Integrating adaptive learning and expectancy-value theory of motivation to enhance L2 learners' writing achievement, error tolerance, and feedback tolerance

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Abstract

This study examines the effects of integrating adaptive learning (AL) and expectancy-value theory of motivation (EVTM) interventions on second language (L2) learners' writing skills, error tolerance (ET), and feedback tolerance (FT). By investigating integration of EVTM instruction within AL environments, the study addresses the need to harness the transformative potential of adaptivity and EVTM in language learning, contributing to effective pedagogical approaches that promote students' writing proficiency and resilience. A total of 120 intermediate-level English proficiency students were randomly assigned to two experimental groups (AL-application use and AL-application use enriched with EVTM instruction) and one control group (technology-enhanced non-AL application use). The study employed writing tasks, ET, FT, EVTM questionnaires, and semi-structured interviews as data collection instruments. Findings indicate that the AL application significantly improves participants' writing outcomes, ET, and FT. Moreover, integration of EVTM interventions within AL environments enhances not only writing skills, ET, and FT but also EVTM. Furthermore, qualitative results suggest a positive impact of AL and EVTM interventions on students' learning processes. Results highlighted that integration of AL and EVTM instruction enhances students' motivation, beliefs, and metacognitive awareness, provides personalized instruction and immediate feedback, and creates a comprehensive and supportive learning environment.

Keywords: Adaptive Learning; Expectancy-Value Theory of Motivation; Error Tolerance; Feedback Tolerance, Technology-Enhanced Learning

Introduction

The increasing integration of digital technologies into writing instruction has fundamentally transformed the landscape of L2 writing development (Jansen et al., 2024).

These developments encompass various areas, including digital multimodal composing (Jiang et al., 2022), the utilization of automatic writing evaluation tools (e.g., Nunes et al., 2022), and corpus-based investigations on writing (e.g., Chen et al., 2015), among others. A new type of technology, AL, is a novel approach in artificial intelligence (AI)-based education that holds significant importance for teaching and learning (Alam, 2022). It involves the utilization of intelligent algorithms and personalized instruction to dynamically tailor the learning experience to the individual needs and capabilities of each learner (Aleven et al., 2016). By continuously analyzing learner performance and adapting instructional content and feedback accordingly, digital AL systems aim to optimize the effectiveness and efficiency of skill development (Zhou et al., 2023).

However, there are some challenges related to student motivation in the context of digital AL that should be addressed to optimize the learning experience. These challenges include the potential decline in motivation due to the reliance on external tools and the risk of disengagement if learners perceive the adaptive system as excessively controlling or lacking available choices (Wan & Yu, 2023). Overcoming these obstacles is crucial to ensuring that digital AL effectively promotes and sustains students' motivation. One potential solution to address these challenges is the implementation of an EVTM intervention. By integrating this theoretical framework into digital AL environments, educators can foster learners' motivation by emphasizing the belief in their ability to succeed (expectancy, Sun et al., 2023) and highlighting the value and relevance of the learning content (value, Tang et al., 2023). This intervention can help reestablish motivation, promote engagement, and enhance the overall learning experience for students in AL settings.

Integrating EVTM instruction in digital environments can enhance students' achievement, ET, and FT, which are the key components of effective writing (Verkuyten et al., 2023; Aben et al., 2023). These traits encourage learners to view errors as opportunities and accept constructive feedback, fostering resilience, adaptability, and improved communication skills (Metcalfe, 2017; King, 2010). While research on L2 writing has explored AL and EVTM independently, little is known about their combined effects. This study addresses this gap by examining how integrating AL with EVTM-based instruction can enhance writing achievement, resilience, and engagement among intermediate EFL learners. These students often struggle with limited vocabulary, inconsistent grammar, and resistance to errors. AI's ability to personalize feedback and foster a growth mindset can help learners overcome these challenges by reinforcing self-belief and promoting continuous improvement. By bridging theoretical and empirical divides, this research highlights the potential of combining AL and motivational frameworks to support essential writing skills and enhance the learning process in personalized language education.

Reviewing literature

Adaptive learning and writing

AL is an instructional method that uses computer algorithms and AI to personalize education based on individual learner needs (Wang & Walberg, 1983; Jing et al., 2023). It aims to offer targeted instruction that enhances engagement and learning outcomes (Liu et al., 2022). Effective AL systems use adaptivity factors such as performance, knowledge, misconceptions, and demographics to customize learning paths (Kaur et al., 2023). AL is grounded in educational theories such as constructivism (Piaget, 1972), the Zone of Proximal Development (ZPD, Vygotsky, 1978), differentiated instruction, and Self-Determination Theory (Ryan & Deci, 2000), all of which emphasize individualized support, autonomy, and intrinsic motivation. In writing instruction, AL tools adjust content, feedback, and pacing to match students' abilities, facilitating scaffolded, constructivist learning within each learner's ZPD (Skains, 2017; Wang & Walberg, 1983). These systems promote engagement through differentiated tasks and support motivation by fostering autonomy and relatedness (Ryan & Deci, 2000). Empirical studies confirm that adaptive technologies improve writing by offering responsive feedback and personalized challenges (Liu et al., 2022; Kaur et al., 2023). Adaptive platforms also facilitate knowledge internalization by combining contextual materials, interactive activities, and model texts (Allen et al., 2016). They support deliberate practice and nurture motivation, especially when tasks align with students' personal goals (Liu et al., 2022). By adjusting to learners' evolving motivations, AL tools sustain engagement. Still, challenges exist, especially in K–12 education, where learning analytics are less widely adopted. Demartini et al. (2024) suggest AI-based dashboards to address dropout and academic performance, but overlook the importance of motivation and feedback resilience.

  Several studies have shown the effectiveness of AL in improving writing outcomes. For example, Yang et al. (2014) demonstrate how tailored environments enhance engagement and performance, while Shafiee Rad et al. (2024a) highlight the role of data segmentation in refining AI-driven writing support. Adaptive tools can thus support pedagogy, writing research, and professional development (Gorzelsky et al., 2017). When integrated effectively, they improve cognitive and metacognitive writing skills by encouraging self-regulation, using feedback, and fostering creativity (Shafiee Rad et al., 2024a, 2024b). More recent empirical work supports these claims. For example, Ipinnaiye and Rísquez (2024) found that use of the LearnSmart AL tool in a Macroeconomics course improved performance with reasonable time investment, although limitations included self-reported data and a single-course focus. Similarly, Contrino et al. (2024) found that CogBooks® boosted achievement in FIT statistics courses, with higher gains in face-to-face formats. While promising, both studies lacked exploration of motivation, prior knowledge, and

broader applicability. It was recommended that future researchers should refine integration strategies, examine long-term impacts, and explore how incorporating the various motivational interventions into AL can further enhance writing proficiency and student outcomes (e.g., Shafiee Rad et al., 2024b).

Expectancy-value theory of motivation

The EVTM explores how individuals' beliefs about success and the value of a task influence their academic persistence and achievement (Eccles, 1983; Eccles & Wigfield, 2020). Key components of EVTM include expectancy for success, or an individual's belief in their ability to succeed, and task values, which reflect the personal importance and interest in a task (Rosenzweig et al., 2019; Wigfield & Eccles, 2024). Task values are categorized into four types: intrinsic value (enjoyment), utility value (relevance to goals), attainment value (self-image), and cost (effort and emotional toll) (Loh, 2019; Wang & Xue, 2022). While EVTM has been applied to academic settings, its use in language teaching and learning remains limited. Wang and Xue (2022) highlight its impact on academic motivation and performance, emphasizing the importance of expectancy and task values. Nagle (2021) applied EVTM to explore how motivation influences language learning in a Spanish course, offering strategies to support student engagement. Zhan et al. (2021) found that self-efficacy and motivational factors significantly affect language learning strategies in EFL settings. However, Loh (2019) noted a lack of empirical research on EVTM's application in language teaching, calling for its integration into L2 instruction to improve student outcomes.

  Several studies have examined the effectiveness of the EVTM in EFL learning and teaching. For example, Tsang et al. (2024) examined EFL listening motivation in Hong Kong, showing that both school-based and informal spoken English exposure positively predicted expectancy, with informal exposure being the strongest predictor and the only factor linked to interest. However, the study's single-context focus, cross-sectional design, and possible self-selection bias limit generalizability. Martinez et al. (2024) explored adult learners' utility value for writing skills, revealing high perceived usefulness across grammar, spelling, and writing processes, influenced by age, education, and reading level. Yet, its small sample and lack of technological context constrain broader applicability. Similarly, Chen (2024) found that expectancy and task values predicted spoken English proficiency among Chinese undergraduates, but reliance on self-reports and context-specific data limits causal claims. Integrating the EVTM into AL can enhance learner engagement and outcomes by aligning tasks with students' beliefs about success and value (Eccles & Wigfield, 2002; Tapola et al., 2013). Adaptive systems that adjust content and difficulty based on learners' evolving expectancies and values maintain optimal challenge (Kaplan & Maehr, 2007) and, with timely feedback, strengthen ability beliefs and task

relevance (Weiner, 1985). By fostering interest-driven, goal-aligned learning, they can support self-directed, transformative engagement (Ryan & Deci, 2000). Despite limited research on EVTM in technology-enhanced environments (Kaplan & Maehr, 2007; Tapola et al., 2013), this study addresses the gap by investigating its effects on L2 writing achievement, ET, and FT.

Integration of expectancy value theory of motivation and adaptive learning

The integration of EVTM, rooted in Eccles et al.'s (1983) foundational work and further developed by Barron and Hulleman (2015), with AL systems, offers a powerful approach to enhancing student motivation and achievement. Since motivation is a key driver of learning outcomes and AL platforms excel at personalizing instruction based on individual needs, combining EVTM's psychological insights with adaptive technology can more effectively address students' unique motivational profiles, thereby maximizing engagement and success. EVTM explains motivation as the result of the interplay between three factors: expectation of success, subjective task value, and perceived costs. Expectation of success involves individuals' confidence in their ability to succeed (Loh, 2019), while subjective task value includes intrinsic interest, utility relevance, and attainment aligned with personal goals. Perceived costs refer to the potential effort, time, and risk associated with engaging in a task (Hoi, 2022). Educational interventions grounded in EVTM have demonstrated success in boosting motivation and performance (Rosenzweig et al., 2022). These programs focus on increasing students' success expectations through goal-setting and growth mindset strategies, addressing perceived costs via time management and resilience, and enhancing task value by connecting activities to students' personal and academic goals. Reflective exercises and peer collaboration further reinforce motivation, with ongoing assessment guiding continued progress.

