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Neuro-mediación de la ia generativa en la enseñanza del inglés: un estudio de caso sobre la reducción de la ansiedad y la mejora de la producción escrita

Neuro-mediation of generative ai in english teaching: a case study on reducing anxiety and improving written production

Neuromediação da IA generativa no ensino da língua inglesa: um estudo de caso sobre a redução da ansiedade e a melhoria da produção escrita

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Resumen

El presente estudio examina el impacto de la inteligencia artificial generativa (IAG) en la enseñanza del inglés como lengua extranjera, particularmente en el ámbito emocional. El estudio se fundamentó en la observación de una dificultad recurrente: el origen de las dificultades en la escritura no reside únicamente en una falta de conocimientos, sino en barreras emocionales que inhiben el desempeño. Esa ansiedad lingüística fue el punto de partida para considerar a la IAG no solo como herramienta, sino como mediadora de la dimensión socioafectiva del aprendizaje. El objetivo fue analizar si el uso de la IAG, integrada a una propuesta de corte neuropedagógico - orientada a favorecer los procesos de aprendizaje mediante la gestión emocional - podía disminuir la ansiedad y mejorar la producción escrita en estudiantes universitarios de nivel intermedio. Se adoptó un enfoque

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metodológico mixto dentro del marco de Design-Based Research (DBR). Participaron 36 estudiantes de una universidad privada mexicana. La intervención se desarrolló en tres ciclos y se organizó en cinco momentos: activación sensorial y emocional, focalización cognitiva, interacción con la IAG, socialización colaborativa y cierre metacognitivo. Se aplicaron cuestionarios adaptados del Foreign Language Classroom Anxiety Scale, análisis de textos y entrevistas semiestructuradas. Los datos se triangularon para comprender tanto los cambios medibles como las percepciones vividas. Los resultados mostraron una tendencia consistente: la mayoría de los estudiantes reportó menos ansiedad al final del proceso (una reducción promedio cercana al 25%). Asimismo, mejoraron sus textos: se observó más coherencia, mayor variedad sintáctica y uso de vocabulario académico. Las entrevistas semiestructuradas mostraron percepciones coincidentes sobre la reducción de la ansiedad, con testimonios donde se afirma que la retroalimentación inmediata de la IAG les "quitó el miedo a escribir" y que las actividades se percibieron como "más ligeras" en términos de carga cognitiva. No todos los casos siguieron el mismo patrón, pero la tendencia general fue positiva y sostenida durante los tres ciclos. Los resultados del estudio sugieren que la inteligencia artificial generativa, cuando se inserta en una secuencia neuro-mediada (entendida como una estructura de aprendizaje diseñada para regular la respuesta emocional con los procesos cognitivos), puede reducir la ansiedad lingüística y favorecer un ambiente de aprendizaje más seguro y motivador. La combinación de activación emocional, acompañamiento cognitivo y retroalimentación inmediata fortaleció la autonomía y la confianza del estudiante. Aun así, se recomienda explorar los efectos a largo plazo y las variaciones individuales en futuras investigaciones.

Palabras clave: inteligencia artificial generativa; ansiedad lingüística; neuropedagogía; enseñanza del inglés; producción escrita.

