistakes. Similarly, Respondent 5 (student) acknowledged that AI helps highlight unnoticed errors. However, despite its speed and accuracy, AI feedback has limitations. It primarily addresses surface-level mistakes and inattentiveness. Respondent 3 highlighted this drawback, stating that "While it is very precise, AI tutoring is not great at developing language style and other aspects," thereby underscoring the tool's limited capacity to foster advanced language skills and accommodate subjective aspects of language development.

#### AI Lacks Personalization

Several participants pointed out that AI feedback tends to be impersonal when compared to human feedback. Respondent 1 (teacher) highlighted this by stating, "Well, AI cannot do that; it cannot actively pick

up on the different ways that students write." Similarly, Respondent 2, an intermediate student, shared experiences where they struggled to understand which AI suggestions to follow, noting that in some cases, the feedback was too vague or did not adequately address their needs. This impersonal and sometimes unclear nature of AI feedback could be a significant drawback for students, especially if the suggestions are not personalised or sufficiently detailed.

#### *Difference between AI and Human Feedback*

*Respondent 3: "Human feedback dives deeper into creative and logical aspects of writing."*

*Respondent 5: "My teacher's feedback is clearer and easier to understand."*

#### *AI is Fast but Generic*

The respondents again emphasised the timeliness of AI feedback but also noted its brevity and limited depth. For example, Respondent 4 (teacher) remarked that AI provides "immediate but sometimes superficial responses," a sentiment that reflects the view that AI lacks the nuance needed for in-depth writing improvement. While the speed of error identification is appreciated, some students, like Respondent 2, found the feedback sometimes problematic. This suggests that although AI offers efficient feedback, its quality can fall short in terms of providing learners with the detailed insights needed for substantial improvement.

#### *Human Feedback is Deeper and Clearer*

In contrast, participants perceived human feedback as offering a more comprehensive approach to writing. Respondent 2 highlighted that human feedback is "clearer" and easier to understand, while Respondent 3 noted that it addresses the creative and logical aspects of writing—areas where AI struggles. Teachers, such as Respondent 4, viewed human input as crucial for providing "tailored" advice. This suggests that human feedback offers a more balanced perspective, covering both technical aspects and areas like argument cohesion and presentation, making it an essential component of the feedback process.

#### *Perceived Benefits of Combined Feedback*

*Respondent 2: "Yes, combining them can help, especially with grammar and content improvement."*

*Respondent 5: "Yes, it can be useful, but I need more guidance from my teacher to understand the AI feedback."*

#### *Complements Each Other*

Several respondents expressed optimism about the potential of a combined human-AI feedback approach. Respondent 3 highlighted the value of such a system, noting that it incorporates feedback from both AI and humans, with each addressing different aspects of writing. While AI is effective at detecting mechanical issues, human input excels in content and conceptual analysis. Similarly, Respondent 1 suggested that a dual system could efficiently evaluate grammatical correctness (an AI strength) and semantic aspects (which require human input). This perspective emphasises that each type of feedback complements the other's limitations, offering a well-rounded system that could significantly enhance EFL writing performance.

#### *Enhances both Technical and Creative Skills*

The interviews suggest that combining different feedback approaches—targeting both technical and creative aspects of writing—can yield optimal results for students. Respondent 3 noted that AI is effective for enhancing accuracy, while human feedback plays a crucial role in fostering creativity. This integration proves particularly beneficial in language learning, as it addresses both linguistic expression and the syntactic/semantic aspects of language. Respondent 2 also recognised the value of this combined approach for content improvement, suggesting that this dual-feedback model could be instrumental in producing more comprehensive learning outcomes.

#### *Challenges in Implementation*

*Respondent 1: "The biggest challenge is balancing the two and ensuring students don't rely too much on AI."*

*Respondent 4: "The main challenge is ensuring students still critically engage with feedback, not just accept it."*

#### *Difficulty Interpreting AI Feedback*

Interpreting AI feedback emerged as a challenge for students, particularly for those with lower proficiency levels. Respondent 5, a beginner student, expressed feeling lost when receiving AI suggestions without further explanation. The same respondent also mentioned encountering confusing and sometimes contradictory feedback from AI. These difficulties highlight that while AI feedback can be effective, it may become too complex or unclear for learners with limited proficiency. This suggests the need for simpler, more comprehensible AI-generated responses or follow-up questions from tutors to ensure students fully understand the feedback provided.

#### *Balancing AI and Human Feedback*

All interviewees highlighted the tension between using AI and human feedback in the classroom.

Respondent 4 raised concerns about overreliance on AI, where students might favour AI responses over the more in-depth insights provided by human feedback. Similarly, Respondent 1 pointed out the challenge of “balancing the two” to ensure neither AI nor human feedback is undervalued. This balance is crucial because, while AI enhances efficiency, over-reliance on it may undermine the development of complex aspects of writing, such as style, coherence, and argumentation, which are best addressed through human feedback.

