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## Abstract

Low English proficiency persists as a structural problem in Ecuadorian secondary education, and neurodidactics, the interdisciplinary field that links cognitive neuroscience with instructional design, offers brain-compatible principles for improving foreign language acquisition. This study examined whether a programme built around six neurodidactic strategies could raise English as a foreign language (EFL) communicative competence among first-year baccalaureate students at Unidad Educativa José Domingo de Santistevan, Junta de Beneficencia de Guayaquil, Ecuador, between October 2024 and April 2025. We used a quasi-experimental design with non-equivalent pre-test and post-test groups: the experimental group (sections A and B, $n = 44$) received the strategies over seven months, whereas the control group (sections C and D, $n = 44$) followed standard instruction. Gain scores (post-test minus pre-test) were compared with independent-samples t-tests under Bonferroni correction (per-comparison $\alpha = .010$), and effect sizes were estimated through Cohen's d with bootstrap confidence intervals and partial eta squared from ANCOVA, adjusting for the pre-test. With 44 participants per group the design reached power of .96 at $d = 0.80$, and weekly observation in both classrooms limited Hawthorne effects. The experimental group improved markedly across all five dimensions (overall $\Delta M = 5.35$ versus 1.22; $t(86) = 6.19$, $p < .001$; $d = 1.32$, 95% CI [0.86, 1.78]; partial $\eta^2 = .318$), and every comparison survived correction. Taken together, the findings indicate that systematic neurodidactic teaching can yield substantial EFL gains in Ecuadorian adolescents, with clear implications for teacher education and curriculum design.

**Keywords:** *neurodidactics; EFL; baccalaureate; neuroplasticity; gamification; multisensory learning; communicative competence; Ecuador.*

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# *Estrategias neurodidácticas para el aprendizaje del inglés como lengua extranjera en estudiantes de Primero de Bachillerato: un estudio cuasiexperimental*


## Resumen

El bajo dominio del inglés es un problema estructural en la secundaria ecuatoriana, y la neurodidáctica, que vincula la neurociencia cognitiva con el diseño instruccional, ofrece principios afines al cerebro para optimizar el aprendizaje de lenguas extranjeras. Se examinó el efecto de un programa de seis estrategias neurodidácticas sobre la competencia comunicativa en inglés de estudiantes de primero de bachillerato de la Unidad Educativa José Domingo de Santistevan (Guayaquil, Ecuador), durante el año lectivo 2024-2025. Se aplicó un diseño cuasiexperimental con grupos no equivalentes (pretest-postest): el grupo experimental (paralelos A y B, $n = 44$) recibió las estrategias durante siete meses y el control (paralelos C y D, $n = 44$) siguió la enseñanza habitual. Las puntuaciones de ganancia se compararon mediante pruebas t independientes con corrección de Bonferroni ($\alpha = .010$), y los tamaños del efecto se estimaron con la d de Cohen, intervalos bootstrap y el eta cuadrado parcial de un ANCOVA ajustado por el pretest. Con 44 participantes por grupo se alcanzó una potencia de .96 con $d = 0.80$, y la observación semanal en ambas aulas limitó el efecto Hawthorne. El grupo experimental mejoró notablemente en las cinco dimensiones (global $\Delta M = 5.35$ frente a 1.22; $t(86) = 6.19$, $p < .001$; $d = 1.32$, IC 95 % [0.86, 1.78]; $\eta^2$ parcial = .318), y todas superaron la corrección. En suma, la enseñanza neurodidáctica sistemática produce mejoras sustanciales en el inglés de los adolescentes ecuatorianos, con implicaciones claras para la formación docente y el diseño curricular.


**Palabras clave:** *neurodidáctica; inglés como lengua extranjera; bachillerato; neuroplasticidad; gamificación; aprendizaje multisensorial; competencia comunicativa; Ecuador.*

## 1. INTRODUCTION

English proficiency in Ecuadorian secondary education sits well below institutional targets. According to the Ministerio de Educación del Ecuador (2023), the average English competence of students enrolled in the Bachillerato General Unificado (BGU) falls between A1 and A2 on the Common European Framework of Reference for Languages (CEFR), which is below the B1 level set by national policy. This gap reflects how persistently grammar-translation and passive-reception methods still dominate many classrooms, and it points to a clear need for evidence-based alternatives.

Over the past two decades, the meeting of cognitive neuroscience and educational science has given rise to the interdisciplinary field of neurodidactics, also known as brain-based learning or mind, brain and education (MBE) science. The field seeks to turn neuroscientific findings into usable instructional principles. Mora (2013) defines neuroeducation as the discipline that examines brain mechanisms in order to improve teaching, whereas Tokuhama-Espinosa (2011) locates MBE science at the meeting point of neurology, cognitive psychology and pedagogy. Neurodidactics is therefore not a loose set of techniques but a principled framework that draws on converging evidence from neuroimaging, cognitive psychology and learning science to identify the conditions under which the brain encodes, consolidates and retrieves information most effectively.

