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Impact of a neuroeducational intervention on factors associated with academic failure and academic performance in medical students.

Impacto de una intervención neuroeducativa en los factores asociados al fracaso académico y al rendimiento académico en estudiantes de medicina.

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Summary.

Background: Academic performance in medical students is a multifactorial phenomenon influenced by intrinsic and extrinsic factors that can either facilitate or hinder learning. Identifying these factors and evaluating neuroeducational interventions can contribute to the design of strategies to strengthen academic performance. **Objective:** To analyze the impact of a neuroeducational intervention on intrinsic and extrinsic factors and academic performance in medical students. **Method:** A mixed-methods study was conducted, integrating a qualitative and a quantitative phase with a quasi-experimental pretest-posttest design, including a control group and an intervention group. The qualitative phase involved 47 failing students; the data were analyzed using ATLAS.ti. The quantitative phase involved 43 students (27 in the control group and 16 in the intervention group). The intervention group received a neurolearning course. Quantitative data were analyzed using pretest-posttest comparisons ($p < 0.05$). **Results:** Failing grades were associated with difficulties in organization, time management, study strategies, and emotions such as anxiety, stress, and nervousness. The intervention group showed a significant improvement in academic emotions ($p = 0.005$) and a significant increase in the third exam grade compared to the first ($p = 0.026$) and second ($p = 0.035$) exams. No significant changes were observed in extrinsic factors. **Conclusions:** The neuroeducational intervention promoted changes in intrinsic factors related to learning and was associated with improved academic performance, providing evidence of its potential in the training of medical students.

Keywords: medical education, medical students, learning, neuroscience, teaching.

Resumen.

Antecedentes: El rendimiento académico en estudiantes de medicina es un fenómeno multifactorial influenciado por factores intrínsecos y extrínsecos que pueden favorecer o dificultar el aprendizaje. La identificación de estos factores y la evaluación de intervenciones neuroeducativas pueden contribuir al diseño de estrategias para fortalecer el desempeño académico. **Objetivo:** Analizar el impacto de una intervención neuroeducativa sobre los factores intrínsecos, extrínsecos y el

rendimiento académico en estudiantes de medicina. **Método:** Se realizó un estudio con enfoque mixto que integró una fase cualitativa y una fase cuantitativa con diseño cuasiexperimental pretest-postest, con grupo control e intervención. En la fase cualitativa participaron 47 estudiantes en situación de reprobación; la información se analizó mediante ATLAS.ti. En la fase cuantitativa participaron 43 estudiantes (27 grupo control y 16 grupo intervención). El grupo de intervención recibió un curso de neuroaprendizaje. Los datos cuantitativos se analizaron mediante comparaciones pretest-postest (p<0.05). **Resultados:** La reprobación se relacionó con dificultades en la organización, la gestión del tiempo, las estrategias de estudio y emociones como ansiedad, estrés y nerviosismo. El grupo de intervención mostró una mejora significativa en las emociones académicas (p=0.005) y un incremento significativo en la calificación del tercer parcial respecto al primero (p=0.026) y al segundo (p=0.035). No se observaron cambios significativos en los factores extrínsecos. **Conclusiones:** La intervención neuroeducativa favoreció cambios en factores intrínsecos relacionados con el aprendizaje y se asoció con una mejora del rendimiento académico, aportando evidencia sobre su potencial en la formación de estudiantes de medicina.

Palabras clave: educación médica, estudiantes de medicina, aprendizaje, neurociencias, enseñanza.

1. Introduction

Course failure is one of the main manifestations of academic failure in higher education and represents a problem that affects students' academic trajectories, in addition to generating personal, family, and institutional repercussions. In medical training, this phenomenon is especially relevant due to the high academic demands of the program and the interaction of personal, social, educational, and institutional factors that influence student performance. Therefore, its study requires a multivariate approach that allows for understanding the complexity of its causes (1-3). In the present study, course failure is understood as insufficient performance to meet the minimum parameters established by an educational institution, operationally manifested by the failure to pass at least one subject (4).

Academic performance in medicine depends on the interaction between intrinsic and extrinsic factors. Intrinsic factors include processes related to metacognition, self-regulation of learning, executive functions, motivation, and academic emotions, while extrinsic factors include family context, social support, and the conditions of the educational environment. Evidence shows that these factors do not act in isolation but interact with each other and influence students' learning and academic performance (5-8). In recent years, neuroscience has provided new knowledge about the brain processes involved in learning, fostering the development of educational strategies based on scientific evidence. Neuroeducation proposes integrating this knowledge into teaching and learning processes, while neurodidactics proposes adapting educational environments and strategies to the neurobiological mechanisms of learning in order to promote more efficient and meaningful learning. Despite the growing interest in these approaches, several authors agree on the need to generate more empirical evidence on their application in the context of medical education (9-11).