AL platforms, leveraging AI and data analytics, can personalize instruction by assessing learners' motivational profiles in real time. Integrating EVTM within these systems enables tailored feedback, customized challenges, and adaptive pacing to strengthen confidence and reduce perceived barriers. Additionally, content can be aligned with students' interests and goals to emphasize utility and attainment values. For example, learners facing high effort costs may receive gamified modules or stepwise support to sustain engagement. This integration combines EVTM's psychological insights with AL's technological capabilities, creating personalized and motivating learning environments. Digitizing EVTM-based interventions within adaptive platforms can increase engagement, enhance achievement by boosting expectations and minimizing costs, and foster meaningful, goal-directed learning. Future research should explore the effectiveness of such digital implementations, the

potential of real-time data to optimize motivational strategies, and the long-term impacts across diverse educational settings (see Figure 1 for conceptualizing this model). Overall, the integration of EVTM and AL represents a transformative educational approach that empowers students to maximize their potential through personalized motivation and support. The integration of EVTM with AL represents a transformative approach to education. By combining the motivational insights of EVTM with the technological capabilities of adaptive systems, educators can create personalized, engaging, and effective learning environments. This synthesis not only addresses individual differences in motivation but also empowers students to achieve their full potential.

Fig. 1

Conceptual interaction between al and expectancy-value theory of motivation (EVTM) for enhancing engagement and task value
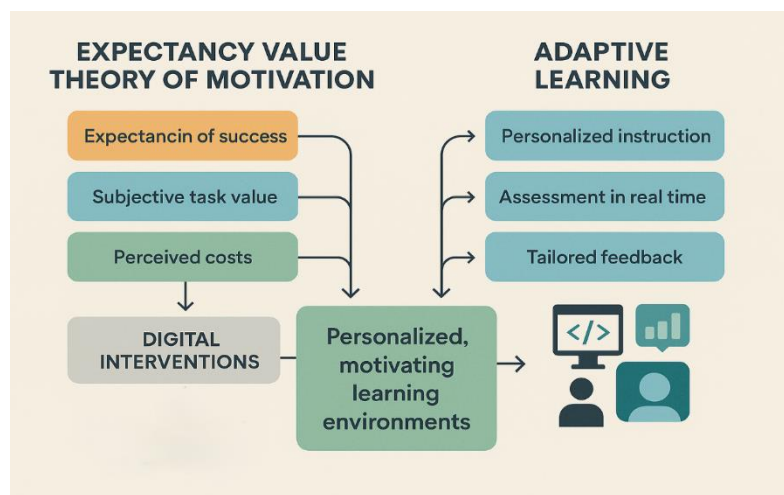
Error tolerance and feedback tolerance

Errors are often viewed as deviations from norms, but defining "norms" is complicated by their subjective and contextual nature (Gloy, 1987; Rach et al., 2012; Aben et al., 2022). Performance may be perceived as erroneous based on personal standards, yet not when judged against external benchmarks (Narciss, 2013). This subjectivity has led to interest in ET, that is, the ability to cope with perceived mistakes in learning (Metcalfe, 2017; Rach et al., 2012). In writing, ET is influenced by trust in feedback providers and how students process their mistakes (Panadero, 2016; Van Gennip et al., 2009, 2010). It includes emotional (affective reactions), cognitive (viewing errors as learning opportunities), and meta-cognitive (reflective and preventive) components (Aben et al., 2022; Rybowiak et al., 1999; Metcalfe, 2017). AL and the EVTM can jointly enhance ET. AL creates low-stakes

environments that encourage risk-taking and mistake-making, while EVTM fosters learners' belief in their ability to succeed and the value of tasks. Together, they support a growth mindset where errors are reframed as productive failures that aid learning. AL systems that personalize ET can better align with learners' expectations, values, and goals, thus promoting deeper learning. Despite this potential, more research is needed on their combined impact on L2 writing proficiency.

Similarly, FT, which is the ability to accept and use feedback constructively, is essential for learning (Smith & King, 2004). Learners with high FT effectively process and act on feedback, while those with low tolerance may react negatively and disengage (King et al., 2009). Like ET, it includes emotional (response to feedback), cognitive (seeing its value), and meta-cognitive (reflection and self-regulation) aspects (Alqassab et al., 2018; Gan & Hattie, 2014; Hattie & Timperley, 2007). Integrating AL and EVTM can also enhance FT. Adaptive systems provide personalized, timely feedback in supportive environments, helping learners view it as developmental rather than judgmental. EVTM's focus on expectancy and value helps sustain motivation when learners believe they can succeed and find meaning in feedback. This integration encourages learners to engage more deeply, restructure misconceptions, and regulate their learning processes. Still, empirical research remains limited. Aben et al. (2022), for instance, found that error and FT significantly shaped students' acceptance of peer feedback and called for further studies on their roles in writing development across contexts.

This study

This study addresses a gap in the literature by examining the effects of EVTM-based instruction on L2 learners' writing achievement, ET, and FT within an AL environment. By exploring these variables, the research aims to generate insights that can inform the design of interventions that empower learners, boost academic performance, and enhance resilience by helping students learn from their mistakes through motivational support. Understanding error and FT also offers practical implications for optimizing adaptive systems, refining feedback delivery, and tailoring instruction to individual needs. Additionally, the study seeks to support the development of effective instructional strategies, strengthen learners' positive beliefs, promote metacognitive skills, bridge research-practice gaps, and deepen theoretical understanding of motivation in L2 writing. The following research questions were formulated:

1. Does AL-enhanced application use result in greater improvement in students' writing achievement, ET, and FT compared to a non-AL-enhanced application use?

2. Does an EVTM instruction in AL-enhanced application use lead to greater improvement in students' writing achievement, ET, and FT compared to a non-AL-enhanced application use?

3. How do students assess the proposed models' efficacy as teaching and learning tools?

Method

Participants

A total of 120 participants, all native Persian speakers aged 19–24, were selected from English Language Institutes based on their intermediate English proficiency. To ensure a homogeneous sample, participants were randomly assigned to three groups, including two experimental (AL-enhanced instruction and EVTM-integrated AL instruction) and one control, using a computerized random number generator. Each participant was assigned a unique ID, and these were randomly distributed across groups in a 2:2:1 ratio. This procedure ensured random assignment, with each participant having an equal chance of inclusion in any group. Group equivalence was verified through demographic comparisons (age, gender, education), with no significant differences observed. A one-way ANOVA for age ($F_{(2,117)} = 0.78$, $p = 0.462$) and a chi-square test for proficiency level ($\chi^2 (4) = 3.21$, $p = 0.523$) confirmed the groups' comparability. The inclusion criteria, intermediate proficiency and the 19–24 age range, were chosen to target learners at a cognitively mature stage, capable of engaging with AI-enhanced instruction and complex feedback processes. This age group also aligns with the core assumptions of EVTM, as learners typically have defined academic goals and motivations. English proficiency was assessed using the Oxford Placement Test (OPT), known for its reliability and comprehensive evaluation of language skills. The test demonstrated high internal consistency (Cronbach's $\alpha = 0.94$). The study was conducted in full accordance with established ethical research standards. Informed consent was obtained from all participants prior to their involvement in the study. Additionally, permission was secured from the heads of the participating language institutes and the classroom teacher. Participants were assured of the confidentiality and anonymity of their responses and were informed of their right to withdraw from the study at any point without any consequences.

Materials

This study employed instructional materials drawn from the book *Collins English for Life: Writing B1 Intermediate,* authored by Campbell-Howes (2013). The intervention spanned a duration of 8 weeks in all three groups, and a summary of the specific details can be found in Figure 2.

Fig. 2

Summary of writing instruction details in the study

Week	Topic
1	Writing Socially
	• Emails to friends
	• Texting
2	Writing Socially
	• Instant massaging
	• Thank you letters
3	Writing to Exchange Information
	• Writing notes
	• Making polite enquiries
4	Writing to Exchange Information
	• Giving instruction
	• Writing a summary
5	Writing Formally
	• Writing an article or essay
	• Writing formal notes and notices
6	Writing Formally
	• A letter or email of complaint
	• Applying for a job: Your cv
7	Writing Online for a Reading Public
	• Travel blogging
	• Tweeting
8	Writing Online for a Reading Public
	• Reviewing online
	• Selling and advertising online

Instruments

Each essay or scale was assigned two ratings. The first rating was provided by an initial evaluator based on a set of predefined criteria, which included factors such as clarity, coherence, and argumentation. The second rating was given by a secondary evaluator, who applied the same set of criteria to ensure consistency and reliability in the assessment process. The final scores were determined by calculating the average of these two ratings, ensuring that both evaluators' perspectives were considered in the final evaluation. This approach allowed for a more balanced and accurate representation of the essays' overall quality.

Writing tasks

Students were instructed to produce a 300–350-word essay on a standardized topic in both pre- and post-test phases. To ensure comparability in terms of topic familiarity, both pre-test and post-test essay prompts were sourced from the "Criterion Topic Library". Students were selected based on their proficiency level, prior writing experience, educational interests, and cultural characteristics of the writing course instructor. Students were given 60 minutes to write their essays using Microsoft Word. The course instructor used text-matching software, Turnitin, to verify the essays' authenticity. Before the writing task, the topics on which the students wrote their essays were not disclosed. The written essays were assessed using Hyland's (2003) analytical scoring rubric. The rubric consisted of four dimensions: format and substance (40 marks), organization and coherence (20 marks), sentence structure (40 marks), and vocabulary (40 marks). Scores were assigned on a scale from 0 to 100. To align with a 0-100 scale, the marks for each dimension of the rubric were proportionally adjusted based on their relative importance. Specifically, the dimensions of sentence structure and vocabulary were considered equally significant in contributing to the overall quality of the writing, and their respective marks were reduced to 28 out of 100, preserving the original balance. In contrast, format and substance, which initially accounted for a larger portion of the total (40 marks), was scaled down to 28 points, while organization and coherence, which had a lower original weight (20 marks), was reduced to 14 points. This proportional adjustment ensures that the emphasis placed on each dimension remains consistent with the original rubric, while simplifying the scoring system to a standardized 0-100 scale for easier interpretation and comparison across tasks or groups. In order to establish the reliability and consistency of the scoring process, both interrater and intrarater reliability indices were computed for the essays administered in the pretest and posttest. Inter-rater reliability (Cohen's Kappa (κ): .91, .91, .94) reflects the agreement between raters, while intra-rater reliability indices (Cohen's Kappa (κ): .91, .95, .97) indicate the stability of individual raters' evaluations across multiple assessments. The six indices correspond to the pretest and posttest of three groups (two experimental and one control), emphasizing consistency in their writing task. All values were notably high, suggesting robust reliability in the rating process.