In foreign language acquisition, neuroscience has accumulated substantial evidence on the roles of neuroplasticity, emotion, dopaminergic reward and social interaction. Using voxel-based morphometry and diffusion tensor imaging, Li et al. (2014) showed that second-language (L2) experience induces measurable structural changes in Broca's and Wernicke's areas, the corpus callosum and the hippocampus, with the magnitude of those changes tracking proficiency. These findings weaken rigid readings of Lenneberg's (1967) critical period hypothesis. Tyng et al. (2017) documented that the amygdala modulates hippocampal memory consolidation according to emotional salience, providing a neurological basis for emotion-enhanced learning. Ripollés et al. (2018) added causal pharmacological evidence that synaptic dopamine availability governs the rate at which newly learned words are consolidated into long-term memory, which directly implicates reward-based strategies in L2 lexical acquisition.

Despite this body of work, the systematic translation of neuroscientific principles into EFL classrooms has been limited in Ecuador. Most quasi-experimental neurodidactic intervention studies have been carried out in Europe, East Asia and North America (Barbosa, 2021; Solano & Vega, 2024), which leaves a notable empirical gap. The present study addresses that gap at Unidad Educativa José Domingo de Santistevan, a public institution of the Junta de Beneficencia de Guayaquil located in the historic centre of the city. The institution runs an extended school day (07:45 to 15:45), treats English as a designated educational hallmark and devotes more instructional time to it than the national BGU standard, conditions that make intensive pedagogical interventions feasible.

### *1.1 Research objective*

The study set out to determine the effect of a seven-month programme of six neurodidactic strategies on EFL communicative competence in First-Year BGU students at Unidad Educativa José Domingo de Santistevan between October 2024 and April 2025. Communicative competence was grounded theoretically in the work of Canale and Swain (1980) and Canale (1983), and was operationalised through five measurable skill dimensions aligned with the CEFR and the Cambridge assessment framework: lexical competence, grammatical competence, listening comprehension, oral production and written production.

### *1.2 Hypotheses*

**$H_1$.** Students in the EG who received the neurodidactic programme would obtain significantly higher post-test gain scores on all five dimensions of the English communicative competence test than students in the CG, after Bonferroni correction (per-comparison $\alpha = .010$).

**$H_0$.** There would be no statistically significant difference in EFL communicative competence gain scores between the EG and the CG following the intervention.

## 2. THEORETICAL FRAMEWORK

### *2.1 Neurodidactics: conceptual foundations*

Neurodidactics is an interdisciplinary field positioned at the intersection of neuroscience, cognitive psychology, applied linguistics and pedagogy. Its central aim is to apply knowledge of brain functioning to the design of instructional strategies that improve learning. Barbosa (2021) and Tokuhama-Espinosa (2011) characterise it as an evidence-based framework that translates findings from neurobiology into concrete pedagogical applications rather than as a fixed method.

A foundational principle of the field is neuroplasticity, the capacity of the brain to reorganise structurally and functionally in response to experience. Through structural neuroimaging, Li et al. (2014) demonstrated that L2 learning induces rapid and sustained changes in grey matter volume and white matter integrity in language-processing regions, with the changes sensitive to proficiency and linguistic distance. This evidence indicates that the adolescent brain retains enough plasticity for productive L2 acquisition, and it requires instructional design to attend to the conditions that most reliably trigger such plastic change.

Communicative competence, the primary construct measured here, is grounded in the model of Canale and Swain (1980), who proposed three components: grammatical competence (mastery of phonological, lexical and syntactic rules), sociolinguistic competence (the contextual appropriateness of language use) and strategic competence (the repair strategies that sustain communication). Canale (1983) subsequently added discourse competence, the cohesion and coherence achieved across utterances. Because that theoretical model describes underlying abilities rather than testable performances, the present study assessed competence through five observable skill dimensions drawn from the CEFR and the Cambridge framework (lexical, grammatical, listening, oral and written), each of which recruits a combination of these competences. This separation between the theoretical construct and its operational dimensions anchors both the assessment design and the pedagogical targets of the intervention.

### *2.2 Emotion, attention and memory in L2 acquisition*

Emotions are not peripheral to learning; they are central mechanisms of memory consolidation. In a comprehensive review in Frontiers in Psychology, Tyng et al. (2017) reported that the amygdala modulates consolidation by amplifying hippocampal encoding signals when stimuli carry emotional salience. For EFL instruction, this implies that linguistic content presented with positive emotional loading is encoded more durably than neutral, decontextualised rule presentation.

Ripollés et al. (2018), in a double-blind pharmacological study published in eLife, established causal evidence that intrinsically regulated word learning is dopamine dependent. A dopaminergic precursor (levodopa) increased learning rates and pleasantness ratings, whereas a dopamine receptor antagonist (risperidone) reduced them, with consolidation benefits that persisted beyond a 24-hour window and were amplified in individuals with high reward sensitivity. These results trace a direct neurochemical pathway from reward-activating instructional strategies to L2 lexical consolidation.

Krashen's (1982) Affective Filter Hypothesis proposed that anxiety, low motivation and lack of confidence raise a psychological barrier that impedes the absorption of comprehensible input. The Input Hypothesis has since been questioned on cognitive-ecological grounds: Atkinson (2010), in his extended and embodied account of second language acquisition, argues that acquisition unfolds through active, socially situated interaction between mind, body and world rather than through passive reception of input. Even so, the affective component of Krashen's model converges with current neuroscience, since reducing cortisol-mediated stress and fostering positive affective states is a necessary, if not sufficient, condition for optimal L2 acquisition.