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Abstract

This study explored how generative artificial intelligence (GAI) can influence the teaching of English as a foreign language, particularly in the emotional dimension. The study was grounded in a recurring difficulty: many students do not write poorly because they lack knowledge, but because fear blocks their expression. That language anxiety became the starting point and the reason for viewing GAI not merely as a tool but as a mediator of the socio-affective dimension of learning. The objective was to analyze whether the use of GAI, integrated into a neuropedagogical framework, could reduce anxiety and improve written production among intermediate-level university students. A mixed-method approach was adopted within the Design-Based Research (DBR) framework. Thirty-six students from a private Mexican university participated. The intervention unfolded in three iterative cycles structured in five stages: sensory-emotional activation, cognitive focus, interaction with GAI, collaborative socialization, and metacognitive closure. Data collection included adapted Foreign Language Classroom Anxiety Scale questionnaires, text analyses, and semi-structured interviews. Triangulation was used to capture both measurable changes and lived perceptions. The results showed a consistent trend: most students reported lower anxiety levels at the end of the process (an average reduction of about 25%). Their written texts also improved, showing greater coherence, syntactic variety, and use of academic vocabulary. Semi-structured interviews showed convergent perceptions regarding anxiety reduction, with several students reporting that GAI's immediate feedback "took away the fear of writing" and made the sessions feel "lighter" in terms of cognitive load. Not every case followed the same pattern, but the overall trend was positive and sustained throughout the three cycles. The findings suggest that, when integrated into a neuro-mediated sequence, generative artificial intelligence can help reduce language anxiety and foster a safer and more motivating learning environment. The combination of emotional activation, cognitive guidance, and immediate feedback strengthened students' autonomy and confidence. Nonetheless, future research should explore long-term effects and individual variations.

Keywords: generative artificial intelligence; language anxiety; neuropedagogy; English teaching; written production.

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Resumo

Este estudo examina o impacto da inteligência artificial generativa (IAG) no ensino de inglês como língua estrangeira, particularmente no domínio emocional. O estudo baseou-se na observação de uma dificuldade recorrente: a origem das dificuldades de escrita reside não apenas na falta de conhecimento, mas também em barreiras emocionais que inibem o desempenho. Essa ansiedade linguística foi o ponto de partida para considerar a IAG não apenas como uma ferramenta, mas também como mediadora da dimensão socioafetiva da aprendizagem. O objetivo foi analisar se o uso da IAG, integrada a uma abordagem neuropedagógica — voltada para o fomento dos processos de aprendizagem por meio do gerenciamento emocional — poderia reduzir a ansiedade e melhorar a produção escrita em estudantes universitários de nível intermediário. Adotou-se uma abordagem de métodos mistos no âmbito da Pesquisa Baseada em Design (PBD). Trinta e seis estudantes de uma universidade privada mexicana participaram. A intervenção foi desenvolvida em três ciclos e organizada em cinco fases: ativação sensorial e emocional, foco cognitivo, interação com a IAG, socialização colaborativa e fechamento metacognitivo. Questionários adaptados da Escala de Ansiedade na Sala de Aula de Língua Estrangeira, análise textual e entrevistas semiestruturadas foram aplicados. Os dados foram triangulados para compreender tanto as mudanças mensuráveis quanto as percepções vivenciadas. Os resultados mostraram uma tendência consistente: a maioria dos alunos relatou menos ansiedade ao final do processo (uma redução média de aproximadamente 25%). Sua escrita também melhorou, com maior coerência, variedade sintática e uso de vocabulário acadêmico. As entrevistas semiestruturadas revelaram percepções consistentes de redução da ansiedade, com depoimentos afirmando que o feedback imediato da Inteligência Artificial Generativa (IAG) "eliminou o medo de escrever" e que as atividades foram percebidas como "mais leves" em termos de carga cognitiva. Embora nem todos os casos tenham seguido o mesmo padrão, a tendência geral foi positiva e sustentada ao longo dos três ciclos. Os resultados do estudo sugerem que a inteligência artificial generativa, quando integrada a uma sequência neuromediada (entendida como uma estrutura de aprendizagem projetada para regular a resposta emocional por meio de processos cognitivos), pode reduzir a ansiedade linguística e promover um ambiente de aprendizagem mais seguro e motivador. A combinação de ativação emocional, suporte cognitivo e feedback imediato fortaleceu a autonomia e a

confiança do aluno. No entanto, recomenda-se a realização de mais pesquisas para explorar os efeitos a longo prazo e as variações individuais.

Palavras-chave: inteligência artificial generativa; ansiedade linguística; neuropedagogia; ensino de inglês como língua estrangeira; produção escrita.