Evidence in neuroeducation indicates that integrating knowledge from neuroscience into educational processes can enrich the design of teaching strategies by incorporating evidence on the mechanisms of attention, memory, executive functions, motivation, and emotional processing involved in learning. Furthermore, this approach considers the influence of factors such as sleep, stress, and other biological processes on brain function and student performance, providing a scientific basis for developing educational interventions grounded in knowledge of the processes involved in learning (12).

In parallel, the systematic identification of factors associated with academic performance is a fundamental step in designing educational interventions that address the real needs of students.

Recently, an instrument was developed and validated that allows for the comprehensive evaluation of intrinsic and extrinsic factors related to academic performance in Mexican medical students, providing a tool for the early identification of academic risk factors and the design of contextualized interventions (13).

Despite the available evidence on factors associated with academic performance and the growing interest in applying neuroscience to medical education, there is still limited evidence on the effect of neuroeducational interventions targeting these factors in medical students. Therefore, the objective of this study was to analyze the impact of a neuroeducational intervention on intrinsic factors, extrinsic factors, and academic performance in first- and second-semester medical students.

2. Methods

2.1 Study design

A mixed-methods study was conducted (Figure 1). The qualitative phase was exploratory in scope and identified intrinsic and extrinsic factors related to academic performance from the perspective of failing students. Subsequently, a quantitative phase was developed using a quasi-experimental pretest-posttest design with a control group and an intervention group. Its purpose was to evaluate the impact of a neuroeducational intervention on intrinsic factors, extrinsic factors, and academic performance.



Figura 1. Integración metodológica de las fases cualitativa y cuantitativa del estudio con enfoque mixto.

2.2 Population

The study was conducted on students of the Medical Surgeon and Midwife program of the Faculty of Medicine and Biomedical Sciences of the Autonomous University of Chihuahua during the school cycles January-June and August-December of 2025.

The qualitative phase was conducted during the January-June semester of 2025 and included 47 first- and second-semester students who were failing the course and enrolled in the subject Anatomical Structures with a Clinical Focus. A non-probability convenience sampling method was used, and participants were all students who agreed to participate voluntarily by signing an informed consent form.

The quantitative phase was conducted during the August-December 2025 semester and included 43 first- and second-semester students who were failing the course and enrolled in the subject Anatomical Structures with a Clinical Focus. These students were divided into a control group (n = 27) and an intervention group (n = 16). During the follow-up period, two participants did not complete the post-test (one per group), so the final analysis included 41 students: 26 in the control group and 15 in the intervention group. The groups had already been formed by the educational institution before the start of the study, so random assignment of participants was not performed. All students included in the study were those who voluntarily agreed to participate by signing an informed consent form.

2.3 Instruments

In the qualitative phase, a previously designed and validated open-ended questionnaire was used to assess intrinsic and extrinsic factors related to academic performance in medical students (12). The instrument was developed using an exploratory sequential design that included a literature review, exploratory interviews, pilot tests, and two rounds of expert review validation. The final version obtained a Content Validity Coefficient (CVC) of 0.974, exceeding international acceptance criteria, and integrates four dimensions: sociodemographic characteristics and academic background, metacognition and learning strategies, academic emotions, emotional management and support network, and sleep habits, mental health, and general well-being.

In the quantitative phase, a battery of questionnaires developed as part of the research project "Neurolearning and Academic Performance Factors in Human Anatomy: An Analysis of Study Techniques and Habits in Medical Students" (CI-046-23) was used. This battery comprised the dimensions of study techniques, study habits, and academic emotions. The instrument corresponding to the study techniques dimension underwent a development and validation process that included a pilot test, content validation through expert review, and internal consistency analysis, yielding a Cronbach's alpha coefficient of 0.62. The battery allowed for the evaluation of factors related to academic performance, which was determined by the grades obtained on the first, second, and third partial exams of the course Anatomical Structures with a Clinical Focus.

2.4 Procedure

The study was conducted in two consecutive phases. The qualitative phase took place during the January-June semester of 2025 with students who had failed the course and were re-enrolled in the course Anatomical Structures with a Clinical Focus. Participants answered the open-ended questionnaire individually and anonymously. Subsequently, the data were organized and analyzed using content analysis with ATLAS.ti software to identify categories, codes, and relationships between emerging intrinsic and extrinsic factors.

