

Article: Research

From neuroscience to the classroom: neurodidactic teacher training, motivation, and academic performance**De la neurociencia al aula: formación docente neurodidáctica, motivación y rendimiento académico**

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Submitted: 02-08-2026

Revised: 14-08-2026

Accepted: 20-09-2026

Published: 09-10-2026

How to cite:

From neuroscience to the classroom: neurodidactic teacher training, motivation and academic performance (J. G. Gómez Dávila, V. M. Romo Pérez, G. Nieto López, & G. A. Zaragoza Alvarado, Trans.). (2026). *Sapiens in Education*, 3(5), 1-21. <https://doi.org/10.71068/SIE00101>

ABSTRACT

Introduction: Neurodidactics brings together contributions from cognitive neuroscience and pedagogy to inform university teaching. In Latin America, needs remain for specialized teacher education and evaluation of educational outcomes.

Objective: To evaluate the effects of a neurodidactic teacher training programme on university students' academic motivation and achievement.

Method: A quantitative quasi-experimental study was conducted using a non-equivalent control group and pretest and posttest measurements. Participants included 40 teachers, evenly divided between experimental and control groups, and 812 students from three public universities in Ecuador, Peru and Colombia. The programme lasted twelve weeks and included six modules with microteaching and pedagogical coaching activities. A motivation scale, grade records and a teacher observation guide were used.

Results: Mean posttest motivation was 5.34 points in the experimental group and 4.31 in the control group; academic achievement reached 7.62 and 7.10 points, respectively. The reported analyses showed differences favouring the experimental group and positive associations between teacher implementation, motivation and achievement.

Conclusions: Neurodidactic teacher training was associated with better motivational and academic outcomes in the institutions studied. These findings support connecting knowledge about learning, instructional redesign and pedagogical coaching while acknowledging the limitations inherent in a quasi-experimental design.

Keywords: neurodidactics; teacher training; academic motivation; academic achievement; higher education; Latin America

RESUMEN

Introducción: La neurodidáctica integra aportes de la neurociencia cognitiva y de la pedagogía para orientar la práctica docente universitaria. En América Latina persisten necesidades de formación especializada y de

evaluación de sus resultados educativos.

Objetivo: Evaluar los efectos de un programa de formación docente neurodidáctica sobre la motivación académica y el rendimiento de estudiantes universitarios.

Método: Se desarrolló una investigación cuantitativa, cuasiexperimental, con grupo control no equivalente y mediciones pretest y posttest. Participaron 40 docentes, distribuidos en grupos experimental y control de 20 participantes, y 812 estudiantes de tres universidades públicas de Ecuador, Perú y Colombia. El programa comprendió doce semanas y seis módulos con actividades de microenseñanza y acompañamiento. Se utilizaron una escala de motivación, registros de calificaciones y una guía de observación docente.

Resultados: La motivación media posttest fue de 5,34 puntos en el grupo experimental y 4,31 en el control; el rendimiento académico alcanzó 7,62 y 7,10 puntos, respectivamente. Los análisis reportaron diferencias favorables al grupo experimental y asociaciones positivas entre implementación docente, motivación y rendimiento.

Conclusiones: La formación docente neurodidáctica se relacionó con mejores resultados motivacionales y académicos en las instituciones estudiadas. Estos hallazgos respaldan la importancia de articular conocimientos sobre aprendizaje, rediseño didáctico y acompañamiento pedagógico, considerando las limitaciones propias del diseño cuasiexperimental.

Palabras clave: neurodidáctica; formación docente; motivación académica; rendimiento académico; educación superior; América Latina

INTRODUCTION

Latin American higher education faces challenges related to the permanence, participation, and academic performance of its students. In this scenario, the pedagogical training of teachers constitutes a relevant component of the improvement of teaching. Advances in cognitive neuroscience have expanded knowledge about attention, memory, and emotional regulation; however, its educational application requires integrating these findings with evidence from learning psychology and didactic research. The relationship between neuroscientific knowledge and teaching practice is not automatic: it materializes in decisions about content organization, opportunities for participation, remedial tasks, and feedback criteria. Therefore, the scientific interest of such training lies in examining observable changes in teaching and their associations with academic results.

Neurodidactics is a field of articulation between neuroscientific knowledge and pedagogical decisions. In the university environment, its application can guide the planning of activities related to selective attention, information processing, knowledge retrieval, and emotional learning conditions. Neuroplasticity describes the capacity of the nervous system to modify itself based on experience, but this general principle does not demonstrate by itself that a given didactic strategy generates specific neural changes. Proposals for the classroom must be based on the set of available educational evidence and be examined through indicators of learning, motivation, and teaching practice (1,2). Its assessment requires distinguishing the conceptual basis from the results actually achieved by students.

Emotions, attention and memory maintain complex relationships with learning. Curiosity and interest can favor participation and the elaboration of content, while high levels of stress can hinder performance in certain tasks. However, these links depend on the characteristics of the educational situation and of each student. Consequently, the present work does not attribute neurochemical

variations or synaptic modifications to the teacher training program, since the variables studied correspond to academic motivation, grades and observation of pedagogical practices. Its interpretation is therefore located in the educational and behavioral level that the instruments applied allow.