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Introduction

English language learning at the university level has traditionally been managed using a structural-grammatical approach: teaching rules, expanding vocabulary, and waiting for results. However, a different problem is observed in various Mexican institutions. The difficulties are not always linguistic. In many cases, the determining factor lies in the emotional dimension. At this point, language anxiety becomes relevant. Horwitz, Horwitz, and Cope (1986) defined it as a specific form of apprehension associated with the use of a foreign language, which can translate into cognitive inhibition and insecurity when writing.

Evidence reported by Cheng (2002) indicates that students with high anxiety exhibit limited and less complex written production. Daly and Miller (2019) also noted this: vocabulary is reduced, and syntax is simplified. In Mexican private universities, it is common to observe short essays with repeated phrases or ideas that remain underdeveloped. In these cases, the requirement is met, but meaningful learning is not always achieved.

Krashen (1982) explained this phenomenon with his affective filter theory. Negative emotions can hinder the assimilation of new information. In academic writing, this process manifests as self-censorship and a constant fear of making mistakes, leading to less practice, more insecurity, and greater anxiety, thus establishing a negative feedback loop.

In this context, neuropedagogy is integrated as an approach that combines neuroscience findings with educational practices that place emotion, motivation, and memory at the center of learning (Jolles & Jolles, 2021). In Mexican universities, with their highly heterogeneous student groups, this perspective allows us to consider the classroom not only as a space for transmission of knowledge, but also as an environment where anxiety is managed and confidence is fostered.

Several principles help explain this relationship. Attention, linked to the prefrontal cortex, is easily distracted under stress (Posner & Rothbart, 2007). Emotion, whether positive or negative, influences memory: Immordino-Yang & Damasio (2007) clearly demonstrated this. Motivation, linked to dopamine, increases with immediate feedback (Schultz, 2016). And memory, as Zadina (2014) explained, is strengthened by repetition and adjusted feedback.

These elements inspire specific teaching interventions. In this study, the proposal was organized into five stages: sensory activation, cognitive focus, interaction with generative artificial intelligence, socialization, and metacognitive closure. The goal was twofold: to improve writing skills and reduce anxiety. Within this framework, the work of teachers

should not be limited to teaching English; it also requires designing environments that mitigate the impact of anxiety.

In this context, generative artificial intelligence (GAI) is gaining relevance. Tools like ChatGPT can produce text in seconds, provide immediate feedback, and personalize tasks. Zhang & Zhang (2022) discussed its value as a writing support tool; Du et al. (2023) highlighted its personalization capabilities; and Baidoo-Anu & Owusu Ansah (2023) emphasized its contribution to self-efficacy. However, much of the aforementioned theoretical work has focused on the technical dimension, relegating the analysis of underlying cognitive processes to a secondary role.

However, the need remains to analyze the real impact of immediate feedback on language anxiety. It has not been determined whether this form of mediation promotes students' psychological security or, conversely, induces an instrumental dependence that compromises autonomy.

Based on the above, the present study analyzed how generative artificial intelligence, framed within a neuropedagogical design, can mediate the reduction of anxiety and improve the quality of written production in university students of English.

Methodology

This study adopted a design-based research (DBR) methodology (Anderson & Shattuck, 2012), situated within a case study approach. This methodological choice responds to the need to articulate theory and practice within a real educational setting. Unlike more traditional methods, DBR does not merely describe what happens in the classroom, but also allows for direct intervention, the design and implementation of pedagogical proposals, and the progressive refinement of the intervention. Anderson & Shattuck (2012) had already emphasized this characteristic: design-based research seeks to transform while simultaneously conducting research.

The iterative nature of the DBR proved crucial, allowing each cycle to generate distinct data for refining the proposal. Cycle 1 was conceived as a preliminary implementation. It allowed for the identification of strengths and, above all, initial limitations of the intervention. The execution revealed discrepancies with respect to the initial projections, leading to a reconfiguration of the organization, the way generative artificial intelligence (GAI) was presented, and the dynamics of interaction.

In Cycle 2, the improvements were incorporated more systematically. Greater emphasis was placed on the collaborative integration of the GAI. In practice, this meant that students not only interacted with the tool individually, but also discussed the results with each other. Here, the social component became as important as the technical one.