The quantitative phase was conducted during the August-December 2025 semester. Before the intervention began, both groups completed a quantitative questionnaire (pretest). Subsequently, the intervention group participated in a seven-week, in-person neuroeducational course consisting of 21 sessions (three one-hour sessions per week). Each session incorporated content from the course "Anatomical Structures with a Clinical Focus I," corresponding to the second and third midterm exams. This content was taught using neuroscience principles applied to learning. The course covered topics related to brain function during the learning process, specifically attention, memory, emotions, and sleep, as well as their relationship to academic performance. It also included instruction and practical application of neurolearning strategies and techniques, such as the Pomodoro Technique, color coding, structured highlighting, summarizing, mind mapping, flashcards, and the PLEMA method. Each technique was explained and related to the characteristics of cognitive processes, executive functions, and the sleep cycle, as these processes are fundamental to learning. Students were shown how each strategy is based on specific neurocognitive mechanisms and the benefits its

application can bring to learning and academic performance. For example, mind maps created using color-coding enhance visuospatial memory and the association between colors and concepts. Similarly, it was explained that summarizing promotes hierarchical organization and deep information processing; flashcards were presented as a strategy for practicing retrieval and spaced repetition to reinforce memory consolidation; structured underlining was linked to selective attention and the identification of relevant information; and the Pomodoro Technique was connected to sustained attention, executive functions, and the reduction of cognitive fatigue through scheduled breaks. The PLEMA method was used as a tool to promote planning, self-regulation, and learning monitoring. Throughout all sessions, spaced study was implemented through the systematic review of previously reviewed content to facilitate long-term memory consolidation. The importance of sleep as a biological process involved in memory consolidation was also explained, as well as the influence of emotions on attention, encoding, and information retrieval during learning. The methodology combined brief presentations, discussions of clinical cases, student development of study materials, and an integrative review session with a mock exam prior to the midterm. The control group continued with the usual academic activities established by the educational program. At the end of the intervention, both groups completed the quantitative questionnaire again (post-test), and the grades corresponding to the first, second, and third midterm exams for the course were obtained to evaluate academic performance.

2.5 Data Analysis

Qualitative data were analyzed using content analysis with ATLAS.ti software, which allowed for the identification of categories, codes, and relationships among emerging factors. Quantitative data were analyzed using Stata statistical software, version 14.2 (StataCorp, College Station, TX). Descriptive analyses were performed to characterize the study population, and pretest-posttest comparisons were conducted within each group to evaluate changes in factors related to the learning process and academic performance. A statistical significance level of 0.05 was considered in all analyses. $p < 0.05$. Additionally, effect sizes were calculated using Hedges' g for pretest-posttest comparisons within each group, along with their 95% confidence intervals, to assess the practical magnitude of the observed changes. The interpretation of effect sizes was based on the following cutoff points: < 0.20, trivial; 0.20–0.49, small; 0.50–0.79, moderate; and ≥ 0.80, large.

2.6 Ethical considerations

This research is part of the project "Neurolearning and Academic Performance Factors in Human Anatomy: An Analysis of Study Techniques and Habits in Medical Students," with internal registration number CI-046-23, approved by the Research Committee of the Faculty of Medicine and Biomedical Sciences of the Autonomous University of Chihuahua on January 22, 2024, and by the Research Ethics Committee of the same Faculty on April 9, 2024. The study was classified as a no-risk investigation, in accordance with Article 17 of the Regulations of the General Health Law on Health Research (2014) (14), since it did not involve the manipulation of substances, reagents, or invasive procedures. In both phases, written informed consent was obtained from all participants, guaranteeing voluntary participation, confidentiality of information, and anonymous data processing.

3. Results

3.1 Qualitative phase

Forty-seven students from the first two semesters of the Medical Surgeon and Midwife program, who were failing the course Anatomical Structures with a Clinical Focus, participated in the study. Qualitative analysis identified various factors related to academic performance, as well as describing study strategies, academic emotions, and some habits associated with the learning process. The qualitative analysis revealed that the students attributed their failure primarily to difficulties related

to organization, time management, and the use of study strategies, accompanied by persistent negative emotions throughout the learning process (Figure 2).