Despite this evidence, studies on teachers' perception and appropriation of neuroeducation in Latin American universities coincide in pointing out important training gaps. Research carried out in Colombian public institutions has documented that a large part of the teaching staff does not receive specific training in neuroeducation during their professional career, even though they express favorable expectations towards their curricular incorporation (3,4). This contrast between interest and available training shows that the declared acceptance of a proposal does not imply its systematic application. It also reinforces the importance of examining training opportunities, available accompaniment, and the specific conditions of university practice. Comparative analysis also allows us to distinguish educational needs and institutional conditions.

In a similar vein, studies carried out in Ecuadorian university faculties have found that a relevant proportion of the teaching staff has not received formal training in the fundamentals of educational neuroscience, although they intuitively apply certain strategies compatible with these principles. This indicates a space to organize training through explicit evaluation activities and criteria. At the international level, evaluations of the training needs of university teachers in neuroeducation have shown that, despite the positive assessment of this area, gaps persist in terms of competencies, available time and institutional resources (5). This background justifies attending to both the declared needs and the observable teaching practice.

In parallel, a growing body of research has explored the relationship between neurodidactic strategies, academic motivation, and student performance in Latin American university contexts. Studies carried out in Peru have found significant associations between the application of such strategies, student satisfaction, and academic performance (6), while research carried out in academic recovery programs in the Caribbean region has shown that motivation, approached from a neuroeducational approach, constitutes a relevant predictor of academic performance (7). Convergently, recent reviews of Latin American teaching practice have identified that the incorporation of these teaching practices is consistently associated with improvements in academic performance indicators, although they warn of the need for more robust experimental designs to establish causal relationships (8).

Research on learning has indicated that direct instruction and active learning activities can complement each other depending on the objectives and prior knowledge of the student body (9). Likewise, evidence-based training programs on learning have been examined in populations with diverse educational needs, which provides background on their pedagogical relevance, although it does not allow their effects to be automatically generalized to all university courses (10). In the program studied here, attention, memory, and accompaniment activities were integrated with instructional design strategies, without assuming that any academic improvement reflects a specific brain mechanism.

However, these advances still have a relevant methodological limitation in the available literature: most studies on these practices in Latin American higher education correspond to descriptive, correlational, or theoretical review designs, while quasi-experimental or experimental research that evaluates the direct effects of teacher training programs on students' motivational and academic outcomes remains scarce. Likewise, much of the evidence is concentrated in institutional case studies from a single country, which limits the possibility of generalizing the findings to the diversity of university contexts in the region. Therefore, the findings must be placed in relation to the type of intervention, the characteristics of the teaching staff, and the evaluation conditions.

By virtue of the above, the present study set out to answer the following research question: what are the effects of a teacher training program based on neurodidactic principles on the academic motivation and academic performance of university students in public institutions in Latin America? To answer this, the objective was to evaluate the effects of a teacher training program focused on brain plasticity, attention, emotion and memory as foundations of instructional design, on academic motivation and academic performance of university students from three Latin American countries. The analysis focused on identifiable educational changes, without using neurophysiological results as indirect indicators of effectiveness. It also considered the experience of teachers belonging to different disciplinary areas.

The following specific objectives can be derived from this general objective: (a) to design and implement a teacher training program in neurodidactics aimed at university teachers; (b) to compare the levels of academic motivation of students before and after the intervention between the experimental group and the control group; (c) to compare the academic performance of students before and after the intervention between both groups; and (d) to analyze the relationship between the degree of implementation of these strategies by teachers and the motivational and academic results of their students. These purposes allowed for an articulated analysis of the training component, its implementation and the students' learning indicators. Each objective was linked to measurements foreseen in the design.

Based on the literature review, the following research hypotheses were formulated: H1, the students whose teachers participated in the specialized training program will present significantly higher levels of academic motivation in the post-test than those in the control group; H2, the students in the experimental group will present significantly higher academic performance in the post-test than in the control group; and H3, there is a positive and statistically significant relationship between the degree of implementation of taught strategies by the teachers and the motivational and academic results of their students. The interpretation of these hypotheses was based on the comparison of the study conditions and the observation of teaching practices. Their formulation does not presuppose absolute equivalence between the groups.

The differential contribution of this study lies in jointly evaluating a structured twelve-week teacher training, its application observed in the classroom and two student outcomes, academic motivation and performance. Unlike interventions focused only on active strategies or theoretical awareness of neuroscience, the NES program combined six modules, micro-teaching, redesign of sequences and

pedagogical accompaniment. This approach allows the training experience of teachers to be related to the application of practices and to the academic changes documented in the participating groups. Thus, the interest of the research is not limited to verifying the acceptance of the training contents, but includes the relationship between training, performance in class and academic experience of the students.

LITERATURE REVIEW

Educational neuroscience and the transfer of evidence to the classroom

Neurodidactics is an intersection between neurobiological explanations of learning, psychological theories, and situated teaching decisions. Neuroplasticity describes the functional reorganization capacity of the nervous system, but its mere existence does not allow us to infer that a specific teaching activity produces a specific neural effect. The review by Guadamuz Delgado et al. provides a useful biological context on this phenomenon; in the field of university practice, Espinoza Rodríguez et al. describe pedagogical applications of this approach during the period 2017-2021 (11,12). The relevance of the approach lies, therefore, in formulating observable pedagogical decisions and assessing their relationship with defined educational outcomes.