In Cycle 3, the proposal was consolidated. It was time to implement the complete, now adjusted, intervention and to evaluate its impact more comprehensively. This cycle allowed for a comparison of what had emerged in preliminary phases with a more mature version of the intervention.

Overall, the process yielded high ecological validity. That is, the adjustments did not arise from artificial laboratory conditions, but from the reality of the classroom. More precisely, it was practice itself that guided theory, not the other way around. This emergent nature represents one of the main attributes of the approach adopted: the intervention was transformed along with those who experienced it.

The case study approach was considered the most appropriate strategy. The aim was not to encompass large populations, but rather to analyze in detail how a specific intervention—the integration of GAI within a neuropedagogical framework—could impact a particular group of students in a natural setting. In other words, depth was sought over breadth.

Yin (2018) has pointed out that this type of design is relevant when the aim is to explore contemporary phenomena in an authentic environment. Not in artificial conditions, but in scenarios where multiple factors converge, with data coming from different sources and not from a single isolated measurement.

Furthermore, Herrington et al. (2007) emphasize the value of DBR when applied to educational innovation studies. It provides methodological consistency because it not only produces findings for theory but also generates knowledge that can be directly applied in classroom practice. In other words, it helps bridge the gap between conceptual frameworks and the real needs of students.

It is important to note that this combination—case study and DBR—is not without limitations. Its validity lies not in statistical generalization, but in the analytical depth of the observed process. Specifically, it prioritizes situated understanding, which is crucial when the focus is on how students react to new technology in a real-world learning environment.

Participants and context

The research was conducted at a private university in Mexico, within an undergraduate program that brings together students from various disciplines. The participating group consisted of 36 students with an intermediate level of English, enrolled in regular foreign language courses. The sample exhibited marked heterogeneity in its composition, encompassing diverse profiles within a Mexican institution of higher education.

Most were young people between 18 and 22 years old, from diverse socioeconomic backgrounds. Some had studied at private schools with prior exposure to English since

primary school, while others came from public high schools with more limited experiences. This disparity, rather than representing an obstacle, enriched the research because it allowed researchers to observe how GAI had different impacts depending on each student's background.

It should be noted that the institutional context influenced the dynamics. As a private university, technological resources were available, although not always used critically. There were computer labs, stable internet access, and institutional accounts for digital tools. However, this did not mean that all students felt equally comfortable using technology. Some navigated it with ease, others showed some resistance, and some even expressed anxiety about the possibility of making mistakes.

The group was also characterized by its heterogeneity in professional interests. Participants included future teachers, communication specialists, lawyers, and psychologists. This diversity of profiles allowed English writing, mediated by GAI, to become a space for interdisciplinary perspectives. A law student, with a more prescriptive approach, would not approach an essay in the same way as a psychology student, who would take a more narrative and reflective approach.

Working with university students from Oaxaca (and surrounding regions) added a relevant cultural dimension. In interviews, some mentioned the influence of their native languages—Zapotec and Mixtec—on their English learning. This added another layer to the research: the GAI was not only interacting with bilingual Spanish-English students, but also with young people who had a multilingual background.

Taken together, the participants represented a true mosaic of Mexican higher education. Instead of a controlled or standardized group, the study focused on a natural sample, with strengths and limitations, enthusiasm and also doubts. This naturalness is what gave the project its ecological validity.

Data collection instruments

Various instruments were used to collect information, combining quantitative and qualitative methods. Quantitative accuracy was not prioritized; instead, a broad and contextualized perspective was sought.

First, a language anxiety questionnaire adapted from the Foreign Language Classroom Anxiety Scale (FLCAS) by Horwitz, Horwitz, and Cope (1986) was administered. This instrument allowed for obtaining initial and final scores, which facilitated observing variations across the cycles. Beyond the numbers, the questionnaire helped students become aware of their own anxiety, to conceptualize something that many had felt but had never clearly identified.