Error tolerance scale

This study employed Rybowiak et al.'s (1999) adapted version of the error orientation questionnaire, which consisted of eight components encompassing emotional, cognitive, and meta-cognitive aspects of ET (see Appendix A). The questionnaire was adapted to the specific context of the writing domain and the targeted age group. Emotional ET was assessed through six items. Cognitive ET was evaluated using four items. Meta-cognitive

ET was measured with five items. All items about ET were rated on a 5-point Likert scale, ranging from 1 (*completely disagree*) to 5 (*completely agree*). It is translated into learners' mother tongue language, and the results of Cronbach's alpha were notably high, with values of α = .88, .93, .91, .93, .96, and .94 for its reliability.

Feedback tolerance

We used an adapted version of King et al.'s (2009) feedback orientation scale, with four components (see Appendix B). The emotional aspect was based on 'sensitivity', while the cognitive and meta-cognitive aspects were from the 'utility' component. We adjusted and translated the items to fit our study's focus on a specific age group in the writing domain. Emotional FT was assessed using eight items. Cognitive FT was measured with four items. Meta-cognitive FT was evaluated through three items. Participants rated all FT items on a 5-point Likert scale, ranging from 1 (*completely disagree*) to 5 (*completely agree*). The results indicated high-reliability Cronbach's alpha, with values of α = .89, .91, .87, .90, .91, and .92. The researchers conducted a pilot study to investigate potential disparities in individuals' receptiveness to feedback from interpersonal sources versus AI-generated feedback. Building upon the insights gained, the researchers adapted the FT scale to incorporate additional items that captured participants' perceptions of the AI-generated feedback's credibility, trustworthiness, and helpfulness.

Expectancy value theory of motivation scale

The adapted version of the motivation survey developed by Nagle (2021) was employed to examine the L2 learners' EVTM (see Appendix C). The survey encompassed seven components, namely expectations of success, attainment value, intrinsic value, utility value, effort cost, learning experience, and willingness to communicate. The motivation survey consisted of a total of 24 items, and participants were required to rate their responses on a 5-point Likert scale, ranging from 1 (*Strongly Disagree*) to 5 (*Strongly Agree*). To ensure comprehension and accuracy, the survey was translated into the participants' native language. The results indicated high-reliability Cronbach's alpha, with values of α = .84, .89, .85, .91,.92, and .93.

Semi-structured interview

The semi-structured interviews were conducted with volunteer participants from both experimental groups to collect in-depth qualitative data. A total of 18 participants (i.e., nine participants from Experimental 1 and nine participants from Experimental 2) were sampled, ensuring a representative mix from both groups. Participants were informed that their involvement was voluntary and that they could withdraw at any time without consequence. To incentivize participation and acknowledge their time and effort, gift cards were

provided for them. The interviews lasted approximately 30 minutes, providing sufficient time for participants to share their perspectives thoroughly while maintaining focus on the key themes. Each interview session was audio-recorded with participants' consent to ensure accurate data capture. Recordings were then transcribed verbatim by the researcher, and the transcripts were carefully reviewed for accuracy. These transcripts were subsequently analyzed using thematic coding to identify key patterns, themes, and insights related to the research topic. The semi-structured format allowed for flexibility, enabling the interviewer to probe deeper into responses while ensuring consistency in addressing the core research questions (see Appendix D for more details).

Procedure

This study was conducted in multiple stages. Initially, participants were randomly selected based on their proficiency level. Subsequently, they were divided into two experimental groups and one control group. Following this, a pretest was administered, which included writing skills tasks, the ET scale, and the FT scale. After confirming the normality of the tests, a writing skills intervention was conducted for a duration of 8 weeks across all three groups. To ensure consistency and minimize potential confounding factors, the same teacher was selected to instruct all three groups to enhance the internal validity of the study. However, in addition to the writing skill instruction, the first experimental group (AL-enhanced application infusion classroom) utilized an AL application to facilitate their assessment and progress monitoring. The second experimental group (EVTM instruction infusion in AL-enhanced application infusion classroom) received the AL application, along with an additional session in the week dedicated to EVTM intervention. Conversely, the control group employed a non-AL application to enhance their writing skills. Following the intervention, a posttest consisting of a writing task, the ET scale, and the FT scale was administered. To confirm the quantitative results, volunteer participants from both experimental groups underwent a semistructured interview. This interview aimed to provide additional qualitative insights and perspectives regarding the outcomes of the intervention (see Figure 3 for more details). This study was conducted in a classroom context, where an English language course focused on improving intermediate-level writing skills. The intervention lasted for eight weeks, utilizing instructional materials designed to enhance students' practical writing abilities. The learning objectives centered on developing effective writing for real-life contexts, improving grammatical accuracy, and building confidence in written communication. After each face-to-face instructional session, students were required to complete an assignment utilizing the designated software. To ensure that learners utilized the applications to enhance their assignments, the teacher required them to record themselves and submit the recordings for review. Additionally, the

teacher requested students to provide feedback on their experiences with the applications for each assignment, as well as their reactions to using these tools.

In the present study, we utilized Quill as an AL-based application and Poe as a non-AL-based application. Quill is an AL platform that tailors content to the individual needs of each learner, adjusting the difficulty level and providing personalized exercises based on student performance. The platform offers real-time feedback that is specific to the learner's progress, helping students understand and correct mistakes. It continuously tracks performance and uses data to make real-time adjustments, ensuring that each learner receives the most appropriate challenges and support. Additionally, Quill provides targeted interventions to address areas where students may be struggling, guiding them through their learning journey with a focus on improvement. The platform also incorporates gamification elements such as points and progress tracking to keep students engaged and motivated. Quill's flexible pacing allows learners to move through content at their speed, ensuring a personalized experience, while educators benefit from detailed analytics that provide insights into student progress and help inform instructional decisions.

In contrast, Poe operates as a non-AL platform, offering a uniform experience for all users. It delivers the same content to every student at the same pace, regardless of their skill levels or performance. Feedback in Poe is typically generic and not personalized, meaning that students may not receive the tailored guidance they need to understand their mistakes or improve. The platform does not adjust to student progress, resulting in a static learning experience where difficulty levels are not altered to suit individual needs. Poe also lacks features like gamification to enhance motivation, and its pacing is inflexible, which may hinder learners who need more time or those who wish to progress faster. Additionally, Poe offers limited insights for educators, providing only basic analytics without the ability to track individual performance in a meaningful way, which reduces the potential for targeted interventions.

Fig. 3

Procedure in the study
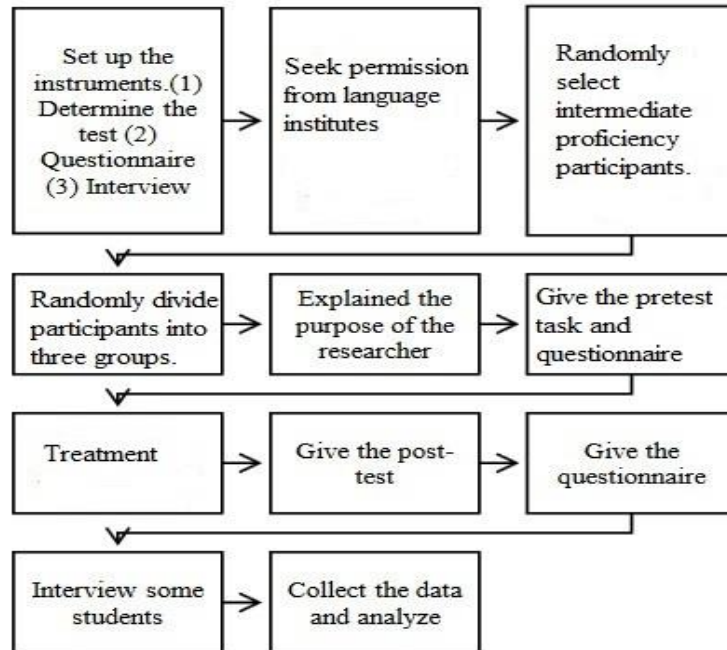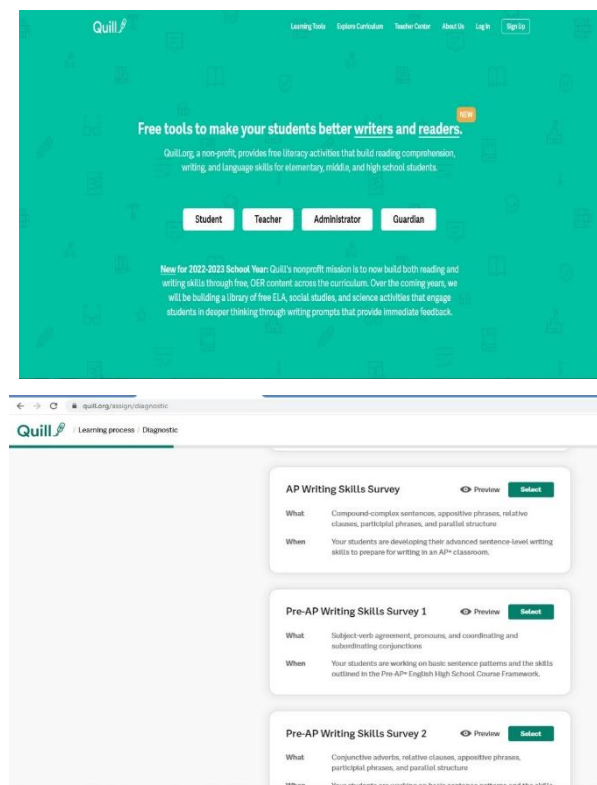

AL-enhanced application infusion (experiment 1)

Participants in the first experimental group received an AL application, Quill platform (https://www.quill.org), as a means to enhance their writing skills and facilitate the completion of homework assignments (see Figure 4). Before the intervention, the teacher assumed the responsibility of describing and explaining the various characteristics of the Quill application to the participants. This included providing detailed instructions on how to effectively utilize the features of the application, such as interactive writing activities, grammar and style suggestions, personalized feedback, and the plagiarism detection feature. The teacher aimed to ensure that participants were well-informed and equipped with the necessary knowledge to navigate and utilize Quill proficiently. Additionally, during the treatment, the teacher effectively utilized Quill's teacher panel features to facilitate and assess students' homework assignments. She created tailored writing tasks, tracked students' progress, and accessed detailed reports to monitor engagement. Additionally, the teacher provided personalized feedback and assessed the quality of students' submissions, while utilizing Quill's plagiarism detection feature to ensure academic integrity.