### *2.3 Neuroscientific rationale for the six strategy classes*

**Multisensory learning.** The simultaneous activation of visual, auditory and kinaesthetic channels recruits distributed cortical networks and generates redundant synaptic encoding that strengthens retrieval pathways (Tyng et al., 2017). Paivio's (1986) dual-coding theory supplies the complementary pedagogical principle, since verbal and imagistic codes activated together produce stronger memory traces than either alone.

**Emotional storytelling.** Affectively loaded narratives trigger amygdalar modulation of hippocampal encoding and convert linguistic content into personally meaningful material (Tyng et al., 2017). Baumeister et al. (2017) showed that emotional memory is stronger in the first language than in the second, which suggests that bridging the affective distance of the L2 through narrative is a particularly powerful lever for EFL consolidation.

**Linguistic gamification.** Reward-structured activities engage the mesolimbic dopaminergic circuit. Ripollés et al. (2018) demonstrated the causal dopaminergic mediation of word consolidation, and Cheng et al. (2025), in a quasi-experimental study with 220 EFL undergraduates, found significant gains in reading proficiency under gamification, with the personally enjoyed dimension of foreign-language enjoyment playing a central role alongside improvements in focus, collaboration and communication.

**Music and rhythm in the L2.** Patel's (2011) OPERA hypothesis specifies five conditions under which musical training transfers to language: overlap of neural resources used by both music and speech, the higher processing precision that music demands, the strong positive emotion that musical activity elicits, the frequent repetition involved in musical practice, and the focused attention it requires. Moreno et al. (2011) found that 20 days of music training produced verbal intelligence gains in 90% of the trained children, which confirms a rapid transfer from musical to linguistic processing.

**Neurostructured cooperative learning.** Social interaction activates the mirror neuron system (Rizzolatti & Craighero, 2004), which underlies the imitation-based learning that is fundamental to communicative L2 production. Vygotsky's (1978) Zone of Proximal Development provides the scaffolding logic, and the neuroimaging evidence of Blakemore (2008) that the adolescent social brain undergoes reorganisation, with heightened sensitivity to peer appraisal and group belonging, makes cooperative structures well aligned with adolescent development.

**Embodied learning and extended TPR.** Physical movement elevates brain-derived neurotrophic factor (BDNF), which promotes hippocampal neurogenesis and synaptic plasticity. In a nine-month randomised controlled trial published in Pediatrics, Hillman et al. (2014) found that a physical activity intervention improved inhibitory control and cognitive flexibility ($d = 0.27$ to $0.34$) with associated increases in P3 event-related potential amplitude, evidence of a direct pathway from exercise to cognition that is applicable to embodied language instruction.

## 3. METHOD

### *3.1 Research design*

The study used a quantitative quasi-experimental design with a non-equivalent pre-test and post-test control group (Campbell & Stanley, 1966). Intact classroom sections were used because random assignment of individual students was not institutionally feasible. Shadish et al. (2002) and Cook and Campbell (1979) note that this design supports sound causal inference in educational settings when baseline equivalence is established and residual pre-existing differences are controlled through ANCOVA.

An a priori power analysis conducted with G*Power 3.1 (Faul et al., 2007), assuming a large effect (d = 0.80; Cohen, 1988), a two-tailed α of .05 and power of .80, indicated a minimum of 26 participants per group. The obtained sample of 44 per group (N = 88) yielded power of .96 at the assumed d = 0.80, which exceeds the .80 threshold. Post-hoc power at the smallest obtained effect (d = 1.18, oral production) reached .999, and at the overall obtained effect (d = 1.32) it exceeded .999 (G*Power 3.1; Faul et al., 2007), confirming that the sample was more than adequate. Because five simultaneous t-tests were performed, one per dimension, a Bonferroni correction set the per-comparison α at .010 (familywise α = .05).

To mitigate the Hawthorne effect, a threat to internal validity that arises when only one group receives a novel treatment, an independent research assistant visited both EG and CG classrooms each week using identical structured observation forms throughout the seven months. Both groups were therefore equally aware of being observed, which removes differential reactivity to observation as an explanation for group differences.

### *3.2 Institutional context*

The study took place at Unidad Educativa José Domingo de Santistevan, Junta de Beneficencia de Guayaquil, in the historic centre of Guayaquil, Ecuador. The institution operates an extended school day (07:45 to 15:45) organised around three pillars: high learning achievement, which includes English as a second language and ICT-integrated learning; humanistic formation through personalised tutoring and socio-affective education; and professional and vocational orientation. English teachers receive three structured in-service technical-pedagogical training sessions each year and access digital resources through an institutional partnership with the Santillana publishing house.

### *3.3 Participants*

The population comprised all four First-Year BGU sections in the 2024 to 2025 school year (N = 88). Sections A and B (n = 44) formed the EG and sections C and D (n = 44) formed the CG. The institution assigned sections before the study began, using administrative scheduling criteria that were independent of the researchers. The inclusion criteria were enrolment in First-Year BGU at the institution, completion of basic education at the same institution, and the absence of severe special educational needs requiring significant curriculum adaptation. All 88 enrolled students met these criteria, and no participants were excluded or lost during the seven-month period. Table 1 presents the demographic distribution.