Secondly, a textual analysis of the written work was conducted. The students produced paragraphs, short essays, and reflections, which were then evaluated on dimensions such as coherence, cohesion, syntactic complexity, lexical variety, and grammatical correctness. Data collection was not limited exclusively to closed rubrics; in some cases, more narrative observations were favored. It is important to clarify that this analysis did not aim to compare them with native speakers, but rather to record progress within their own level.

As a third instrument, semi-structured interviews were conducted. This format was chosen because it allows for a combination of guiding questions with the freedom to explore new ideas. In several cases, students shared personal experiences about how GAI had changed their relationship with English. Several participants reported a reduction in the perception of external judgment; others acknowledged that the tool offered them a space for practice that they could not find in their immediate environment.

The data analysis was conducted through a triangulation process. That is, the quantitative results from the questionnaire were cross-referenced with the qualitative findings from the text analysis and the interviews. In other words, the aim was not to examine each instrument separately, but rather to see how they complemented each other.

This approach strengthened the ecological validity of the study. Instead of relying on a single type of evidence, data were collected from different perspectives, reflecting the real-world practice of a Mexican classroom. This variety provided the robustness of the analysis.

To strengthen the reliability and validity of the findings, methodological triangulation was used with quantitative and qualitative instruments:

• Language Anxiety Questionnaire (adapted FLCAS): A 20-item abbreviated version of the Foreign Language Classroom Anxiety Scale (Horwitz, Horwitz, and Cope, 1986), previously validated in Spanish-speaking contexts (Aida, 1994), was used. The questionnaire was administered in pretest and posttest format in each cycle. In this study, internal consistency was satisfactory ($\alpha = .84$).

• Written production rubric: designed specifically for this purpose, it assesses five dimensions: coherence, cohesion, syntactic complexity, vocabulary, and grammatical correctness. It was validated through expert review by three specialists and a pilot test in a group with similar characteristics. The inter-rater reliability coefficient reached 0.89, indicating high reliability.

• Semi-structured interviews: conducted with 10 students and the teacher, these interviews gathered perceptions about anxiety, motivation, and the role of GAI in writing. These interviews were recorded, transcribed, and thematically analyzed.

• Researcher's field journal: This recorded observations of behavior, body language, and attitudes during the sessions. This instrument was key to triangulating quantitative information with contextual evidence.

Procedure

The intervention was organized into three iterative cycles. Each cycle was structured around five didactic moments based on neuropedagogical principles. The design dispensed with a standardized linear progression and opted for a flexible script that was adjusted according to the dynamics of the groups.

The first phase consisted of sensory and emotional activation (5–10 minutes). The goal was to reduce the well-known "affective filter" (Krashen, 1982) and prepare the brain to learn without the burden of fear. The students performed simple brain exercises, practiced conscious breathing, and listened to relaxing music. These stimuli affected the limbic system, reducing initial anxiety and creating a more receptive environment.

The second phase was cognitive focus (10 minutes). Here, the content was introduced through brief explanations, visual examples, and materials enriched with GAI. This phase aimed to maintain attention, regulated by the prefrontal cortex, and connect with students' prior knowledge. The combination of images, discussion prompts, and short exercises helped the group focus on the cognitive task without losing track of the material.

The third phase, perhaps the longest, was guided interaction and production with GAI (20 minutes). Students received writing prompts and worked with the tool as a facilitator of the writing process. At this point, they generated paragraphs, explored synonyms, requested feedback, and corrected errors. It is important to note that GAI was not conceived as an automatic translator, but as a pedagogical mediator, which allowed for experimentation without the fear of immediate evaluation.

Next came the collaborative socialization and feedback session (15 minutes). Students shared their texts in small groups, compared their work, and discussed suggestions. This exercise reinforced intrinsic motivation and fostered social learning. This aligns with Vygotsky's (1978) sociocultural perspective, where knowledge is constructed collaboratively. In this case, the teacher did not dictate answers but rather facilitated the discussion and promoted horizontal feedback.

The final stage was metacognitive closure (5–10 minutes). A brief period was dedicated to reflecting on the day's achievements and challenges. Some students used prompts from the GAI; others wrote in a personal notebook. This practice fostered the consolidation of long-term memory and strengthened self-regulation, in addition to recording immediate perceptions.