During the treatment phase, students actively utilized a range of features offered by the Quill platform to enhance their effectiveness in completing homework assignments. Central to their engagement was the utilization of interactive writing activities, which specifically aimed to address key aspects of grammar, sentence structure, and vocabulary.

Through these activities, students practiced and reinforced their understanding of grammar rules, such as verb tenses and subject-verb agreement, resulting in improved accuracy and fluency in their writing. The activities also focused on sentence structure, guiding students to experiment with different sentence types, sentence combining techniques, and sentence expansion for improved clarity and coherence. Additionally, the interactive activities targeted vocabulary development, exposing students to new words and idiomatic expressions, enabling them to enrich their writing with a wider range of vocabulary. Quill's real-time grammar and style suggestions provided timely support by identifying errors and offering suggestions, ensuring accurate and coherent written work. Furthermore, the personalized feedback feature of Quill offered individualized comments and recommendations, allowing students to gain insights into their writing strengths and areas for improvement, leading to the refinement of their writing skills and the production of higher-quality homework submissions.

Fig. 4

Screenshots from the Quill application environment

EVTM instruction infusion in AL-enhanced application infusion classroom (experiment 2)

The second experimental group, like the first, also used the AL application Quill (https://www.quill.org). The identical procedure to that of the AL-enhanced application infusion in Experiment 1 was replicated for the second experimental group. This entailed following the same steps, protocols, and instructional methods when implementing the intervention. The purpose of employing the same procedure was to ensure consistency and comparability between the two experimental groups, allowing for a more accurate evaluation and comparison of the outcomes.

Fig. 5

The EVTM of achievement (adapted from Eccles et al., 1983; Barron & Hulleman, 2015)
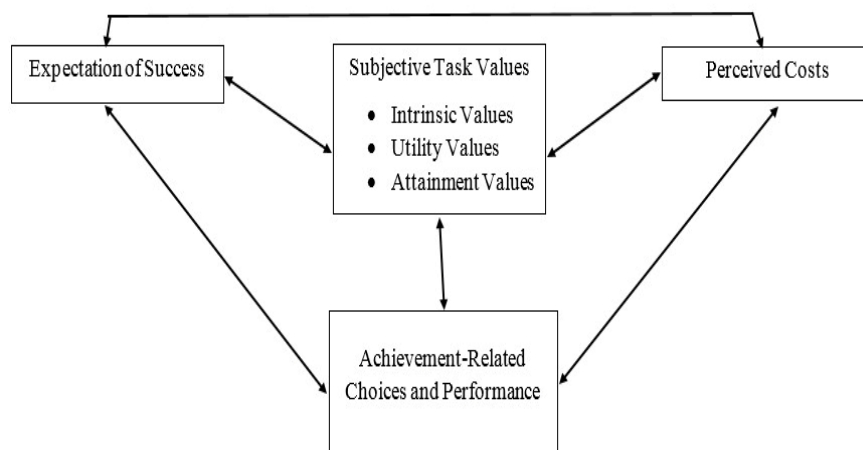
The only distinction between the first and second experimental groups lay in the attendance of the participants in the second experimental group at the EVTM intervention, which took place once per week during the intervention period. The EVTM instruction was delivered exclusively in a face-to-face classroom setting, while the Quill application was utilized for learning and completing assignments related to writing skill. This additional intervention session was exclusive to the second experimental group and was not included in the treatment plan for the first experimental or control groups. The framework utilized for the EVTM instruction was adapted from Eccles et al.'s (1983) and Barron and Hulleman's (2015) EVTM of achievement (see Figures 5 & 6 for more details).

Fig. 6

Intervention details during the 8 weeks

Week	Discussion Topic
1	• Introduce the Expectancy-Value-Cost Model of Achievement Motivation to students.
	• Discuss the correlation between Expectation of Success, Perceived Costs, and Subjective Task Values.
	• Help students understand the concept of Intrinsic Values and its impact on achievement-related choices and performance.
2	• Engage students in activities that promote a positive expectation of success.
	• Provide examples and case studies showcasing successful individuals who have overcome challenges.
	• Encourage students to set realistic goals and develop a growth mindset.
3	• Explore Perceived Costs and its influence on achievement-related choices.
	• Discuss different types of costs, such as time, effort, and social pressures.
	• Guide students in identifying strategies to manage and reduce perceived costs.
4	• Focus on subjective task values, particularly Utility Values.
	• Help students recognize the practical benefits and relevance of the tasks they are engaged in.
	• Highlight the importance of finding personal meaning and value in their academic pursuits.
5	• Shift the emphasis to Attainment Values.
	• Encourage students to connect their academic achievements with their personal aspirations and long-term goals.
	• Foster a sense of pride and fulfillment in their accomplishments.
6	• Review the interplay between Expectation of Success, Perceived Costs, and Subjective Task Values.
	• Provide opportunities for students to reflect on their own experiences and identify patterns or barriers.
7	• Facilitate discussions and group activities to promote peer support and collaboration.
	• Encourage students to share their strategies for maintaining high expectations, managing costs, and enhancing task values.
8	• Assess and evaluate the impact of the intervention on students' achievement-related choices and performance.
	• Reflect on individual progress and set goals for future academic endeavors.
	• Provide resources and recommendations for students to continue applying the lessons learned from the intervention.

Non-AL-enhanced application infusion classroom (control group)

The control group in this study utilized a non-AL-enhanced application called Poe (https://poe.com) for their homework assignments (see Figure 7). Before the intervention, the teacher took on the role of describing and explaining the different features of the Poe application to the participants. This involved giving comprehensive instructions on how to effectively utilize the application's features. Poe's application offered a specific feature that greatly benefited students in the development of their writing skills: the automated analysis of their written work. Through the utilization of advanced algorithms, Poe thoroughly examined students' written assignments, providing detailed feedback and suggestions for improvement. This feature enabled students to identify and address specific areas of weakness in their writing, such as grammar errors, sentence structure, and vocabulary usage. The automated analysis not only saved time but also offered objective assessments, allowing students to gain insights into their writing strengths and areas for growth. With this feature, students were able to refine their writing skills and gradually enhance the clarity, coherence, and overall quality of their written work. In this group, the teacher implemented a series of activities comparable to those conducted in the experimental

groups. The teacher created tailored writing tasks for the students, tracking their progress and accessing detailed reports to monitor engagement. Additionally, the teacher provided personalized feedback and assessed the quality of the students' submissions, while also utilizing a plagiarism detection feature to ensure academic integrity. However, it is important to note that all of these activities were conducted in a face-to-face classroom setting, rather than in an online learning environment. This meant that the teacher had direct, in-person interactions with the students, as opposed to the virtual interactions facilitated by the AL application. In the non-AL, technology-enhanced environment, it was challenging to control the specific feedback that participants received. However, the writing tasks were identical across the three experimental groups. Additionally, the teacher provided explanations to all participants on how to receive feedback for particular aspects, such as grammar, structure, and other specific details.

Students were taught to use specific prompts with Poe, such as asking it for suggestions to improve clarity and engagement, or to enhance the flow of ideas in their writing. These prompts were designed to guide the AI in providing constructive feedback that would help students refine their work while maintaining their voice and intent. The teacher instructed students to record their screens while using Poe and subsequently submit the recordings for review. This approach enabled the teacher to monitor the students' engagement with the AI tool and assess their interaction processes. The research effectively highlighted the differences between systems that placed the burden of learning adaptation on the student (Poe) versus systems that provided adaptive support (Quill). This distinction allowed for a deeper understanding of how student agency and interaction with technology impacted learning outcomes, engagement, and achievement. Poe's emphasis on independent prompting shed light on how self-directed learning influenced cognitive processes, while Quill's adaptability illustrated how personalized interventions influenced student performance and motivation. Ultimately, comparing these systems in a controlled research setting provided valuable insights into the balance between student autonomy and system-driven support in digital learning environments.

Fig. 7

Screenshot from Poe application environment
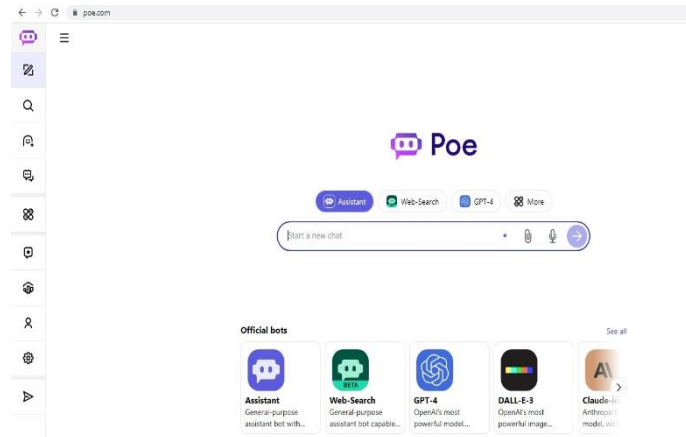
Data analysis

The quantitative data in this study were analyzed through a combination of descriptive and inferential statistical methods. Descriptive statistics, including means (M), standard deviations (SD), skewness, and kurtosis, were calculated to summarize the key research variables. The Kolmogorov-Smirnov test was conducted to assess normality, ensuring the appropriateness of parametric analyses. A repeated measures analysis of variance (ANOVA) was utilized to examine differences between groups across time points, specifically comparing pre-intervention and post-intervention scores. Post hoc analyses with Bonferroni adjustments were performed to identify specific group differences, and effect sizes were calculated using Cohen's d to evaluate the practical significance of the results.