In teacher training, it is essential to differentiate principles supported by cognitive studies from generalizations that can become neuromyths. Jiménez Pérez and Calzadilla-Pérez documented the presence of neuromyths among university teachers, which justifies incorporating critical reading of evidence and discussion of its scope (13). In addition, Apolo et al. systematized educational applications of neuroscience, while Muñoz and Jacho examined factors and strategies to improve learning in higher education (14,15). These contributions complement the analysis of training activities, but do not replace indicators of motivation and academic performance. The critical review of materials makes it possible to assess which recommendations derive from research on teaching and which are insufficiently supported extrapolations. This criterion guides the responsible selection of adequately justified classroom practices.

Recent research provides concrete experiences of professional development based on educational neuroscience. Hachem, Daignault and Wilcox studied the perceptions of school staff after a training program and found evidence of greater understanding of neuroscientific concepts and perceived changes in teaching practice (16). Luzzatto, Shalom and Rusu analyzed a training program aimed at future special education teachers and documented favorable evaluations of the relevance of this knowledge for pedagogical work (17). These are different populations and designs from the one in this article, which reinforces the need to distinguish professional perceptions from changes measured in students.

Attention, memory and design of neurodidactic strategies

University learning requires coordinating attention, the organization of new information, and its subsequent retrieval. In instructional design, this can be translated into activities with explicit objectives, activation of prior knowledge, comprehension checks, and application sequences. The teacher training examined articulates these resources with micro-teaching, the redesign of units, and

feedback. The convenience of using several sensory channels should depend on the task and not on an automatic attribution of benefits due to their multisensory nature. In this framework, the teacher's planning should contemplate how the content is presented, how its understanding is verified, and what opportunities the student has to retrieve and apply the knowledge. These elements are observable in the classrooms.

The activities of retrieval and distribution of the study can complement expository and collaborative methods; however, their implementation requires considering the difficulty, time, and disciplinary particularities. García et al. analyzed this approach in the professionalization of teachers in virtual teaching environments, a context that broadens the discussion on the adaptation of strategies to different modalities (18). At the same time, Bejarano et al. compiled neuroeducational strategies applied to the classroom that illustrate the diversity of teaching resources, without their adoption being interpreted as a universal guarantee of higher performance (19). The adequacy of each resource must be documented through the purpose of the activity and the training needs of the course.

In university students, Cherrier et al. evaluated NeuroStratE, an educational neuroscience intervention focused on planning and procrastination strategies. The study demonstrates the usefulness of defining specific behavioral outcomes in addition to knowledge about the brain (20). This distinction is pertinent to the NES program: learning theoretical principles and applying them during a teaching sequence are distinct processes. Their articulation requires guided practice activities, feedback opportunities, and monitoring of the use of the strategies in real classroom situations. In addition, the results on procrastination are not interpreted as equivalent to general academic performance. Their usefulness for this research is to show how training can link cognitive knowledge with educational behaviors that can be followed.

Academic motivation, emotions and university performance

Academic motivation is related to the reasons why students initiate, maintain, or avoid their learning activities. Experiences of autonomy, achievement, belonging, and feedback are involved in this relationship, but their manifestations are not equivalent. Reina and Sosa addressed neuroeducational strategies in university feedback activities; Narváez and Aldas studied proposals related to emotional intelligence in a specific educational context (21,22). These contributions guide the content of the training, although the characteristics of each population must be considered before transferring conclusions to the general university environment. Hence, motivational evaluation must recognize the diversity of responses and not assume the same meaning in any dimension.

The relationship between motivation and performance is multidimensional, and may be conditioned by the evaluation criteria, curricular demands, and personal resources of the student. Farrokhnia et al. examined motivation, self-regulation, and satisfaction in e-learning environments, which reminds us that teaching practices can be associated with student experiences through several interrelated processes (23). Similarly, Hilario et al.'s review of critical thinking in academic writing shows that higher education outcomes include complex competencies that are not reduced to a single grade

(24). Therefore, the interpretation of grades must incorporate the type of task and the structure of the training process.

Teacher training can also modify the motivational environment. Girard and de Guise evaluated a training program aimed at supporting student motivation and participation during the internships of future physical education teachers (25). Although it is a different educational level and area, this work offers a methodological reference for linking teacher training, teacher behavior, and motivational results. In the NES program, emotional support and participation practices are integrated with attention and memory; this combination requires recognizing that its components can act together on the student's experience. The relationship between motivational strategies and participation may depend on discipline, training stage, and student autonomy.

Teacher development and evaluation of the intervention

Training programs usually integrate conceptual presentation, planning exercises, and accompanying activities. Their quality does not depend only on the duration, but also on the relevance of the contents, the opportunities for transfer, and the observation of practices actually carried out. Bruna et al. analyzed a university teacher training program on self-regulated learning through a quasi-experimental design and multilevel models. They reported changes in self-efficacy and teaching practices, while the result on knowledge was not significant (26). This difference between indicators highlights the importance of not confusing self-perceived knowledge, teaching behavior, and student learning. Likewise, the intervention requires recording whether the planned activities are incorporated into the classroom on a regular basis.