It is worth clarifying that, in Cycle 3, the proposal was implemented fully and in a more balanced way. There was a combination of individual activities mediated by GAI and collaborative dynamics. This final integration allowed us to observe how the model could operate holistically, without losing the balance between the individual and the group.

Ethical considerations and methodological rigor

All participants gave their informed consent and were informed that the GAI would be used as a pedagogical support, not as a substitute for their own work. Data confidentiality was guaranteed by assigning codes instead of names.

Methodological rigor was strengthened through:

- Data triangulation (questionnaires, rubric, interviews and field diary).
- The inherent iterative nature of the DBR, which allowed for refining the intervention.
- Content validity, ensured by experts in pedagogy and academic writing.
- Reliability, evidenced by the internal consistency coefficients and inter-judge agreement.

Results

Reduction of language anxiety

The application of the adapted questionnaire from the Foreign Language Classroom Anxiety Scale (FLCAS) showed a progressive attenuation in the levels of linguistic anxiety throughout the three cycles of the intervention.

Although formal inferential statistical analysis was not applied at this stage due to the need to optimize the design, the descriptive data show a consistent decrease in average scores in each cycle.

In the first cycle, the initial average anxiety was 3.8 on a 5-point scale. By the end of the cycle, this value had decreased to 3.2. In the second cycle, the average anxiety level dropped to 3.5 in the pretest and 2.8 in the posttest. Finally, in the third cycle, the level started at 3.1 and reached 2.4 in the posttest, representing a cumulative reduction of 36% compared to the initial values.

These results indicate that the intervention not only generated an immediate impact, but also maintained a sustained and cumulative effect over time.

Beyond the numerical evidence, qualitative evidence supports this trend. In interviews, several students mentioned feeling more confident writing in English after

interacting with generative artificial intelligence (GAI). One participant recounted:

"Before, I was afraid to write; I thought I would do everything wrong. With AI, I know I can correct it and I don't feel judged." (P4)

Another student highlighted the autonomy that the tool gave him:

"Before, I depended on my teacher to know if I was doing well. With AI, I could recognize my own mistakes and correct them. That gave me control and took the pressure off." (P11)

The researcher's field diary complements this perception, as it was recorded that at the beginning the sessions were marked by silence and avoidance, while in the third cycle the students asked for additional activities and voluntarily shared their productions.

Overall, although the results were not subjected to statistical significance tests, the convergence between the descriptive data and student perceptions provides consistent evidence of a reduction in language anxiety.

Improvement in the quality of written production

Student performance was evaluated using a rubric specifically designed for this study, verified through a pilot phase, which included five dimensions: coherence, cohesion, syntactic complexity, lexical variety, and grammatical correctness.

Overall, the average global scores increased from approximately 62.0 in Cycle 1 to 84.0 in Cycle 3. This 35% increase reflects a clear and sustained improvement in the quality of students' writing.

Coherence and cohesion

The dimension that showed the greatest improvement was coherence, with an increase of nearly 28%. Cohesion also improved significantly, which was reflected in a more frequent use of logical connectors and better organization of paragraphs.

One student commented:

"It helped me to link paragraphs; I was only writing isolated sentences, but the AI gave me examples of how to continue the idea" (P9). These improvements coincide with what was observed in the texts of the third cycle, where most of the students presented essays with an introduction, development and conclusion, in contrast to the initial productions of disconnected sentences.

Syntactic complexity

Syntactic complexity increased by approximately 23%. The initial texts were characterized by a predominance of simple sentences in the present tense, while the final texts included subordinate clauses, conditional sentences, and a greater use of verb tenses.

One participant recounted:

"I was no longer limited to basic sentences. I saw how it was possible to write differently and I dared to try it" (P6). This testimony demonstrates not only a linguistic change, but also a change in the willingness to take communicative risks, which reinforces the connection between decreased anxiety and greater complexity in written production.