Qualitative data were analyzed using thematic analysis, involving the systematic coding and categorization of interview transcripts to uncover core themes and patterns. To enhance the trustworthiness of the analysis, validation strategies such as member checking and peer debriefing were employed. The integration of quantitative and qualitative findings facilitated a comprehensive understanding of the intervention's effects, enabling alignment between statistical outcomes and participants' experiences and perceptions.

Results

Whether AL-Enhanced Application Use and EVTM Instruction Within AL-Enhanced Applications Lead to Greater Improvement in Students' Writing Achievement, Error Tolerance, and Feedback Tolerance Compared to Non-AL-Enhanced Application Use

Table 1 provides a summary of the descriptive statistics about the research variables. It presents the means (M), standard deviations (SD), skewness (Skew), and kurtosis (Kurt) for the pre-intervention and post-intervention scores in the experimental and control groups. The experimental groups displayed significant improvements in the writing task scores, indicating the effectiveness of the intervention. Additionally, the two experimental groups showed greater improvements in ET and FT scores compared to the control group. However, only the second experimental group demonstrated advancements in EVTM scores compared to the first experimental and control groups. The normality of the data was assessed using the Kolmogorov-Smirnov test, and it was found that all variables exhibited normal distribution as evidenced by p-values greater than .05.

Table 1

Descriptive data of different groups for pretest and posttest measures

		N	Pre-Intervention				Post-Intervention			
			M	*SD*	Skew	Kurt	*M*	*SD*	Skew	Kurt
Writing	Experimental1	40	40.1	9.0	.123	-.025	67.8	6.8	.104	-.891
Task	Experimental2	40	40.4	9.01	.194	-.246	81.5	6.40	-.133	1.67
	Control	40	40.9	9.30	.090	-.477	50.0	9.58	-.403	-.706
ET	Experimental1	40	1.65	.184	-.295	-.017	4.17	.317	.066	-.600
	Experimental2	40	1.67	.186	-.503	.039	4.16	.299	.030	-.469
	Control	40	1.66	.187	-.161	-.444	1.67	.178	-.520	-.151
FT	Experimental1	40	1.66	.183	-.449	-.155	4.18	.303	-.086	-.370
	Experimental2	40	1.65	.175	-.537	.006	4.11	.288	-.111	.319
	Control	40	1.64	.180	-.331	-.014	1.65	.174	-.575	.120
EVTM	Experimental1	40	1.66	.182	-.449	-.155	1.64	.175	-.584	.136
	Experimental2	40	1.65	.183	-.039	-.491	4.11	.301	.139	.722
	Control	40	1.63	.173	-.372	.022	1.65	.173	-.606	.197

The ANOVA tests for pre-intervention equivalence across the three groups (Experimental 1, Experimental 2, and Control) revealed no significant differences in writing task, ET, and FT scores. Specifically, the F-statistics for the writing task (0.43), ET (0.64), FT (0.91), and EVTM (0.86) resulted in p-values of 0.65, 0.53, 0.65, and 0.51, respectively, all of which are greater than 0.05, indicating no significant differences among the groups for these measures. Subsequently, a repeated measures analysis of variance (ANOVA) was performed, and the results of this analysis are succinctly presented in Table 2.

Table 2

Tests of between-subjects effects of repeated measure anova for three groups

	Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Writing	Intercept	687047.004	1	687047.004	8057.415	.000	.986
Tasks	Group	9610.033	2	4805.017	56.351	.000	.491
	Error	9976.463	117	85.269			
ET	Intercept	1496.952	1	1496.952	19731.161	.000	.994
	Group	83.910	2	41.955	553.003	.000	.904
	Error	8.876	117	.076			

FT	Intercept	1478.726	1	1478.726	23717.027	.000	.995
	Group	83.985	2	41.992	673.507	.000	.920
	Error	7.295	117	.062			
EVTM	Intercept	1028.707	1	1028.707	20684.639	.000	.994
	Group	84.672	2	42.336	851.272	.000	.936
	Error	5.819	117	.050			

The results demonstrate that both the group factor and the intercept have significant influences on the variables studied, including writing tasks, ET, FT, and EVTM. The high F-values and small p-values indicate that the differences observed between groups are unlikely to be due to random variation. Furthermore, the large Partial Eta Squared values underscore the practical significance of these effects. Based on the significant between-subject effects revealed by the repeated measures ANOVA, indicating notable differences across groups and measures, post hoc tests were conducted to explore specific contrasts in greater detail (see Table 3).

Table 3

Bonferroni post hoc tests for multiple comparisons

	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval		*d*
						Lower Bound	Upper Bound	
Writing Task	Experimental1	Control	8.5000*	1.46004	.000	4.9537	12.0463	2.23
		Experimental2	-6.9750*	1.46004	.000	-10.521	-3.4287	1.45
	Experimental2	Control	15.4750*	1.46004	.000	11.9287	19.0213	1.78
ET	Experimental1	Control	1.2527*	.04355	.000	1.1470	1.3585	1.02
		Experimental2	-.0031	.04355	.982	-.1089	.1027	0.01
	Experimental2	Control	1.2559*	.04355	.000	1.1501	1.3617	1.06
FT	Experimental1	Control	1.2760*	.03948	.000	1.1801	1.3719	2.24
		Experimental2	.0434	.03948	.823	-.0525	.1393	0.02
	Experimental2	Control	1.2326*	.03948	.000	-.1393	.0525	1.45
EVTM	Experimental1	Control	.0208	.03526	.942	-.0649	.1064	0.01
		Experimental2	-1.2495*	.03526	.000	1.1846	1.3559	1.32
	Experimental2	Control	1.2703*	.03526	.000	1.1639	1.3351	1.65

The results indicated significant differences in writing tasks between the experimental groups and the control group, as well as between the first and second experimental groups. These findings provide support for the effectiveness of the AL and EVTM interventions in improving the writing skills of L2 students, with particular emphasis on the effectiveness of EVTM. In terms of the ET measure, significant differences were observed between the experimental and control groups, but no significant differences were found between the first and second experimental groups. Similar findings were observed for the FT scale, where significant differences were found between the experimental and control groups, but

no significant differences were observed between the first and second experimental groups. Regarding the EVTM measure, it is noteworthy that only the second experimental group exhibited significant differences in comparison to both the control group and the first experimental group.

The results of this study suggest potential interaction effects between the group factor and the outcome measures (writing task, ET, FT, and EVTM]). Significant differences across groups for specific outcomes highlight how group membership moderates the impact of the experimental interventions on various variables. The experimental interventions had a significant influence on writing task performance. Experimental Group 1 outperformed the control group with a mean difference of 8.500 (d = 2.23, p < .001), indicating a substantial effect size. Experimental Group 2, although showing a significantly lower mean than Experimental Group 1 (mean difference = -6.975, d = 1.45, p < .001), still significantly outperformed the control group (mean difference = 15.475, d = 1.78, p < .001). These findings suggest a complex interaction between the group factor and the interventions, reflecting their differential effectiveness in enhancing writing performance. ET was significantly higher in both experimental groups compared to the control group. Experimental Group 1 showed an increase of 1.253 (d = 1.02, p < .001), while Experimental Group 2 exhibited a similar increase of 1.256 (d = 1.06, p < .001). However, no significant difference was observed between the two experimental groups (mean difference = -0.003, d = 0.01, p = .982). This consistency suggests that while both interventions effectively promoted engagement, their relative impact was comparable across the experimental groups. A similar pattern emerged for FT. Experimental Group 1 demonstrated a significant increase compared to the control group (mean difference = 1.276, d = 2.24, p < .001), and Experimental Group 2 also showed a notable improvement (mean difference = 1.233, d = 1.45, p < .001). Again, no significant difference was found between the two experimental groups (mean difference = 0.043, d = 0.02, p = .823). This consistency in results implies that while both interventions enhanced focus, neither intervention proved more effective than the other in this domain. The differences in EVTM outcomes were more distinct. Experimental Group 2 significantly outperformed both the control group (mean difference = 1.270, d = 1.65, p < .001) and Experimental Group 1 (mean difference = -1.250, d = 1.32, p < .001). However, no significant difference was observed between Experimental Group 1 and the control group (mean difference = 0.021, d = 0.01, p = .942). These results indicate that the intervention in Experimental Group 2 was particularly effective in enhancing EVTM, whereas Experimental Group 1 did not produce measurable improvements in this outcome.

How students evaluate the efficacy of the proposed models as teaching and learning tools

The analysis of semi-structured interview results involved several stages. Firstly, the interviews were transcribed verbatim to ensure accurate representation. Researchers then familiarized themselves with the data, identifying initial patterns and themes. Coding followed, with segments of data labeled and categorized based on meaning or relevance. Themes were developed by grouping related codes, and interpretations were made in light of research objectives and existing literature. Validation techniques, such as member checking and peer debriefing, helped ensure reliability and validity. Finally, the findings were synthesized into a coherent narrative, including illustrative quotes, implications, limitations, and recommendations. These stages often involved iterative processes to refine the analysis and deepen understanding of the data. The Cohen's Kappa for the coding was 0.85, indicating a nearly perfect level of agreement. Krippendorff's Alpha was calculated to be 0.82, reflecting a high degree of reliability.

  The participants in the first experimental group provided descriptions of their positive and negative opinions regarding the utilization of the AL application to enhance their writing skills. The themes, sub-themes, and their corresponding descriptions are summarized in Figure 8.