Continuous training is also developed in academic communities with their own institutional traditions and constraints. Vuojärvi et al. addressed the role of contextual knowledge in the pedagogical development of higher education and provided arguments for interpreting improvement actions from the needs of the educational community (27). In institutions in several countries, this perspective is important because the conditions of implementation may vary even when the same modules, activities, and materials are used. The diversity of subjects imposes criteria of flexibility in the organization of the accompaniment, without losing sight of the central contents of the program. Consequently, understanding the context provides information to interpret the adoption of the strategies.

The main particularity of the NES program is to combine six training components over twelve weeks with micro-teaching, individual accompaniment and an observation guide of pedagogical practices. The intervention connects teacher participation with two student indicators, motivation and performance, and adds effective implementation as a dimension of analysis. Its study requires interpreting the comparisons according to the quasi-experimental design described and recognizing the variations between courses and groups. Thus, the review allows us to situate the contribution of the article in the relationship between training, pedagogical practice and student results. The combination of these dimensions broadens the discussion beyond satisfaction with a refresher course.

METHOD

Design

The study was developed with a quantitative approach and a quasi-experimental design of a non-equivalent control group, with pre-test and post-test measurements (28). This strategy was chosen due to organizational constraints to randomly assign teachers. The intervention condition was established by academic units that agreed to participate in the training and comparison. Consequently, the differences observed between conditions are interpreted considering the non-random selection and the characteristics of the groups, without equating this design with a randomized experimental trial. The use of previous and subsequent measures provided information on the trajectory of the variables examined. The comparison was established between teachers who participated in the program and teachers who continued with their usual practices.

The independent variable was teacher participation in the neurodidactic training program; the dependent variables were motivation and student academic performance, measured before the intervention (week 0) and at the end of it (week 13). The degree of application of the program's strategies was examined based on structured observations of the teaching staff. The intervention had the teacher as the unit of exposure, while the motivational and academic results were recorded in students. This organization generates observations grouped by teacher and constitutes a relevant aspect for interpreting the statistical analyses. Therefore, the methodological description differentiates the training condition, the individual indicators, and the observational measures of implementation. This distinction is necessary to understand the level at which each variable was recorded.

Background

The research was carried out in three public universities in Ecuador, Peru, and Colombia, identified as universities A, B, and C to preserve their institutional confidentiality. The institutions offered face-to-face undergraduate programs in the areas of social sciences, engineering, and health sciences. A non-probabilistic convenience sampling was used based on the availability of the academic units and the corresponding collaboration agreements. Institutional diversity allowed the intervention to be examined in three university contexts, although the selection used does not constitute a representative sample of Latin American higher education. Although the institutions shared a face-to-face training offer, their curricular and administrative differences had to be considered when interpreting the results. Institutional identification by letters maintained the organization used in the study.

Participants

A total of 40 university professors participated (mean age = 41.3 years; SD = 8.6; 57.5% women), distributed in an experimental group (n = 20) and a control group (n = 20), belonging to social sciences, engineering, and health sciences. The inclusion criteria were having two years or more of experience, teaching a semester-long subject, and participating in the condition assigned by their academic unit. Those who had received equivalent certified training in neuroeducation or neurodidactics during the

previous two years were excluded. The distribution of faculty by sex, age, experience, discipline, and country is presented in Table 1. The eligibility criteria sought to form groups with sufficient experience to apply the training sequences in their courses.

A total of 812 students enrolled in the subjects taught by the selected teachers also participated: 406 in the experimental group and 406 in the control group. Their ages ranged from 18 to 27 years ($M = 20.8$; $SD = 2.1$), and 54.2% were women. The size of the courses varied from 18 to 24 students per teacher. The baseline contrasts reported did not identify statistically significant differences in the indicators examined; this result describes the comparisons made, but does not demonstrate equivalence between non-randomized groups nor does it rule out differences in unmeasured variables. Table 1 presents the sociodemographic and professional characteristics of the teachers of the two conditions, with the corresponding descriptive values and initial contrasts.

Table 1.

Sociodemographic characteristics of participating teachers by group ($N = 40$)

Variable	Experimental group (n = 20)	Control group (n = 20)	p
Age, M (SD)	40.8 (8.2)	41.8 (9.1)	.712
Female, n (%)	12 (60.0)	11 (55.0)	.749
Years of teaching experience, M (DE)	9.4 (4.1)	9.1 (4.6)	.832
Area: Social Sciences, n (%)	7 (35.0)	7 (35.0)	-
Area: Engineering, n (%)	7 (35.0)	6 (30.0)	-
Area: Health Sciences, n (%)	6 (30.0)	7 (35.0)	-
Country: Ecuador, n (%)	7 (35.0)	7 (35.0)	-
Country: Peru, n (%)	7 (35.0)	6 (30.0)	-
Country: Colombia, n (%)	6 (30.0)	7 (35.0)	-

Note. M = mean; SD = standard deviation. The p-values correspond to the tests reported for the initial comparisons.