**Table 1**

*Demographic Distribution of Participants by Section and Group*

| Section | Group | n | Male | Female |
|---|---|---|---|---|
| A | Experimental | 22 | 11 | 11 |
| B | Experimental | 22 | 10 | 12 |
| C | Control | 22 | 12 | 10 |
| D | Control | 22 | 11 | 11 |
| **Total** | — | **88** | **44** | **44** |

*Note.* EG = experimental group; CG = control group. Gender distribution did not differ significantly between groups, $\chi^2(1) = 0.18$, $p = .672$, $\phi = .05$. No participants were lost during the study period.

### *3.4 Baseline equivalence*

Before the intervention, independent-samples t-tests on overall pre-test scores confirmed baseline equivalence between groups ($M_{EG} = 10.51$, $SD = 2.46$; $M_{CG} = 10.44$, $SD = 2.39$; $t(86) = 0.14$, $p = .893$, $d = 0.03$, 95% CI [−0.39, 0.45]). No significant difference appeared on any individual dimension (all $p > .60$). Levene's test confirmed homogeneity of variances across all dimensions and groups (all $p > .10$), and Shapiro-Wilk tests confirmed univariate normality within each group for all dimensions (all $W \geq .962$, all $p > .05$), a result corroborated by visual inspection of Q-Q plots.

### *3.5 Instruments and scoring*

**English communicative competence test.** Adapted from the Cambridge A2 to B1 Key for Schools (KfS) assessment framework and structured across five sub-scales: lexical competence (20 items; multiple choice and gap-fill); grammatical competence (20 items; sentence transformation and error correction); listening comprehension (15 items; multiple choice based on audio recordings); oral production (a five-criterion analytic rubric covering fluency, pronunciation, vocabulary range, grammatical accuracy and communicative achievement, each scored from 0 to 4); and written production (a five-criterion analytic rubric covering task completion, coherence, vocabulary, grammar and mechanics, each scored from 0 to 4). Each sub-scale is converted to a score out of 20 points, and the overall score is the unweighted arithmetic mean of the five dimension scores (range 0 to 20). An expert panel validated the instrument ($k = 7$ doctoral-level experts in EFL and language assessment; a 4-point relevance scale across 15 evaluated criteria; Aiken's $V = .89$, 95% CI [.82, .94]; threshold $\geq .75$; Aiken, 1985). Pilot internal reliability with a comparable sample ($n = 30$) was good, with Cronbach's $\alpha = .87$ and McDonald's $\omega = .88$.

**Motivated Strategies for Learning Questionnaire (MSLQ).** An adapted EFL version (Pintrich et al., 1991) with 15 items on a 7-point Likert scale measuring intrinsic motivation and self-efficacy for English, used as a secondary outcome. Internal reliability in this sample was acceptable (α = .82).

**Teacher reflective journal.** A weekly structured qualitative log of implementation fidelity and classroom dynamics, used for descriptive triangulation of the quantitative findings.

### 1.1. *3.6 Intervention programme*

The EG received a systematic seven-month neurodidactic intervention that integrated six strategy classes (Table 2 sets out the descriptions and rationale). The CG followed standard institutional instruction with the Santillana textbook, explicit grammar teaching and traditional reading comprehension exercises, which constitute the established BGU curriculum for English. Both groups received the same total instructional time in English during the study period. Table 3 presents the chronological schedule.

**Table 2**

*Neurodidactic Strategies Implemented: Classroom Description and Neuroscientific Rationale*

| Strategy | Classroom description | Neuroscientific rationale |
|---|---|---|
| 1. Multisensory learning | Illustrated mind maps, picture-word matching, pop songs with mime and theatrical role-play. | Multimodal stimulation recruits distributed cortical networks and generates redundant synaptic encoding; multiple retrieval pathways strengthen retention (Tyng et al., 2017; Paivio, 1986). |
| 2. Emotional storytelling | Short stories and fables as scaffolding for target grammar and vocabulary; students co-create personalised narratives. | The amygdala amplifies hippocampal encoding for emotionally salient stimuli, producing durable traces (Tyng et al., 2017; Baumeister et al., 2017). |
| 3. Linguistic gamification | Kahoot!, Quizlet Live and Wordwall with weekly points, badges and leaderboards; vocabulary quests and peer-competition rounds. | Reward anticipation activates the mesolimbic dopaminergic circuit, potentiating declarative memory consolidation (Ripollés et al., 2018; Cheng et al., 2025). |
| 4. Music and rhythm in the L2 | Pedagogical raps and pop songs for verb tenses, pronunciation and vocabulary; rhythmic dictations and lyric-gap activities. | Music and language share neural substrates, and the five OPERA conditions specify how musical training transfers to speech (Patel, 2008, 2011; Moreno et al., 2011). |
| 5. Neurostructured cooperative learning | Bilingual Jigsaw and Think-Pair-Share for oral discussion; individually accountable outputs assessed with analytic rubrics. | Social interaction engages the mirror neuron system, and adolescent social-brain sensitivity favours cooperative L2 contexts (Rizzolatti & Craighero, 2004; Blakemore, 2008; Vygotsky, 1978). |
| 6. Embodied learning / extended TPR | Physical-response grammar commands, vocabulary dance and grammar dramatisations in every session. | Movement elevates BDNF, promoting hippocampal neurogenesis and gains in executive function (Hillman et al., 2014). |

*Note.* L2 = second language; TPR = Total Physical Response; BDNF = brain-derived neurotrophic factor; OPERA = overlap, precision, emotion, repetition, attention (Patel, 2011). Each strategy class was implemented across an average of 18 sessions of 45 minutes in the corresponding phase. The CG received the same session count with standard instruction.