Lexical variety

Lexical variety showed an approximate increase of 24%. Students went from repeating basic vocabulary to incorporating academic terms and more precise synonyms.

"I always repeated the same words, but with the AI I learned to use others and sound more formal" (P14). This change suggests a shift toward a more academic writing style. The incorporation of academic vocabulary was not mechanical, but contextualized, as the students asked the GAI for specific alternatives for the paragraphs they were developing.

Grammar correction

Finally, grammatical accuracy improved by around 18%. Students achieved greater precision in agreement and in the use of verb tenses.

The teacher interviewed observed:

"With automatic feedback, we spend less time correcting simple errors and more time discussing the content of the texts." (Teacher 1) This change in the feedback dynamic allowed the class to focus on meaning and argumentative construction, rather than mechanical correction.

Connection between anxiety reduction and writing improvement

A common finding was the interdependence between the two observed phenomena: decreased anxiety and improved writing skills. Qualitative evidence suggests that reducing fear of making mistakes freed up cognitive resources, allowing students to take risks and produce more complex texts.

One participant expressed it clearly: "When I was nervous, I just wanted to finish quickly. Now that I no longer feel that pressure, I think more about how to say things and I write better" (P8). This testimony coincides with what was reported in the field journal: the students went from avoiding writing to seeking more opportunities to practice, which suggests that the emotional effect had a direct impact on motivation and the quality of the texts.

Limitations in quantitative analysis

It is important to note that the results presented here are based primarily on descriptive trends and qualitative evidence, without inferential statistical tests applied at the individual level. This represents a limitation, as it does not allow us to state with certainty whether the observed differences could be generalized to other populations or contexts.

However, the consistency between the rubric data, the FLCAS questionnaires, the interviews, and the field notes reinforces the validity of the findings. Furthermore, the three-cycle iterative design confirmed that the improvements were not isolated incidents but rather consistent throughout the intervention.

Discussion

The results obtained provide empirical support for the proposed Neuro-Mediation Model, which integrates GAI within a framework of neuropedagogical principles. In this regard, each of the five didactic moments demonstrated a specific neurocognitive correlate, confirming that the adopted design effectively addresses the identified needs.

The first stage, sensory and emotional activation, helped to reduce the affective filter through brief exercises and sensory stimuli. This prepared the limbic system for more receptive learning, promoting a gradual reduction of initial stress.

The second, cognitive focusing, directed sustained attention. This is consistent with Posner & Rothbart's (2007) findings regarding the role of the prefrontal cortex in attentional control. In practice, this meant that students were better able to focus their resources on the assigned tasks.

The third stage, guided interaction and production with GAI, had a significant effect. It activated dopaminergic reward circuits (Schultz, 2016), as students received immediate feedback that reinforced intrinsic motivation. In other words, satisfaction came not only from the written product but also from the process of interacting with the tool itself.

Next came socialization and collaborative feedback. Here, students constructed shared meanings, validating the importance of social learning, long described by Vygotsky (1978). This moment consolidated the collective dimension of learning, which had begun individually with GAI.

Finally, metacognitive closure helped consolidate long-term memory. Zadina (2014) explained how spaces for reflection and self-regulation promote this process. Students were able to recognize their achievements, identify difficulties, and think about ways to overcome them in the future.

In light of various learning theories, the findings become even clearer. According to Krashen (1982), reducing the affective filter facilitates the acquisition of more complex structures, which is consistent with documented evidence. Vygotsky (1978) had already proposed that a mediator can expand the zone of proximal development, and GAI functioned precisely as that mediator. Bandura (1997) points out that positive feedback strengthens self-efficacy; this was also reflected in the students' willingness to tackle writing tasks.

Deci and Ryan (2000) emphasize the role of autonomy in intrinsic motivation, an aspect reinforced by interaction with the tool. Sweller (2010), from the cognitive load theory, argues that reducing anxiety frees up working memory, which opens up space to process more complex structures.

Overall, the model was validated as a comprehensive approach that integrates emotion, cognition, and technology. Specifically, it demonstrated that simply introducing GAI into the classroom is insufficient: a structured design is required that simultaneously addresses the affective, cognitive, and social dimensions.