Instruments

Four instruments were used for data collection. Academic motivation was assessed by adapting the Academic Motivation Scale (EMA) into Spanish, cited in the literature on instruments for Spanish-speaking university students (29). The version used included 24 items with seven-point Likert responses (1 = strongly disagree; 7 = strongly agree), organized into intrinsic motivation, extrinsic motivation, and amotivation. Internal consistency was $\alpha = 0.87$ in the pre-test and $\alpha = 0.89$ in the post-test. The joint score presented in the results is expressed on a scale from 1 to 7, although each

dimension has a different motivational meaning, especially amotivation; therefore, interpretations of the global score should be limited to the indicator used.

Academic performance was examined using grades expressed on a scale of 0 to 10 points. The previous measure was the cumulative average of the previous semester and the subsequent measure was the final grade of the subject taken during the intervention. Both measures reflect academic performance, although they synthesize different sets of activities and subjects. For this reason, the comparison is interpreted as variation between two related academic indicators, not as if they were two applications of the same standardized test. This particularity is relevant because the grades may reflect different criteria between semesters. Consequently, the changes described must be placed in the context of the subjects, their assessment instruments and the grading decisions of the teaching staff.

The Observation Guide for Neurodidactic Practices (GOPN) was organized around four dimensions: pertinent multisensory stimulation, emotional classroom management, activation of selective attention, and memory consolidation strategies. Their score followed a four-category scale, from 1 (not implemented) to 4 (systematically implemented). The study reported content review by five experts (Aiken's $V = 0.86$) and two observations of non-consecutive classes by trained external teachers, with interobserver agreement expressed by Cohen's $\kappa = 0.81$. Because some formative practices could be recognized during observation, the study condition is not considered completely hidden from evaluators.

Finally, teachers answered a questionnaire on perception and self-perceived knowledge about neuroeducation, based on a history of teacher training needs (5). The scores were expressed on a five-point scale, applied before and after the intervention to describe the evolution of the knowledge declared by the participants. This indicator reflects self-perception and is distinguished both from the knowledge demonstrated by tests and from the observable implementation of classroom strategies. The responses made it possible to complement the observational information with an assessment expressed by the participants themselves. Both sources remained differentiated because the perception of competence does not necessarily imply the mastery demonstrated in an external evaluation.

Intervention program

The teacher training program, called "Neurodidactics for Higher Education" (NES), lasted twelve weeks and was structured in six theoretical-practical training modules, with a total load of 60 hours (30 synchronous hours and 30 hours of autonomous work with accompaniment). The modules were: (1) fundamentals of cognitive neuroscience applied to learning; (2) attention, executive functions and design of didactic sequences; (3) emotion and classroom climate as conditions for meaningful learning; (4) memory, consolidation and spaced retrieval strategies; (5) neuroplasticity and instructional redesign of learning units; and (6) formative assessment and feedback from a neurodidactic perspective.

The training methodology combined face-to-face workshops, micro-teaching with peer feedback, and individualized pedagogical accompaniment (teacher coaching) during the implementation of the strategies in their own subjects. Each teacher in the experimental group designed and implemented, as a learning product of the program, at least three redesigned didactic sequences according to the fundamentals worked on during the training, which were applied during the intervention semester. The control group did not receive any training intervention during the study period and continued to develop its usual teaching practice; this group was offered access to the training program once data collection was completed, as a measure of ethical equity (waitlist design).

Table 2.

Structure of the Neurodidactics Teacher Training Program (NES)

Module	Core content	Duration
1	Fundamentals of cognitive neuroscience applied to learning	8 h
2	Attention, executive functions and design of didactic sequences	10 am
3	Emotion and classroom climate as a condition for meaningful learning	10 am
4	Memory, consolidation, and spaced retrieval	10 am
5	Neuroplasticity and instructional redesign of learning units	12 h
6	Formative assessment and neurodidactic feedback	10 am

Note. The NES programme included 60 hours of training over twelve weeks. Prepared by the authors.

Procedure

The procedure was developed in four phases. During the preparatory phase, carried out in the first month, the approval of the institutional ethics committees of the three participating universities was obtained and the characteristics of the research were communicated to the academic authorities. Likewise, the informed consent of teachers and adult students was obtained, guaranteeing voluntariness, confidentiality and withdrawal without academic consequences. Subsequently, in the baseline phase, corresponding to week 0, the motivation instruments were administered to the students, the grades prior to the intervention were collected and the perception questionnaire was applied to the teaching staff.

In the intervention phase, between weeks 1 and 12, the Neurodidactics for Higher Education program was implemented exclusively with the teachers of the experimental group. The teachers in the comparison group maintained their usual teaching activities during the same period. Finally, in the

post-test evaluation phase, located in week 13, the motivation and teacher perception questionnaires were applied again, the semester's grades were collected and observations were made using the GOPN under both conditions. The sequence made it possible to organize the collection of indicators before and after the training period.