## Discussion

### *Impact of Feedback Quality and Timeliness on Language Fluency*

The regression analysis in the study indicates a significant positive relationship between FQT and LF in EFL writing performance. These findings align with the literature, which emphasises the importance of timely and high-quality feedback in language learning. Research suggests that feedback enhances learner self-regulation and enables students to make corrections that improve attentiveness, fluency, and delivery (Ferris, 2014; Hyland, 2019). The immediacy of feedback also plays a crucial role, as it helps students correct mistakes promptly, preventing the development of bad habits (Song & Song, 2023). By providing consistent, actionable, and timely feedback, both human and AI systems support learners in refining their verbal concepts into written form.

### *The Mediating Role of Writing Enjoyment*

The data also indicate that Writing Enjoyment partially mediates the relationship between FQT and LF. This finding aligns with earlier research, which suggests that engaging students enhances their acceptance of feedback, encourages rewrites, and boosts their proactivity. Students who enjoy writing are more likely to self-edit and monitor their writing fluency compared to those who dislike writing (Robertson, 2015). Positive Psychological theory further highlights that pleasure, and positive affect can increase engagement and improve learning outcomes (Edwards & Cooper, 2024). As students develop a liking for writing, they become more inclined to review their work and feedback, ultimately excelling. The combined feedback loop, incorporating both AI and human input, likely enhances enjoyment and encourages a smoother editing process. The prompt, clear instructions from AI reduce the cognitive burden of revising complex writing tasks, eliminating the need for mid-process review (Hutson & Plate, 2023).

### *The Mediating Role of Cognitive Competencies*

The analysis further emphasises that pre-scientific quantitative thinking (FQT) significantly influences LF, with CC, such as metacognition and self-regulation, mediating this relationship. This aligns with SCT, which focuses on the understanding and classification of learning processes as either valid or not (Wootton, 2024). Metacognitive abilities enable students to analyse feedback, identify recurring mistakes, and improve their self-regulation in the writing process (Zimmerman & Schunk, 2013). Both AI and human feedback contribute to these competencies, with AI offering structured and precise feedback through an iterative learning process. This empowers students to make focused revisions, ultimately enhancing their language proficiency. Such feedback forms are valued because they promote self-regulation and metacognition, facilitating broader learning and improving writing fluency, especially where integration of grammar, cohesion, and coherence is required (Guo et al., 2024).

## Conclusion

The primary research question of this study was to evaluate the effectiveness of integrating human feedback and AI in improving EFL students' written productivity, focusing on language accuracy, richness, and fluency. Additionally, the study explored the impact of various factors, such as the teaching environment, teachers' content knowledge, experience, and the type and timeliness of feedback, on writing achievement. The mediating roles of writing enjoyment and cognitive skills, such as self-regulation and metacognition, were also examined. The research employed a quantitative methodology, gathering data through structured self-completed questionnaires from EFL learners in tertiary institutions. Multiple regression and mediation analyses were used to test the hypothesised relationships among the study variables. The results revealed that feedback quality and frequency, coupled with teacher knowledge and experience, significantly enhance EFL writing performance. Moreover, both writing enjoyment and cognitive competencies were found to be key mediators in these relationships. Writing enjoyment motivated students to engage with and apply feedback positively, while cognitive competencies enabled them to reflect on and regulate their writing behaviour effectively. The study highlights the importance of using a human-AI collaborative feedback system to support EFL writers, suggesting that this hybrid approach is a potent tool for improving writing performance by addressing both cognitive and affective learning domains. These findings support the notion that a combined AI-human feedback system creates a student-friendly learning environment, enhancing EFL students' writing outcomes.

### Limitation and Future Direction

It is essential to acknowledge several limitations of the present study. Firstly, self-administered questionnaires may be prone to bias, as students might overestimate their writing progress. Additionally, the study did not encompass all tertiary-level EFL students, which may limit the validity of the findings, particularly concerning other groups of EFL learners across different educational levels or age groups. The generalisability of AI feedback tools examined in this study is another potential limitation, as the research focused on a specific range of AI-generated feedback, excluding other AI characteristics that may influence writing productivity and could have been evaluated. Future research should consider expanding the sample to include a broader range of students in terms of grade level and educational background. Additionally, employing quantitative methods, such as pre- and post-tests, would provide a more robust assessment of writing development. Further studies could also explore the impact of formative feedback generated by human–AI collaborations on EFL writing progress over extended periods, offering insights into the long-term effects of such systems on learners' writing abilities. Expanding the current study by incorporating a wider array of AI applications and integrating qualitative data collection methods, such as interviews or focus group discussions, could provide a more comprehensive understanding of students' experiences. These directions would contribute to the refinement of human–AI feedback systems, enhancing their applicability for diverse learners across various educational contexts.

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