**Table 3**

*Chronological Neurodidactic Intervention Schedule (October 2024 to April 2025)*

| Month | Phase | Strategies applied | Assessment instruments |
|---|---|---|---|
| Oct 2024 | Diagnosis | Pre-test; VAK learning-style inventory; programme orientation; baseline MSLQ. | Cambridge A2–B1 KfS adapted pre-test; MSLQ baseline |
| Nov 2024 | Phase I: sensory activation | Strategies 1 and 6: pop songs with mime, mind maps, physical vocabulary drills. | Oral production rubric; observation checklist |
| Dec 2024 | Phase II: narrative and emotion | Strategy 2: fables, guided creative writing, theatrical role-play. | Vocabulary and grammar written test |
| Jan 2025 | Phase III: gamification | Strategy 3: Kahoot!, Quizlet Live, Wordwall; weekly badge and points system. | Adapted MSLQ (mid-point); participation log |
| Feb 2025 | Phase IV: music and rhythm | Strategy 4: pedagogical raps, rhythmic dictations, lyric-gap activities, grammar karaoke. | Listening comprehension test; pronunciation rubric |
| Mar 2025 | Phase V: cooperative | Strategy 5: bilingual Jigsaw, Think-Pair-Share, group projects. | Peer co-evaluation rubric; reflective journal |
| Apr 2025 | Consolidation and post-test | Integrative review of all six strategies; final oral presentation. | Post-test (identical to pre-test); post-MSLQ; satisfaction survey |

*Note.* VAK = visual-auditory-kinaesthetic; MSLQ = Motivated Strategies for Learning Questionnaire; KfS = Key for Schools. The CG followed the standard BGU English curriculum during the same period.

### *3.7 Statistical analysis*

Data were analysed in IBM SPSS Statistics v27.0. Normality was verified with Shapiro-Wilk tests per group and dimension (all $W \geq .962$, all $p > .05$) and confirmed through Q-Q plot inspection, and homogeneity of variances was tested with Levene's test (all $p > .10$). The primary analysis comprised independent-samples t-tests on gain scores ($\Delta M$ = post-test minus pre-test) for each of the five dimensions and the overall composite, with a Bonferroni correction setting the per-comparison $\alpha$ at .010 (familywise $\alpha = .05$). ANCOVA models with the pre-test score as covariate were also run for each dimension and the overall score to adjust for residual baseline differences; the homogeneity-of-regression-slopes assumption held for all models (all Group × Covariate interaction $p > .30$). Effect sizes were computed as Cohen's d, where d equals the difference in gain means divided by the pooled standard deviation of gain scores, and as partial eta squared from the ANCOVA. As expected, the partial eta squared from ANCOVA (Table 6) is larger than the value derived from the unadjusted t-test (Table 5), because the ANCOVA removes pre-test variance from the error term and so yields a more precise estimate of the treatment effect. The two sets of values are reported separately and labelled accordingly. Bootstrap confidence intervals for d (BCa method, 2,000 iterations) and for partial eta squared (percentile method, 2,000 iterations) are reported, and all confidence intervals exclude zero.

### *3.8 Ethical considerations*

The study received ethics approval from the Institutional Review Committee of Unidad Educativa José Domingo de Santistevan (Res. No. 2024-CE-014), reported to the Junta de Beneficencia de Guayaquil. The legal guardians of all students provided written informed consent, and students provided written informed assent. Data were anonymised through alphanumeric codes before analysis. A waitlist design ensured that the CG received the full neurodidactic programme once the study concluded. The research followed the principles of the Declaration of Helsinki as adapted for educational intervention research (World Medical Association, 2013).

## 4. RESULTS

### *4.1 Pre-test and post-test comparison and t-test results*

Table 4 presents means, gain scores ($\Delta M$ = post-test minus pre-test) and independent-samples t-test statistics by group and dimension, after Bonferroni correction. The overall score is the unweighted arithmetic mean of the five dimension scores.

**Table 4**

*Pre-test and Post-test Means, Gain Scores (ΔM) and t-test Results by Group and Dimension*

| Dimension | EG pre | EG post | ΔM_EG | CG pre | ΔM_CG | t(86) |
|---|---|---|---|---|---|---|
| Lexical competence | 11.34 | 16.82 | 5.48 | 11.21 | 1.26 | 6.66 |
| Grammatical competence | 10.87 | 15.91 | 5.04 | 10.73 | 1.16 | 6.00 |
| Listening comprehension | 10.12 | 15.44 | 5.32 | 10.05 | 1.27 | 5.82 |
| Oral production | 9.78 | 14.96 | 5.18 | 9.81 | 1.13 | 5.53 |
| Written production | 10.43 | 16.17 | 5.74 | 10.39 | 1.29 | 7.08 |
| **Overall score** | **10.51** | **15.86** | **5.35** | **10.44** | **1.22** | **6.19** |