Data analysis

The analysis was performed using Jamovi 2.6 and R 4.4. Participant characteristics and pre-test and post-test scores were summarized using means, standard deviations, and frequencies. Distribution assumptions were examined using Shapiro-Wilk and homogeneity of variances using Levene. For initial comparisons, Student's t-tests were applied and, for post-test results, ANCOVA with the initial score as a covariate; F, significance, partial eta-squared, and Cohen's d were presented. Associations between GOPN and changes in student indicators were explored using Pearson correlations, with $p < 0.05$ as a significance criterion. The observations share the teaching unit and are interpreted considering the potential dependence between students of the same course.

Ethical considerations

The research followed the ethical provisions applicable to educational studies with adults and the rules of the participating institutions. The faculty and students received information about the objectives and procedures and granted written informed consent, with voluntary participation, confidentiality of the answers and the possibility of withdrawing without academic repercussions. The motivation evaluation was kept separate from the ordinary grading processes. The study was reviewed by the institutional ethics committees, in accordance with the authorizations described by the authors. The information provided to the participants included the academic nature of the research and the conditions of data processing. Participation did not modify the ordinary opportunities for evaluation of the subjects.

RESULTS

The results are presented in four sections that correspond to the initial characteristics of the groups, academic motivation, performance, and teaching implementation. The measurements made before and after the program are considered, as well as the information collected through classroom observations. The presentation differentiates the descriptive indicators from the statistical contrasts reported for each result. It also distinguishes the results corresponding to students from those recorded at the teaching level. This order facilitates the joint reading of the motivational changes, grades, and practices observed, without modifying the values included in the four tables of the article. The organization by hypothesis was maintained.

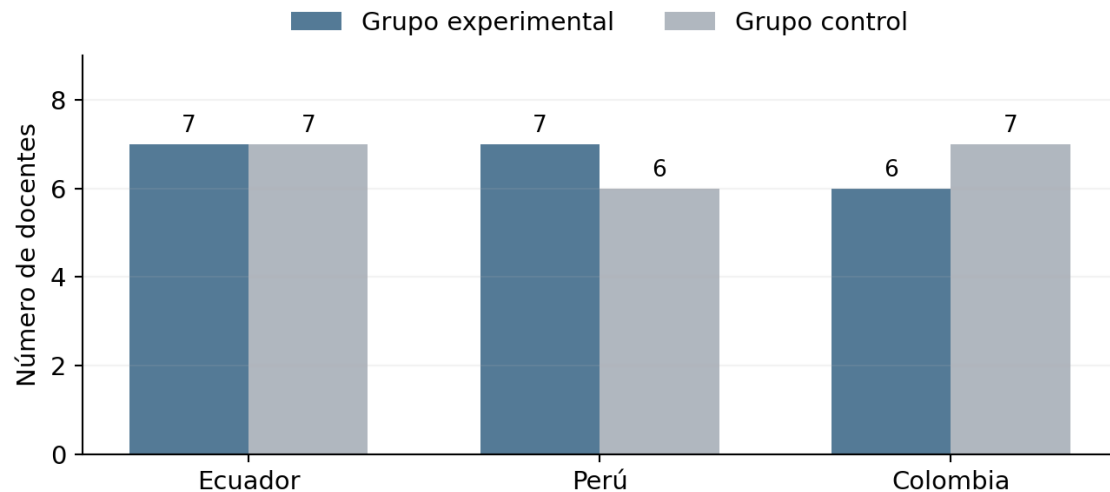
Initial comparison of the groups

In the initial comparisons, no statistically significant differences were identified in the characteristics of the teaching staff considered or in the student indicators evaluated. In academic motivation, the experimental group obtained $M = 4.12$ ($SD = 0.85$) and the control $M = 4.09$ ($SD = 0.81$), $t(810) = 0.51$; $p = 0.612$. For previous academic performance, $M = 6.85$ ($SD = 1.12$) and $M = 6.79$ ($SD = 1.15$) were reported, respectively, $t(810) = 0.77$; $p = 0.441$. These comparisons describe the starting point of the

variables examined; the absence of statistical significance does not mean demonstrating equality between the groups, since the distribution of teachers was not random. Baseline measures differentiated motivation and academic performance.

Figure 1.

Distribution of teaching staff by country and study condition.



Note. Elaboration based on the teaching frequencies presented in Table 1. N = 40.

Effects on academic motivation

The experimental group recorded an increase in academic motivation from $M = 4.12$ ($SD = 0.85$) in the pretest to $M = 5.34$ ($SD = 0.79$) in the posttest; in the control group the means were $M = 4.09$ ($SD = 0.81$) and $M = 4.31$ ($SD = 0.88$). The ANCOVA adjusted for the initial score indicated differences between conditions in the posttest, $F(1, 809) = 156.42$; $p < 0.001$; $\eta^2p = 0.162$. The adjusted means reported were 5.31 and 4.34, and Cohen's $d = 0.62$ was reported. These results are compatible with the direction foreseen in the H1 hypothesis, within the scope of the quasi-experimental design. The contrast is expressed in the motivational scale used and considers the initial measurements.

Table 3.