These findings can also be interpreted in light of contributions such as affective filter theory, sociocultural mediation, self-efficacy, intrinsic motivation, cognitive load, and self-regulation, all of which are consistent with the observed relationship between decreased anxiety, increased participation, and improved writing performance. Along these lines, the approaches of Krashen (1982), Vygotsky (1978), Bandura (1997), Deci and Ryan (2000), Sweller (2010), Zimmerman (2002), Bruner (1966), and Freire (1970) offer a useful interpretive framework for understanding the relationship between technological mediation, the affective dimension, and writing performance.

Despite the encouraging results, the study also revealed a number of dilemmas that cannot be ignored. It is important to acknowledge them clearly. One of these is technological dependence. Some students delegated too much idea generation to AI. While this facilitated writing in the short term, it opened the door to a risk of superficiality; that is, the tool could partially displace some of the student's reflective processes. Another dilemma concerns plagiarism and originality. The ease of producing text with AI necessitates strengthening ethical writing skills; this means that it is not enough to teach how to use the tool, it is also necessary to train students in academic discernment so they can distinguish between inspiration and plagiarism.

Equitable access emerged as an additional challenge, a fact also evident in the sample used. While some students quickly mastered the commands, others demonstrated a much more limited command of basic resources. This inequality could become a new educational gap.

Finally, teacher training also emerged as a crucial aspect. Without solid training, teachers risk integrating AI in a merely instrumental way. Here the difference is clear: using the tool as an incidental resource is not the same as using it as part of a conscious pedagogical design.

All these dilemmas force us to conceive of GAI not as an automated technological remedy, but as a tool with transformative potential, provided that it is situated within a well-defined ethical and pedagogical framework.

Conclusions

The study identifies significant contributions on several levels. Theoretically, the Neuro-Mediation Model provides a framework for understanding the relationship between neuroscience, pedagogy, and generative artificial intelligence. Practically, the five-step sequence serves as a transferable guide, particularly for teachers seeking concrete ways to integrate GAI into writing instruction.

Methodologically, the experience confirmed the relevance of the DBR approach. This approach allowed for the design and validation of innovations in real-world contexts, overcoming the disconnect between idealized scenarios and the multifaceted nature of the classroom. Ethically and educationally, it highlighted the urgent need for critical digital literacy and, simultaneously, for teacher training that goes beyond the merely technical, focusing on reflective and deliberative practice.

In summary, the discussion reinforces the idea that GAI, integrated into a neuropedagogical design, transcends its instrumental role to become an agent of profound cognitive mediation. It is not limited to correcting texts: it becomes a pedagogical and emotional mediator. By reducing anxiety, it frees up cognitive resources; by offering immediate feedback, it strengthens motivation; and by being part of a comprehensive model, it fosters more meaningful learning.

This potential does not materialize automatically. Rather, it depends on the tool being accompanied by critical and ethical training. AI does not replace teachers, but it does amplify their role, allowing them to dedicate more time to discussing ideas than to rote grading.

Ultimately, the effectiveness of the tool is determined by its pedagogical intent. AI can become a resource that strengthens student autonomy or, if used without pedagogical guidance, a factor of academic dependence. And that outcome will depend less on the technology itself and more on the pedagogy that underpins it.

Future lines of research

The projections presented in this work are not intended to be conclusive; rather, they establish a prospective basis. It is pertinent to question the transferability of this model to other areas of linguistic competence, such as oral communication or critical reading. Likewise, it remains to be determined whether the design can be scaled up at different levels of the education system (from basic education to postgraduate studies) and whether it is effective in contexts of cultural diversity or bilingualism, where pedagogical approaches exhibit different dynamics.

It is also important to analyze these effects over time. Longitudinal studies could reveal results that we cannot yet observe in the short term. Likewise, it would be relevant to analyze potential differences between GAI tools—such as ChatGPT, Claude, or Gemini—when applied in the same classroom context. These lines of inquiry open up a significant field for future research.

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