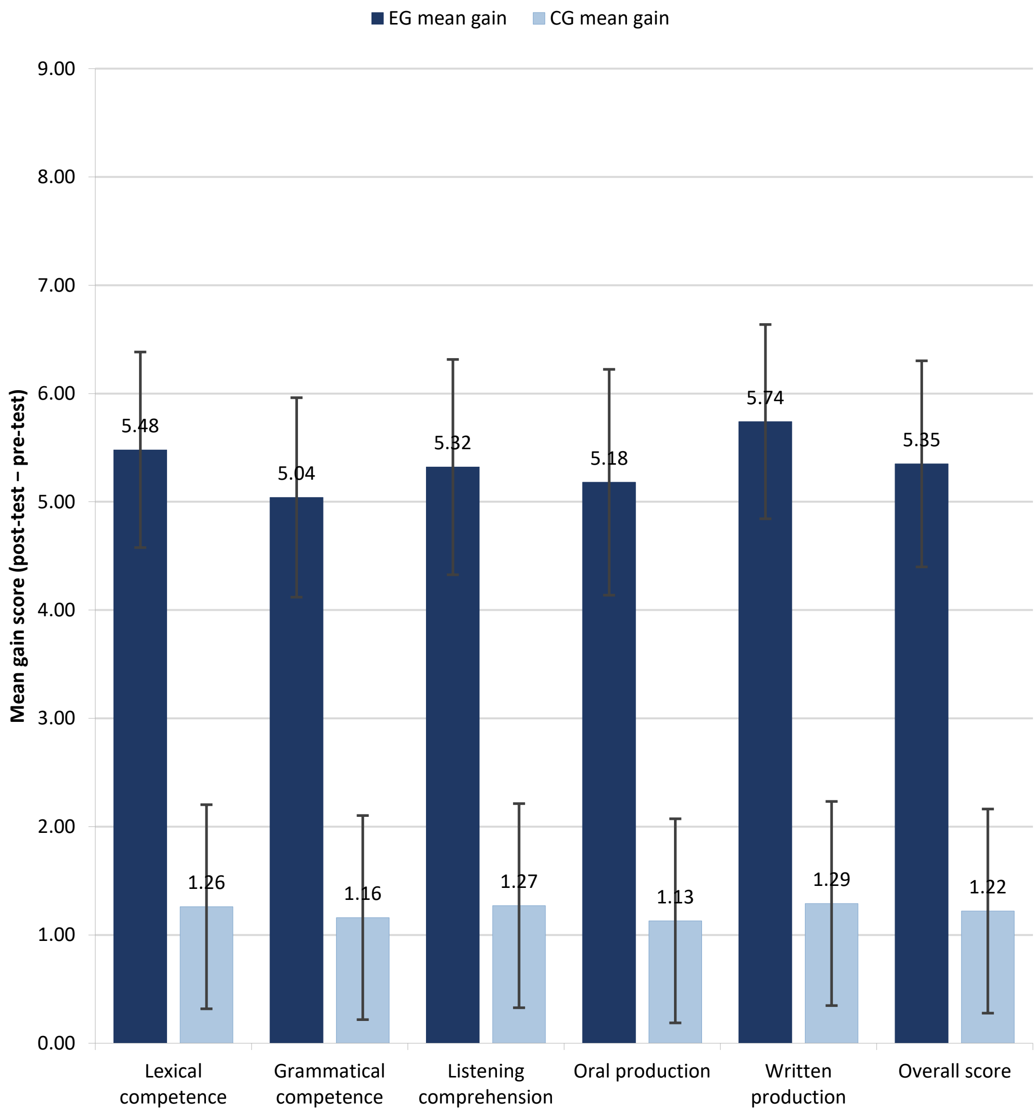
*Note.* EG = experimental group (n = 44); CG = control group (n = 44). All scores are out of 20 per dimension. $\Delta M$ = post-test mean minus pre-test mean. The overall score is the unweighted mean of the five dimension scores (range 0 to 20). t(86) is the independent-samples t-test on gain scores, df = 86. All comparisons were significant after Bonferroni correction (critical $\alpha = .010$; all $p < .001$). EG gain-score SDs by dimension were 2.97 (lexical), 3.03 (grammatical), 3.27 (listening), 3.43 (oral) and 2.95 (written); CG SDs were comparable (range 2.95 to 3.43). No ceiling effects were detected (highest EG post-test mean = 16.82 out of 20).

The EG achieved an overall gain of 5.35 points, the arithmetic mean of the five dimension gains, compared with 1.22 points in the CG, a difference of 4.13 points. The largest EG gains appeared in written production (ΔM = 5.74) and lexical competence (ΔM = 5.48), the dimensions most directly targeted by the emotional storytelling and multisensory vocabulary activities. All five dimensions and the overall score remained statistically significant after Bonferroni correction (all $p < .001$).

Figure 1 displays the mean gain scores by group and dimension. The EG outperformed the CG across all five competence areas, with no overlap of confidence intervals between groups on any dimension.