Academic motivation and academic performance of students, pre-test and post-test, by group (N = 812)

Variable and moment	Experimental M (DE)	Control M (DE)	F (gl)	p	d
Academic motivation - Pre-test	4.12 (0.85)	4.09 (0.81)	-	.612	-
Academic motivation - Post-test	5.34 (0.79)	4.31 (0.88)	156.42 (1, 809)	<.001	0.62

Variable and moment	Experimental M (DE)	Control M (DE)	F (gl)	p	d
Academic performance - Pre-test	6.85 (1.12)	6.79 (1.15)	-	.441	-
Academic Performance - Post-Exam	7.62 (1.05)	7.10 (1.18)	48.32 (1, 809)	<.001	0.48

Note. Academic motivation was measured on a scale of 1 to 7 points and performance on a scale of 0 to 10. F, p, η^2p , and d are presented according to the analyses of the study. Cohen's d = d.

Effects on academic performance

The mean academic performance of the experimental group went from 6.85 (SD = 1.12) to 7.62 (SD = 1.05), while the control group went from 6.79 (SD = 1.15) to 7.10 (SD = 1.18). The ANCOVA reported differences between conditions after considering the initial score, $F(1, 809) = 48.32$; $p < 0.001$; $\eta^2p = 0.056$; the adjusted means were 7.58 for the experimental group and 7.14 for the control group, with Cohen's $d = 0.48$. The direction of the differences corresponds to H2, although it is convenient to interpret them taking into account that the initial and final measures came from different academic evaluation benchmarks. Both measurements were assessed considering the academic criteria of each moment.

Teacher implementation and its relationship with student outcomes

The implementation of these strategies, measured by the GOPN, was positively associated with changes in academic motivation ($r = 0.57$; $p < 0.001$) and performance ($r = 0.44$; $p < 0.001$), according to the correlations reported. The GOPN corresponds to the observed practice of each teacher and the educational results were recorded in students belonging to their courses. Therefore, the link between both levels describes the relationship between the teaching application and the academic evolution of its students, without turning these associations into evidence of a causal or mediation mechanism. The observed trend is consistent with the H3 hypothesis. Its analysis requires differentiating the level of implementation of the teacher and the results reported by students within each course.

In the questionnaire on perception and self-perceived knowledge, a change from $M = 2.1$ (SD = 0.6) in the pre-test to $M = 4.3$ (SD = 0.5) in the post-test was recorded, in the post-test, on the five-point scale used. In the control group, means of 2.0 and 2.2, respectively, were described. These descriptive differences suggest a favourable evolution of the knowledge declared by the teachers who received training, without equating the self-report to a direct measurement of teaching competence. The assessment of one's own knowledge is relevant to know the training experience, but it has a different scope than the observations and grades. Its interpretation is complemented by the description of the contents of the programme.

Table 4.

Correlations between implementation of neurodidactic strategies (GOPN) and changes in motivation and academic performance

Variables	r of Pearson	p	n
GOPN - Change in academic motivation	.57	<.001	40 teachers / 812 students
GOPN - Change in academic performance	.44	<.001	40 teachers / 812 students

Note. GOPN = Guide to Observation of Neurodidactic Practices, with answers of 1 to 4 points.

DISCUSSION

The results describe favorable differences in academic motivation and university performance for the group that received specialized teacher training. The intervention combined content related to cognitive processes, microteaching, didactic redesign, and pedagogical accompaniment. These components coincide with the studies on neurodidactic strategies, satisfaction, and academic performance in higher education (6) and with research that links motivation with student performance (7). The magnitude of the reported motivational contrast, $d = 0.62$, should be read together with the means and the specific measure of motivation used. Likewise, the educational data do not allow attributing the observed change to particular neurobiological mechanisms that were not part of the measurements (19).

The differences in academic performance were less extensive than those observed for motivation according to the reported effect size values ($d = 0.48$ and $d = 0.62$, respectively). This behavior is consistent with the multidimensional nature of university performance, influenced by curricular, institutional, and personal conditions (30). Motivation is a theoretically plausible way of relating classroom practices and performance, but in this study a specific mediation model was not estimated; therefore, this explanation constitutes a theoretical interpretation and not a statistically identified mediating relationship. In addition, the grading criteria used in different subjects may contribute to the observed variation. This circumstance should be considered when comparing student results from different courses and universities.

The association between the observed degree of application of strategies worked on in the program and the evolution of student indicators reinforces the importance of examining the transfer of training to the classroom. Mere attendance at the sessions does not necessarily equate to the systematic use of teaching strategies, and accompaniment can favor their implementation. These findings are in dialogue with research that describes differences between declared knowledge and pedagogical performance (3,4). When analyzing the reported coefficients, it should be borne in mind that the GOPN was recorded per teacher and the motivational and academic results correspond to students grouped in their subjects. This distinction is important to understand the scope of the indicators and to relate the observations to the content actually taught during the training.

The present findings also dialogue with the international literature on the neuroscience of active learning, which has pointed out the complementarity between direct instruction and active learning

strategies depending on the neurocognitive mechanisms involved (9). The NES program, by integrating both attentional and emotional and mnesic principles, sought precisely to avoid an uncritical adoption of isolated strategies, favoring instead an integrated and evidence-based instructional design, in line with the recommendations made by recent review studies on neuroeducation and brain plasticity in higher education. The complementarity of procedures helps to avoid simplifying oppositions between teacher exposure and active participation. What is relevant is to analyze the coherence of each strategy with the learning goals and tasks.