Fig. 8

The themes, sub-themes, and their descriptions derived from experiment 1

Theme	Subtheme	Descriptions
Enhanced Writing Accuracy	• Improved Grammar and Syntax • Enhanced Spelling and Punctuation • Improved Proofreading Skills	Using the Quill application, AL-enhance app, improved participants' grammar, syntax, spelling, punctuation, and proofreading skills, leading to more accurate and polished writing.
Increased Writing Confidence	• Boosted Self-Assurance • Strengthened Writing Skills • Reduced Writing Anxiety	The use of the AL application resulted in increased writing confidence among students, as they felt more equipped to produce high-quality work, strengthened their writing skills through feedback and guidance, and experienced reduced writing anxiety due to the support and guidance provided throughout the writing process.
Efficient Writing Process	• Time Management Improvement • Streamlined Writing Structure • Improved Writing Focus	The use of AL application improved participants' time management and productivity by helping them become more efficient in their writing, streamlined the writing process through structure and organization suggestions, and facilitated focus and coherence in their compositions through prompts and exercises.
Increased Writing Productivity	• Enhanced Writing Speed • Improved Writing Output • Enhanced Writing Efficiency	The use of AL application resulted in increased writing speed, improved writing output with more substantial compositions, and enhanced writing efficiency through the utilization of tools and resources, enabling students to allocate their time and energy more effectively.
Lack of Goal Clarity and Relevance	• Unclear Learning Objectives • Absence of Personal Goal Setting	Students expressed frustration with the lack of clear learning objectives, limited opportunities for personal goal setting, and a lack of real-world relevance in AL application's writing exercises, leading to difficulties in understanding the purpose and relevance of the tasks, a lack of motivation, and diminished perception of the practical applications of their writing skills.
Limited Autonomy and Choice	• Lack of Writing Topic Freedom • Limited Decision-Making Opportunities	Participants felt that AL application's limited freedom in choosing writing topics, along with predefined guidelines and restricted decision-making opportunities, resulted in a lack of personal investment, diminished autonomy, and decreased motivation in the writing exercises.

As evident from the findings, the quantitative data was corroborated by students' accounts, affirming the positive influence of the AL application on their writing proficiency. In addition, the subthemes related to grammar, syntax, spelling, punctuation, and proofreading were present in 85% of participant responses, with coding frequencies assigned as 1, 2, or 3. Participants frequently reported improvements in these areas due to the Quill app. For instance, one participant shared, "*The feedback from the Quill app really helped me notice mistakes I didn't catch before, like word order and subject-verb agreement. My grammar is much better now*" (Participant 7). Another noted, "*I used to miss a lot of spelling errors, but with the Quill app, it's like a safety net. I'm more confident*

in my writing now" (Participant 12). Additionally, a third participant explained, "*I've improved my proofreading skills because the app suggests where I should look for errors, making me more careful*" (Participant 4). These quotations provide strong evidence of the app's positive impact on participants' writing accuracy.

The issue of lack of goal clarity and relevance emerged in 70% of participant responses, with many expressing frustrations over unclear learning objectives and the absence of personal goal-setting opportunities. One participant noted, "*I don't always understand why I'm writing what I am. It feels like there's no purpose to some of the tasks*" (Participant 13), while another shared, "*The app gave me exercises, but I wanted to set my own goals. I didn't feel like I was in control of my learning*" (Participant 14). These quotations underscore participants' dissatisfaction with the lack of clarity and relevance in the tasks, reinforcing the theme of goal ambiguity and limited personal agency.

The issue of limited autonomy and choice was raised by 80% of participants, with many expressing dissatisfactions over the lack of freedom in selecting writing topics and making decisions about their writing. One participant remarked, "*I didn't feel like I had any choice in the topics I was given. I would have preferred to write about things that interest me*" (Participant 15). Another shared, "*The app told me exactly how to write, which made it feel less personal. I wish I had more control over the process*" (Participant 16). These quotes highlight participants' frustrations with the restricted decision-making opportunities provided by the app, reinforcing the subtheme of limited autonomy.

The same procedure was also employed to analyze the qualitative findings of the second experimental group. The summarized results of the study are presented in Figure 9:

Fig. 9

The themes, sub-themes, and their descriptions derived from experiment 2

Theme	Subtheme	Description
Enhanced Goal Clarity and Relevance	• Clear Learning Objectives • Personalized Goal Setting • Real-World Application Emphasis	The integration of the EVTM Intervention alongside with AL application provided students with clear learning objectives, personalized goal-setting opportunities, and a stronger connection between their writing exercises and real-world applications, enhancing their sense of purpose, motivation, and relevance in their writing practice.
Effective Feedback and Support	• Specific and Constructive Feedback • Timely and Immediate Feedback • Personalized Interaction and Support	The EVTM Intervention alongside AL application improved feedback quality and timeliness, provided personalized interaction and support, and facilitated timely adjustments, leading to enhanced writing skills and student improvement.
Engaging and Stimulating Learning Experience	• Varied and Interactive Exercises • Creative Expression and Freedom	The integration of the EVTM Intervention alongside AL application expanded the variety of writing exercises and interactive elements, creating an engaging and stimulating learning experience, while also promoting creative expression and individuality in students' writing.
Increased Perceived Value and Importance of Writing Skills	• Recognition of Writing Skills' Relevance • Understanding the Benefits of Writing Proficiency • Increased Sense of Personal Value	The EVTM Intervention alongside AL application helped students recognize the relevance and importance of writing skills in academic and professional contexts, while also highlighting the benefits of proficiency in writing, including improved communication, critical thinking, and academic success.
Enhanced Self-Efficacy and Confidence in Writing	• Belief in Writing Competence • Overcoming Writing Challenges • Growth Mindset in Writing	The EVTM Intervention alongside AL application fostered participants' belief in their writing competence, facilitated their ability to overcome challenges, and promoted a growth mindset, resulting in increased self-efficacy and confidence in their writing abilities.
Increased Motivation and Engagement in Writing Tasks	• Intrinsic Motivation • Sense of Purpose and Relevance • Increased Task Engagement	The EVTM Intervention alongside AL application heightened students' intrinsic motivation, fostered a sense of purpose and relevance in their writing tasks, and increased their engagement, resulting in greater enjoyment, satisfaction, and investment in their writing.

The results indicated that participants in the second experimental group exhibited positive beliefs regarding the integration of EVTM instruction alongside the AL application in the writing classroom. The theme of Enhanced goal clarity and relevance emerged in 70% of participant responses, particularly regarding clear learning objectives, personalized goal-setting, and the emphasis on real-world applications. One participant noted, "*The learning objectives were much clearer, and I knew exactly what I was supposed to achieve in each task. It made my writing feel more focused*" (Participant 3). Another remarked, "*I really appreciated setting my own goals because it felt like the app was helping me work toward something meaningful for my career*" (Participant 5). Additionally, a participant shared, "*The connection between the tasks and real-world applications made everything seem more relevant to me. I could see how these skills would help me later on*" (Participant 8). These quotations highlight how the integration of the EVTM intervention with the AL

application significantly improved goal clarity and relevance, fostering a stronger sense of purpose and motivation among students.

The theme of effective feedback and support was highlighted by 80% of participants, who emphasized the quality, timeliness, and personalization of feedback as a key factor in improving their writing experience. One participant noted, "*The feedback I received was always specific, telling me exactly what to improve and how. It helped me make my writing stronger*" (Participant 11). Another shared, "*Getting feedback right away allowed me to make changes quickly. It made the whole process more efficient and less stressful*" (Participant 6). A third participant added, "*The personalized support made me feel like the app cared about my progress. I was able to apply what I learned to improve my writing*" (Participant 4). These quotes underscore how the prompt, specific, and personalized feedback provided through the integration of the EVTM intervention and AL application played a pivotal role in enhancing students' writing skills and creating a supportive learning environment.

The theme of engaging and stimulating learning experience was raised by 65% of participants, who highlighted the interactive nature of the exercises and the promotion of creative expression. One participant shared, "*The variety of exercises kept things interesting and made me want to keep going. It wasn't just about completing tasks; it was about expressing myself creatively*" (Participant 9). Another participant noted, "*The app gave me the freedom to approach writing in different ways. It let me be myself in my writing*" (Participant 7). These responses confirm that the integration of EVTM with the AL application fostered a dynamic and engaging learning environment, encouraging students to express their creativity and individuality in their writing.

The theme of increased perceived value and importance of writing skills was identified by 75% of participants, who recognized the relevance of writing skills in both academic and professional contexts, as well as a heightened sense of personal value. One participant shared, "*I now understand how important writing is in both school and work. It's a skill that I'll continue to use no matter what career I choose*" (Participant 12). Another remarked, "*The app helped me see how good writing can improve my communication and thinking skills. It feels more valuable now*" (Participant 10). These statements highlight the shift in students' perceptions, demonstrating a deeper appreciation for the relevance and personal significance of writing in their academic and professional lives.

The theme of enhanced self-efficacy and confidence in writing was mentioned by 60% of participants, who reported increased confidence in their writing abilities and a stronger belief in their competence. One participant noted, "*I feel more confident in my writing now. I can tackle challenges better because I believe I can handle them*" (Participant 13). Another shared, "*The app helped me realize that writing is a skill I can improve over time. I'm not afraid of the challenges anymore*" (Participant 14). These quotes underscore how

the intervention fostered a growth mindset, enhancing students' self-efficacy and confidence in their writing abilities.

The theme of increased motivation and engagement in writing tasks was identified by 70% of participants, who reported heightened intrinsic motivation, a sense of task relevance, and greater engagement in their writing activities. One participant shared, "*I actually look forward to writing now. The tasks feel more relevant to me, and I'm invested in doing well*" (Participant 16). Another noted, "*The sense of purpose in the writing tasks made me want to engage more. I felt like I was working toward something important*" (Participant 15). These remarks demonstrate how the integration of the EVTM intervention with the AL application significantly boosted students' motivation, engagement, and satisfaction with their writing tasks.