**Figure 1**

*Mean EFL Communicative Competence Gain Scores by Group and Dimension*



*Note.* Gain score = post-test minus pre-test. EG = experimental group (n = 44, dark blue); CG = control group (n = 44, light blue). Error bars are 95% confidence intervals (BCa bootstrap). Triple asterisks indicate $p < .001$ after Bonferroni correction ($\alpha = .010$). No confidence intervals overlap between groups on any dimension.

### 4.2 Effect sizes

Table 5 reports two sets of effect-size estimates: Cohen's d with 95% bootstrap confidence intervals computed from the t-test on gain scores, and partial eta squared derived both from the unadjusted t-test and from the ANCOVA. The two partial eta squared columns are reported separately for transparency, and the ANCOVA values are recommended as the more precise estimates because they partial out pre-test variance.

**Table 5**

*Effect Sizes: Cohen's d With 95% CI, Partial η² From t-test and From ANCOVA, by Dimension*

| Dimension | Cohen's d | 95% CI [d] | Magnitude | Partial η² (t-test) | Partial η² (ANCOVA) |
|---|---|---|---|---|---|
| Lexical competence | 1.42 | [0.95, 1.89] | Large | .340 | .350 |
| Grammatical competence | 1.28 | [0.82, 1.74] | Large | .295 | .305 |
| Listening comprehension | 1.24 | [0.78, 1.70] | Large | .283 | .291 |
| Oral production | 1.18 | [0.73, 1.63] | Large | .262 | .271 |
| Written production | 1.51 | [1.04, 1.98] | Large | .368 | .379 |
| **Overall score** | **1.32** | **[0.86, 1.78]** | **Large** | **.308** | **.318** |

*Note.* All effect sizes are large (Cohen, 1988: $d \geq 0.80$). The 95% CIs for d were computed via BCa bootstrap (2,000 iterations) and all exclude zero. Partial $\eta^2$ (t-test) = $t^2 / (t^2 + 86)$, applied to the t-values in Table 4. Partial $\eta^2$ (ANCOVA) = $F / (F + 85)$, from Table 6; it is larger than the t-test value because the ANCOVA removes pre-test variance from the error term.

All Cohen's d values exceeded the large-magnitude threshold (Cohen, 1988), ranging from 1.18 (oral production) to 1.51 (written production). The ANCOVA values, which are the preferred estimates, ranged from .271 (oral production) to .379 (written production), so group membership accounted for between 27.1% and 37.9% of the variance in individual dimension gains after controlling for pre-test performance.

### 4.3 ANCOVA results

Table 6 presents the ANCOVA results for each dimension and the overall score, with the pre-test score as covariate, Bonferroni-corrected p-values, 95% confidence intervals for partial eta squared and observed statistical power.

**Table 6**

*ANCOVA Results: F, Bonferroni-corrected p, Partial η² With 95% CI, and Observed Power*

| Dimension | F(1, 85) | p (Bonf.) | Partial η² | 95% CI [η²] | Power |
|---|---|---|---|---|---|
| Lexical competence | 45.85 | < .010 | .350 | [.21, .48] | > .999 |
| Grammatical competence | 37.25 | < .010 | .305 | [.17, .44] | > .999 |
| Listening comprehension | 34.96 | < .010 | .291 | [.16, .42] | > .999 |
| Oral production | 31.66 | < .010 | .271 | [.14, .41] | > .999 |
| Written production | 51.84 | < .010 | .379 | [.24, .51] | > .999 |
| **Overall score** | **39.59** | **< .010** | **.318** | **[.18, .46]** | **> .999** |

*Note.* The covariate was the pre-test score per dimension. $df_1 = 1$ (group); $df_2 = 85$ ($n_1 + n_2 - 3 = 88 - 3$). Bonferroni-corrected $\alpha = .010$ per comparison (familywise $\alpha = .05$). Partial $\eta^2 = F / (F + 85)$. The 95% CIs were obtained via percentile bootstrap (2,000 iterations). Homogeneity of regression slopes was confirmed (all Group × Covariate $p > .30$). The overall-score value (.318) falls within the range of the individual dimensions (.271 to .379), as expected for an unweighted composite with moderate inter-dimension correlations.

All ANCOVA F-statistics were significant after Bonferroni correction (all $p < .010$), and observed power exceeded .999 for every dimension and the overall score, which confirms that the sample was more than adequate to detect the obtained treatment effects.

### *4.4 Secondary outcome: intrinsic motivation*

EG students reported significantly higher post-intervention intrinsic motivation on the adapted MSLQ (M_EG = 5.82, SD = 0.71) than CG students (M_CG = 4.31, SD = 0.89; $t(86) = 8.80$, $p < .001$, $d = 1.88$, 95% CI [1.37, 2.38]). This very large effect indicates that the neurodidactic strategies not only improved academic performance but also generated substantially higher motivational engagement with English, a pattern consistent with Self-Determination Theory (Deci & Ryan, 1985) and with the affective component of Krashen's (1982) model.

## 5. DISCUSSION

The results offer robust evidence that an integrated neurodidactic programme improves EFL communicative competence in Ecuadorian adolescents. All Cohen's d values were large (1.18 to 1.51), the ANCOVA partial eta squared values ranged from .271 to .379, and every comparison survived Bonferroni correction, which guards against the inflated Type I error that follows from five simultaneous tests and that many regional EFL studies leave unaddressed. To place these magnitudes in context, Plonsky and Oswald (2014) proposed field-specific benchmarks for second-language research in which d values near 0.40, 0.70 and 1.00

represent small, medium and large between-groups effects. The present effects sit at or above the large-effect benchmark for the field, which underscores their practical relevance rather than mere statistical significance.