In the teaching questionnaire, an increase in self-perceived knowledge about neuroeducation was observed in the experimental group, from $M = 2.1$ to $M = 4.3$ points on a scale of five. This result is consistent with the history of training needs of university teachers (5), but its declarative nature makes it necessary to distinguish perception of knowledge and practical mastery. The combination of a teaching questionnaire with an observation guide represents a strength of the intervention, since it allows the examination of different dimensions of the training experience without treating them as interchangeable measures. Consequently, the declared increase can be understood as a favorable indicator of formative perception, but it does not replace the measurement of performance in teaching situations by itself.

The participation of universities from Ecuador, Peru and Colombia made it possible to examine training in three different academic contexts and to recognize possible differences between disciplines and institutional environments. However, this diversity does not equate to statistical representativeness of the region: the institutions were selected for convenience and the assignment was not random. The most appropriate interpretation is limited to the populations and conditions of the study. Future multicenter studies with broader selection and multilevel procedures may clarify the stability of the relationships observed between training, teaching practices and student outcomes. These selection conditions delimit the institutional scope of the experience and prevent interpreting the origin of three countries as a guarantee of regional generalization.

Limitations of the study

Among the limitations is the quasi-experimental design with non-equivalent groups, which restricts causal inferences and does not exclude possible unobserved baseline differences. The 812 students were distributed among 40 teachers, which can generate intraclass correlation and affect the accuracy of contrasts that treat each record as independent. The performance comparison used a previous academic average and the grade of a subsequent subject, related measures, but not identical in their coverage. The multidimensional nature of motivation, the characteristics of the self-report instruments, and the possibility of recognizing the teaching condition during the observations should also be considered. Follow-up was limited to the intervention semester; therefore, the permanence of long-term changes was not evaluated.

CONCLUSIONS

Teacher training based on educational neuroscience constitutes a line of professional development relevant to higher education, as it relates knowledge about attention, emotion, memory and learning

with concrete teaching decisions. The study examined a twelve-week program organized into six modules, with microteaching, redesign of sequences and pedagogical accompaniment. This integration provides a practice-oriented training perspective, rather than being limited to the dissemination of theoretical concepts on brain functioning. Its importance lies in promoting a sustained articulation between planning, classroom experience and learning assessment.

After the intervention, the experimental group presented higher means than those of the control group in academic motivation and performance. The post-test scores were 5.34 vs. 4.31 in motivation and 7.62 vs. 7.10 in performance, with ANCOVA results favorable to the training condition in both indicators. These differences support the relevance of studying structured programs that connect teacher training and educational outcomes. As it is a quasi-experimental design, its interpretation is limited to the conditions of the participating groups and institutions, without attributing all the changes exclusively to the intervention or extending the conclusions to all Latin American universities.

The positive relationship between the implementation of pedagogical practices and student changes highlighted the importance of transferring training to the daily activities of the classroom. The correlations reported were 0.57 with the change in academic motivation and 0.44 with the change in performance. Therefore, the training program should not be evaluated exclusively based on the hours of training given: the preparation of sequences, the accompaniment and the conditions to execute the planned activities are also relevant. The observation of teaching practice allows enriching the understanding of how the pedagogical proposal is concretized in different subjects and contexts.

The evaluation of the programme allowed several components of the educational process to be considered: a 24-item motivation indicator, academic qualifications, observation of teaching activities and a self-perceived knowledge questionnaire. Each instrument provides information of a different nature and therefore its results should be interpreted according to the construct and scale used. In particular, motivation includes intrinsic, extrinsic and amotivating dimensions, while pre- and post-qualifications come from different academic benchmarks. This distinction helps to avoid overly broad interpretations and provides a basis for improving institutional systems for monitoring teacher education without reducing university learning to a single measure.

Finally, the experience presented offers elements to guide continuing education actions in university institutions with different pedagogical needs and organizational conditions. It is convenient to develop proposals that integrate critical reading of scientific evidence, teaching planning, supervised practice, feedback and monitoring of the activities carried out. Subsequent work may expand the temporal monitoring, incorporate comparisons between disciplines and examine in greater detail the relationships between classroom strategies, motivation and learning. In this way, this line of research can continue to be strengthened as an interdisciplinary field through the dialogue between scientific findings and situated educational practices, without reducing the complexity of learning to exclusively neural explanations.

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ETHICAL CONSIDERATIONS

The research was carried out with voluntary participation, written informed consent of teachers and adult students, and confidential treatment of the information. The authors point out that the corresponding protocols were submitted to review by the ethics committees of the participating institutions.

ARTIFICIAL INTELLIGENCE (AI) USAGE STATEMENT

The authors state that the AI tool was used exclusively to support the organization of the article and the translation of the text. Its use did not determine the scientific content, study design, selection of sources, data analysis, interpretation of results, or conclusions. Full responsibility for the content remains with the authors.

FUNDING

The authors state that this study did not receive any external funding from public, private, or non-profit organizations. All research, analysis, and development activities were carried out with their own resources.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest related to this study and that all the procedures followed comply with the ethical standards established by the journal. They also confirm that this work is unpublished and has not been published, either partially or totally, in any other publication.

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