Based on the information provided, there appears to be a strong connection between the quantitative results suggesting a positive effect of AL and the qualitative results indicating positive opinions and experiences of L2 learners in the EVTM environment. The quantitative findings showed that the use of the AL-enhanced application, such as Quill, led to improvements in more accurate and polished writing. This aligns with the qualitative findings that the AL and EVTM environment had a significant and positive impact on the learners' ET, FT, and various aspects of their writing, including enhanced writing accuracy, improved grammar and syntax, and enhanced spelling and punctuation. Furthermore, the qualitative data suggests that the integration of the EVTM Intervention alongside the AL application resulted in increased writing confidence, an efficient writing process, and enhanced writing productivity among the learners. These findings corroborate the quantitative results, which indicated that the use of the AL within the EVTM environment strengthened their writing skills, ET, FT, and EVTM. The qualitative data also highlights how the EVTM Intervention, in combination with the AL application, addressed the limitations of the AL application alone, such as the lack of goal clarity, relevance, and autonomy. The EVTM Intervention provided clear learning objectives, personalized goal-setting, real-world application emphasis, effective feedback and support, and an engaging and stimulating learning experience, leading to increased perceived value and importance of writing skills, enhanced self-efficacy and confidence, and increased motivation and engagement in writing tasks.

Discussion

The present study represents a deliberate endeavor to investigate the efficacy of two interventions, namely EVTM and AL application, individually and in combination, on the enhancement of L2 learners' writing skills, ET, and FT. This research adopts a mixed-methods design, which allows for the integration of both quantitative and qualitative data to provide a comprehensive understanding of the phenomenon under investigation.

The initial findings indicated that the integration of AL into the learning environment had a positive and significant impact on learners' writing skills when compared to a non-AL-enhanced instructional setting through several key advantages. Firstly, AL offers personalized instruction, tailoring learning experiences to address individual learners' needs and focus on specific areas requiring improvement (Liu et al., 2022). Secondly, immediate feedback in AL environments allows learners to make prompt revisions and corrections, leading to faster progress (Kaur et al., 2023). Thirdly, continuous assessment in AL facilitates ongoing monitoring of learners' progress, enabling instructors to provide targeted interventions (Skains, 2017). Fourthly, AL adjusts task difficulty to challenge learners appropriately, enhancing engagement and motivation (Gorzelsky et al., 2017). Additionally, the flexibility and accessibility of AL empower learners to practice at their own pace and convenience and data-driven insights provide instructors with valuable information to make informed instructional decisions and deliver effective interventions.

The second finding of the study revealed a substantial and statistically significant effect of AL application on L2 learners' ET and fluency FT. AL applications enhance ET and FT through various mechanisms. Improved writing skills and accuracy played a significant role. The use of AL-enhanced applications, such as Quill, led to improvements in grammar, syntax, spelling, punctuation, and proofreading skills, resulting in more accurate and polished writing. This enhancement in writing accuracy and quality likely contributed to increased ET, as students felt more confident in their abilities and were more open to receiving feedback on their work (Gan & Hattie, 2014). The AL application also resulted in increased writing confidence among students, as they felt more equipped to produce high-quality work. The support and guidance provided throughout the writing process also led to reduced writing anxiety, allowing students to be more receptive to feedback and willing to learn from their mistakes (Alqassab et al., 2018). This increased writing confidence and reduced anxiety were important factors in the enhanced ET and FT. Furthermore, the AL application improved participants' time management, writing structure, and focus, leading to a more efficient writing process. The increased writing speed, output, and efficiency enabled students to allocate their time and energy more effectively, potentially enhancing their ability to learn from feedback and incorporate it into their writing. The integration of the EVTM Intervention was also a crucial factor. When combined with the AL application, the EVTM Intervention addressed the limitations of the AL application alone, such as the lack of goal clarity, relevance, and autonomy. The EVTM Intervention provided clear learning objectives, personalized goal-setting, real-world application emphasis, effective feedback and support, and an engaging learning experience. These elements likely fostered a greater sense of purpose, motivation, and relevance in the writing tasks, leading to an increased willingness to learn from feedback and a more positive attitude toward error correction (Aben et al., 2022).

The intriguing findings of the study indicate that the combination of EVTM instruction alongside the AL application environment yielded a positive and statistically significant effect on learners' writing skills, surpassing both the control group and the AL application environment alone. The observed positive effects may be attributed to various justifications. Firstly, the integration of EVTM instruction alongside the AL application environment enhanced motivation by addressing learners' beliefs in their capabilities and the value they attributed to writing (Rosenzweig et al., 2019). Secondly, the inclusion of EVTM fostered metacognitive awareness, promoting self-regulation and reflection throughout the writing process (Lazarides et al., 2022). Moreover, the comprehensive nature of EVTM, which encompasses multiple writing components, synergistically complements AL's personalized instruction, leading to the development of holistic writing skills (Wigfield & Eccles, 2024). Collectively, these factors contributed to the significant improvements observed in learners' writing abilities, surpassing the outcomes achieved by the control group and the AL application environment alone (Loh, 2019).

The study's findings are compelling as they reveal that the incorporation of EVTM instruction alongside the AL application environment yielded a substantial and statistically significant influence on learners' ET and FT. Importantly, this integrated intervention exhibited superior performance compared to the control group and not the AL application environment, indicating its effectiveness in enhancing these specific language learning outcomes. The integration of EVTM instruction in an AL environment may enhance learners' ET and FT through motivational enhancement, metacognitive development, personalized instruction, immediate feedback, and enhanced engagement and persistence. By targeting learners' beliefs and intrinsic motivation, EVTM instruction promotes perseverance in the face of errors and a proactive approach to seeking feedback (Wigfield & Eccles, 2024). The incorporation of metacognitive strategies fosters self-regulation and the ability to identify areas for improvement. AL environments provide personalized instruction and timely feedback, aligning with EVTM instruction to support learners' error and FT (Lazarides et al., 2022). Additionally, the combination of cognitive and linguistic skill development, along with a positive learning experience, further strengthens learners' willingness to tolerate errors and use feedback for continuous improvement.

The final results of the study reveal that the statistically significant and positive effect observed in the EVTM instruction was solely evident in the group that received the intervention within an AL environment. This finding underscores the efficacy of EVTM instruction in an AL setting for enhancing motivation. The superiority of this intervention can be attributed to several key factors. Firstly, the targeted motivational enhancement employed in the EVTM instruction directly addresses learners' motivational beliefs, such as self-efficacy and task value. By tailoring instruction and feedback to individual learners' needs, the intervention fosters a sense of personal relevance and enhances engagement

(King et al., 2009). Secondly, the integration of metacognitive skill development within the EVTM instruction promotes learners' metacognitive awareness, enabling them to regulate their learning process effectively. By setting goals, monitoring their progress, and making adjustments based on feedback, learners develop a sense of control and ownership over their learning, leading to heightened motivation (Smith & King, 2004). Thirdly, the emphasis on a mastery orientation within the EVTM instruction is crucial for fostering a growth mindset and promoting a focus on learning progress rather than solely outcome-oriented performance (Aben et al., 2022). Lastly, the synergistic effects of the EVTM instruction and the AL environment contribute to the superior improvement in motivation. The adaptive nature of the AL environment, with its provision of personalized instruction, immediate feedback, and progress monitoring, complements and reinforces the motivational strategies employed in the EVTM intervention. Together, these factors create a comprehensive and supportive learning environment that maximizes the enhancement of motivation among learners (King et al., 2009).

Conclusion

In sum, this study aimed to investigate the effectiveness of two interventions, EVTM and AL application, individually and in combination, on improving L2 learners' writing skills, ET and FT. The findings demonstrated that AL application alone had a significant positive impact on writing skills, ET, and FT compared to a non-AL-enhanced instructional setting. The integration of EVTM instruction alongside the AL application yielded superior results, surpassing both the control group and the AL application alone. This integrated intervention enhanced motivation, addressed learners' beliefs and metacognitive awareness, provided personalized instruction and immediate feedback, and created a comprehensive and supportive learning environment. The study highlights the efficacy of combining EVTM and AL approaches to enhance motivation, metacognition, and writing skills in L2 learners.

 The present study yields significant theoretical and practical implications. Theoretically, it contributes to the understanding of motivation in second language acquisition by integrating the EVTM within an AL environment. This integration underscores the critical role of metacognitive skill development, mastery orientation, and a growth mindset in promoting effective learning strategies and enhancing language proficiency. The findings highlight the synergistic potential of combining motivational enhancement with personalized and adaptive instruction, offering a more comprehensive framework for understanding learner engagement and progress in L2 contexts. Practically, the study provides empirical support for the effectiveness of integrating EVTM and AL approaches in improving L2 writing outcomes. These results inform pedagogical practice by advocating for instructional designs that incorporate motivational strategies, such as goal

setting, progress tracking, and the cultivation of a supportive classroom climate. Additionally, the use of AL technologies facilitates personalized feedback and AL pathways tailored to individual learners' strengths, needs, and challenges. The incorporation of real-time, fine-grained feedback, via peer review, teacher input, or AI-driven tools, enables learners to address writing issues more efficiently and effectively. Furthermore, the strategic application of AI and AL technologies enhances instructional responsiveness, providing consistent, timely, and individualized support.

Grounding the instructional approach in EVTM, this study suggests that students may experience enhanced motivation, engagement, and persistence in the writing process, resulting in increased effort, time on task, and improved writing outcomes. The integration of EVTM with adaptive digital learning tools enables the creation of personalized learning pathways that accommodate individual differences in writing proficiency, interests, and learning styles, thereby fostering more effective and engaging instruction. The adaptive capabilities of the digital platform also allow for the delivery of tailored feedback aligned with learners' specific needs and motivational profiles. This personalization supports the development of a growth mindset, ET, and FT, promoting continuous improvement in writing skills. Furthermore, the EVTM-based approach contributes to the cultivation of transferable academic dispositions, such as positive attitudes toward learning, that may benefit students across broader educational and professional contexts. Importantly, the findings suggest that this instructional model may help reduce achievement gaps by offering more equitable access to high-quality, personalized writing support. The scalability of digital and adaptive instruction also presents a viable solution to systemic challenges in delivering individualized feedback at scale, making it a resource-efficient approach for enhancing instructional quality. By leveraging EVTM-aligned AL technologies, educators may optimize their time and resources while providing more targeted and impactful support, ultimately leading to improved student outcomes in writing.