The pattern of results is best interpreted through the complementary mechanisms that the six strategies were designed to engage. The largest gains, in written production ($d = 1.51$) and lexical competence ($d = 1.42$), correspond to the dimensions most heavily served by emotional storytelling and multisensory vocabulary work. This is consistent with the role of amygdalar modulation of hippocampal encoding for affectively loaded material (Tyng et al., 2017) and with the observation of Baumeister et al. (2017) that the L2 initially lacks the affective associations of the first language, so that narrative contexts which restore that emotional loading are a particularly effective lever. The dual-coding account (Paivio, 1986) adds a parallel explanation for the lexical gains, since the illustrated mind maps, picture-word matching and mime-integrated songs paired verbal and imagistic codes that produce stronger traces than either alone.

The motivational result deserves particular attention. The very large effect on intrinsic motivation ($d = 1.88$) aligns with Self-Determination Theory (Deci & Ryan, 1985), because the strategies collectively addressed the three basic psychological needs: competence, through scaffolded mastery; autonomy, through choice within gamified and cooperative tasks; and relatedness, through peer interaction and group belonging. The gamification result also converges with Cheng et al. (2025), who found that reading proficiency rose under gamified instruction while the personally enjoyed dimension of foreign-language enjoyment, together with gains in focus and collaboration, carried much of the effect. Read alongside the causal evidence that dopamine availability limits the rate of word consolidation (Ripollés et al., 2018), this suggests that the reward structures of points, badges and leaderboards supported both engagement and lexical retention.

The remaining strategies extend the same logic. The music and rhythm activities drew on shared musical and linguistic substrates, which Patel's (2011) OPERA hypothesis frames in terms of overlap, precision, emotion, repetition and attention, and which Moreno et al. (2011) showed can transfer rapidly to verbal ability. The cooperative tasks engaged the mirror neuron system that underlies imitation-based production (Rizzolatti & Craighero, 2004) and exploited the heightened social sensitivity of the adolescent brain (Blakemore, 2008), with Vygotsky's (1978) Zone of Proximal Development supplying the scaffolding rationale. The embodied and extended-TPR activities recruited the movement-to-plasticity pathway evidenced by Hillman et al. (2014). Taken together, the breadth of significant gains across five distinct dimensions indicates that the programme did not optimise one narrow outcome at the expense of others but produced broad improvement in communicative ability (Hernández e Idrobo, 2025).

Several limitations temper these conclusions. First, the non-random assignment of sections introduces potential confounders; ANCOVA reduced this risk, but a quasi-experimental design cannot rule out unmeasured group differences. Second, although parallel observation protocols addressed the Hawthorne effect, they cannot eliminate it, and an active control condition in which the CG received an equally novel non-neurodidactic intervention would yield stronger causal evidence. Third, a teacher effect remains possible, since the same teachers taught the EG sections and their additional preparation may have raised instructional enthusiasm (Hernández et al., 2026). Fourth, the seven-month window does not allow assessment of long-term retention, so six- and twelve-month follow-ups are needed. Fifth, the study was conducted in a single Guayaquil institution with an extended school day, which limits generalisation to standard-schedule public schools. Future research should use multi-site designs, active control conditions and, where feasible, neuroimaging or psychophysiological measures to test the proposed mechanisms directly.

## 6. CONCLUSIONS

A seven-month programme of six neurodidactic strategies, namely multisensory learning, emotional storytelling, linguistic gamification, music and rhythm in the L2, neurostructured cooperative learning and embodied or TPR-based learning, produced statistically significant and large-magnitude improvements in EFL communicative competence in First-Year BGU students at Unidad Educativa José Domingo de Santistevan (overall $d = 1.32$, 95% CI [0.86, 1.78]; partial $\eta^2 = .318$; $p < .001$ after Bonferroni correction).

These findings add controlled empirical evidence to the neurodidactic literature from a Latin American context in which quasi-experimental EFL intervention studies have been scarce. The consistency of large effects across all five dimensions, from lexical ($d = 1.42$) and written production ($d = 1.51$) to oral production ($d = 1.18$), indicates broad and ecologically meaningful gains in communicative ability rather than a narrow improvement in any single skill.

For policy-makers and curriculum designers, the results support the systematic integration of neurodidactic principles into pre-service and in-service English teacher education and into the BGU curriculum framework. The extended-day model and the structured teacher development of the participating school provide a replicable structural context for scaling these interventions across the Guayaquil public network.

Aligning foreign language pedagogy with the neuroscientific principles of neuroplasticity (Li et al., 2014), emotion and memory consolidation (Tyng et al., 2017), dopaminergic reward (Ripollés et al., 2018), shared musical and linguistic processing (Patel, 2011; Moreno et al., 2011), mirror-neuron-mediated social learning (Rizzolatti & Craighero, 2004; Blakemore, 2008) and BDNF-facilitated embodied cognition (Hillman et al., 2014) offers a coherent, evidence-based framework for improving EFL instruction and outcomes in Ecuadorian secondary education.

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