The study has a small sample size, which limits the generalizability of the findings to a larger population of L2 learners. Larger sample sizes allow for greater statistical power and the ability to detect more subtle effects, as well as to better account for confounding variables and individual differences. This is particularly important when exploring the complex relationship between motivation, AL, and writing outcomes, as there can be significant variability among L2 learners. Additionally, the short duration of the intervention may not capture the long-term effects of the combined EVTM and AL approaches. The relatively short timeframe may have been insufficient for participants to fully engage with and integrate the EVTM-based AL tools and strategies into their writing processes. Longer-term studies would enable a more comprehensive assessment of the persistence and durability of any observed improvements, given the dynamic and complex nature of these constructs, which various contextual and individual factors can influence

over time. The focus on a single language restricts the applicability of the findings to other languages with different characteristics. Writing processes and the effectiveness of instructional approaches can vary significantly across languages with diverse linguistic and orthographic characteristics. Expanding the research to investigate the combined EVTM and AL strategies in the context of other languages would be necessary to assess the generalizability of the instructional approach and its potential to support writing development in a wider range of educational settings.

Moreover, the controlled setting of the study may not fully reflect the complexities of real-world language learning environments, potentially affecting the outcomes. Real-world classrooms often involve a range of individual differences, instructional approaches, and environmental influences that could potentially impact the effectiveness of EVTM-based AL strategies. Evaluating the instructional approach in more naturalistic educational contexts would provide valuable insights into its applicability and transferability to diverse learning settings, enhancing the ecological validity of the research findings. However, despite these limitations, the study provides valuable insights within its sample context and serves as a starting point for future research to address these limitations and advance our understanding of the combined EVTM and AL approaches in language learning. Finally, focusing on intermediate proficiency adult learners limits the generalizability of findings as the results may not apply to learners at different proficiency levels, age groups, or cultural backgrounds. Adult learners' unique motivations, strategies, and external factors such as work or family responsibilities may influence language acquisition in ways that differ from other groups. To enhance generalizability, future studies should include a more diverse range of learners across various proficiency levels, ages, and contexts.

Appendix A

Error Tolerance Questionnaire based on Rybowiak et al.'s (1999) in L2 writing skill

Error Competence
When I make a mistake in my writing, I usually know how to correct it, especially with help from AI tools.
When I notice an error in my writing, I try to fix it immediately.
If it's possible to correct a writing error, I usually know what to do, even if I use an AI assistant.
Even when I make writing mistakes, I stay focused on improving my writing skills.

Learning from Errors
Mistakes in my writing help me improve my writing skills.
Writing errors provide useful feedback that helps me become a better writer.
I use the feedback from AI tools to learn from my writing mistakes.
I have improved my writing by reflecting on and learning from my past errors.

Error Risk Taking

To improve my writing, I am willing to try new things, even if I might make mistakes.

It's better to take writing risks and learn from mistakes than to avoid writing altogether.

I accept that things may go wrong when I experiment with different writing styles or structures.

I prefer making errors and learning from them over playing it too safe in my writing.

Error Strain

I feel stressed when I find mistakes in my writing.

I am often afraid of making errors in my written assignments.

I feel embarrassed when an AI tool points out my writing mistakes.

I get upset when I make writing errors, even with AI assistance.

While writing, I worry that I might make mistakes.

Error Anticipation

When I write, I know that mistakes are likely to happen.

I start writing with the awareness that I might make errors.

I am usually not surprised when I make a writing mistake.

I expect to make some mistakes when writing, even with AI assistance.

I understand that making errors is a natural part of the writing process.

Covering Up Errors

I avoid pointing out my writing mistakes if they're not obvious.

I feel it's disadvantageous to share my writing errors openly.

I don't find it useful to discuss my writing mistakes with others.

I sometimes prefer to ignore my writing mistakes rather than fix them.

I'd rather keep my writing mistakes to myself than share them.

Writers who admit to their errors may appear less competent.

Error Communication

When I make a mistake in my writing, I share it so others can avoid making the same mistake.

If I can't correct a writing error, I ask a peer or use AI to help.

When I'm unable to correct a mistake in my writing, I turn to someone for feedback.

When I make a writing mistake, I ask others how I could improve it.

Thinking About Errors

After I make a writing error, I think about why it happened.

I often reflect on how I could have prevented a writing mistake.

If something goes wrong in my writing, I analyze it carefully.

After a writing mistake, I take time to figure out how to avoid it in the future.

When I make a writing error, I reflect on it thoroughly.

Appendix B

Adapted version of King et al.'s (2009) Feedback Orientation Scale for L2 writing skill

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Utility

I think feedback from AI tools and teachers is vitally important in improving my writing.

I usually reflect on the feedback provided by AI or my teacher.

I pay attention when AI tools or my teacher provides feedback on my writing.

I feel encouraged when I receive positive feedback, whether from AI or teachers.

I believe that feedback offers clear direction on how to improve my writing.

Feedback from AI tools and teachers can be a valuable form of recognition.

I pay close attention to the suggestions given in instructional feedback.

Feedback motivates me to work harder and write better.

Feedback from AI or teachers is not helpful in improving my writing.

I feel relieved when I receive positive feedback on my writing.

Sensitivity

My feelings can be hurt by critical feedback from AI tools or teachers.

I sometimes feel threatened by corrective feedback on my writing.

Negative feedback about my writing affects me emotionally.

I find corrective feedback intimidating.

I'm usually not emotionally affected by corrective feedback.

It takes me a while to recover from negative writing feedback.

I find it embarrassing to receive negative feedback on my writing.

I often dwell on the negative emotions caused by feedback.

Corrective feedback increases my stress about future writing tasks.

Confidentiality

I don't like receiving corrective writing feedback in front of others.

I prefer others not hear the feedback I receive on my writing.

I don't mind being singled out in feedback discussions.

I would rather receive feedback on my writing in private.

I'm okay with others hearing the feedback I get on my writing.

Retention

I often forget what AI tools or teachers recommended in their feedback.

I tend to miss important points when I receive feedback on my writing.

I usually don't keep track of the feedback I receive on my writing.

Appendix C

Adapted EVTM Questionnaire based on Nagle (2021) for L2 writing skill

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Expectations of Success

I am certain that I can master the writing skills required in my English course this semester.

Even if the writing tasks are challenging, I believe I can succeed if I try.

I am confident that I can earn a good grade on my English writing assignments.

Attainment Value

Being good at writing in English is important to me.

Being skilled in English writing is an important part of who I am.

Participating in writing activities is a key part of how I see myself as a learner.

Intrinsic Value

I enjoy writing in English.

I find English writing tasks interesting and engaging.

I would like to take more courses that help improve my English writing skills.

Utility Value

Improving my English writing will help me in the future (e.g., in a job, at university, or in daily life).

Being able to write well in English will be useful for me in the long term.

Good English writing skills are practical and beneficial for my goals.

Effort Cost

When I think about the hard work needed to improve my English writing, I am not sure it's worth the effort.

Improving my English writing will take more effort than I am willing to put in.

For me, learning to write better in English may not be worth the time and energy.

L2 Writing Experience

I enjoy the atmosphere of my English writing class.

I like how my teacher supports and guides my writing development.

My teacher gives useful feedback that helps me improve my English writing.

Willingness to Communicate Through Writing

I would write messages in English to my classmates about my weekend plans.

I would write to a friend in English about my day.

I would email my teacher in English about my writing assignments.

If I don't understand a writing task, I would write a message asking for clarification in English.

Appendix D

A sample of interview questions

- Can you describe how the writing application you used affected your grammar and syntax while writing?

- In what ways did the application help you improve your spelling and punctuation?

- How has your proofreading ability changed as a result of using the application? Could you provide specific examples?

- Do you feel more confident in your writing since using the application? Why or why not?

- How has the application helped you strengthen your writing skills?

- Have you experienced any reduction in writing anxiety? How did the application contribute to this?

- How has your time management and productivity improved while using the application?

- Can you describe any changes in how you structure your writing? Did the application help you streamline the writing process?

- How did the application assist you in staying focused and ensuring coherence in your writing?

- Have you noticed any changes in your writing speed since using the application? Can you explain?

- How has the application affected the quality and length of your writing output?

- How has your overall writing efficiency improved while using the application?

- Did you experience any frustration with unclear learning objectives in the writing exercises? Can you explain?

- How did the lack of personal goal setting impact your motivation or engagement with the tasks?

- Did you find the writing exercises relevant to real-world writing skills? Why or why not?

- How did the predefined guidelines and limited topic choices affect your sense of autonomy in the writing exercises?

- Did you feel a lack of personal investment in the tasks because of the restricted decision-making opportunities? Please explain.

- How did the learning objectives and goal-setting opportunities impact your writing experience?

- Did the connection between writing exercises and real-world applications help you understand the relevance of your writing tasks? Can you provide examples?

- How would you describe the feedback you received while using the application? Was it timely and helpful?

- Can you give examples of how feedback impacted your writing improvements?

- How did the support you received from the application affect your progress?

- Can you describe how the variety of writing exercises changed your engagement with the tasks?

- Did you feel you had more freedom for creative expression? How did this impact your writing experience?

- How has the application helped you understand the importance of writing skills in academic or professional settings?

- How do you now perceive the benefits of being proficient in writing?

- How has the application helped you develop a stronger belief in your writing competence?

- Can you share any experiences where you overcame writing challenges due to the support from the application?

- Do you feel more confident in your writing abilities now compared to before? Why?

- Has your intrinsic motivation to write increased after using the application? Can you provide examples?

- How did the sense of purpose and relevance in the tasks affect your engagement and enjoyment of writing?

- Do you feel more invested in the writing tasks since using the application? Why or why not?

- Is there anything else you'd like to share about your experience using the writing application that we haven't covered?

- Do you have any suggestions for improving the application to further enhance your writing experience?

Abbreviations
AI: Artificial Intelligence
AL: Adaptive Learning
ET: Error Tolerance
EFL: English as a Foreign Language
EVTM: Expectancy-Value Theory of Motivation
FT: Feedback Tolerance
L2: Second Language
OPT: Oxford Placement Test

Author's contributions

The first author led the writing and analysis; the second author contributed to methodology and data curation, with supporting roles from the Third and Fourth authors in investigation and review.

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Availability of data and materials
The datasets used and/or analyzed during the current study may not be shared due to data privacy and protection policies.

Declarations

Competing interests
The author declares that he has no competing interests.

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