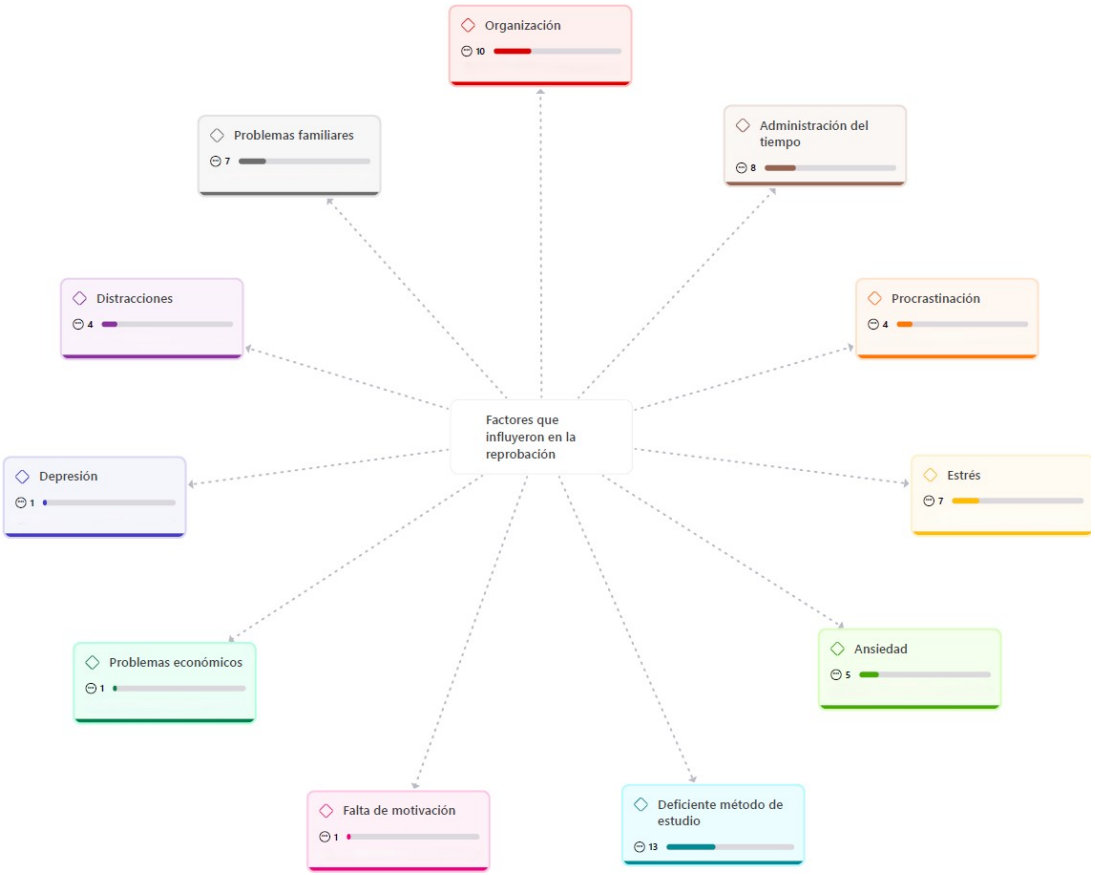


Figura 2. Factores que influyeron en la reprobación según los estudiantes.

Regarding the study strategies used, the most frequently mentioned techniques were the use of flashcards, the Pomodoro Technique, and underlining, followed by summarizing, exam simulations, and spaced repetition. The use of mind maps, images, and other learning resources was also identified (Figure 3). Although students reported using various study techniques, the qualitative analysis revealed that, in many cases, their implementation was inadequate. For example, some participants underlined virtually all of the material or created summaries by transcribing almost the entire content, which limited the effectiveness of these strategies.



Figura 3. Técnicas de estudio más utilizadas por los estudiantes.

Self-assessment of learning was based primarily on taking exams and using exam simulators to evaluate their preparation, while other strategies, such as explaining topics to other people, answering quizzes, asking questions, or presenting content, were used less frequently (Figure 4).

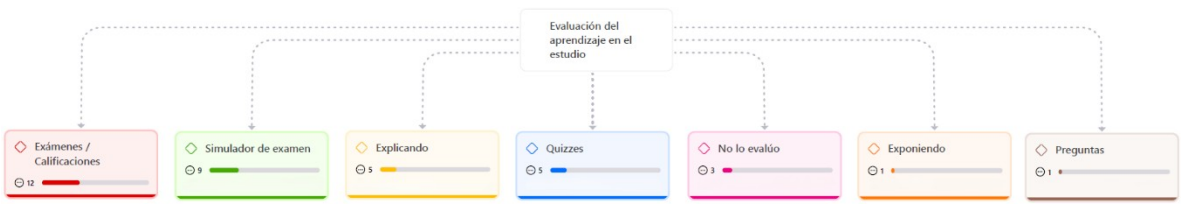


Figura 4. Estrategias utilizadas por los estudiantes para evaluar su aprendizaje.

The analysis of emotions prior to attending the course showed a clear predominance of negative emotional states, such as nervousness, Anxiety and stress were also identified. Likewise, manifestations of demotivation, frustration, fear, and sadness were identified, while positive emotions such as tranquility, motivation, enthusiasm, or enjoyment of the subject were infrequent (Figure 5).

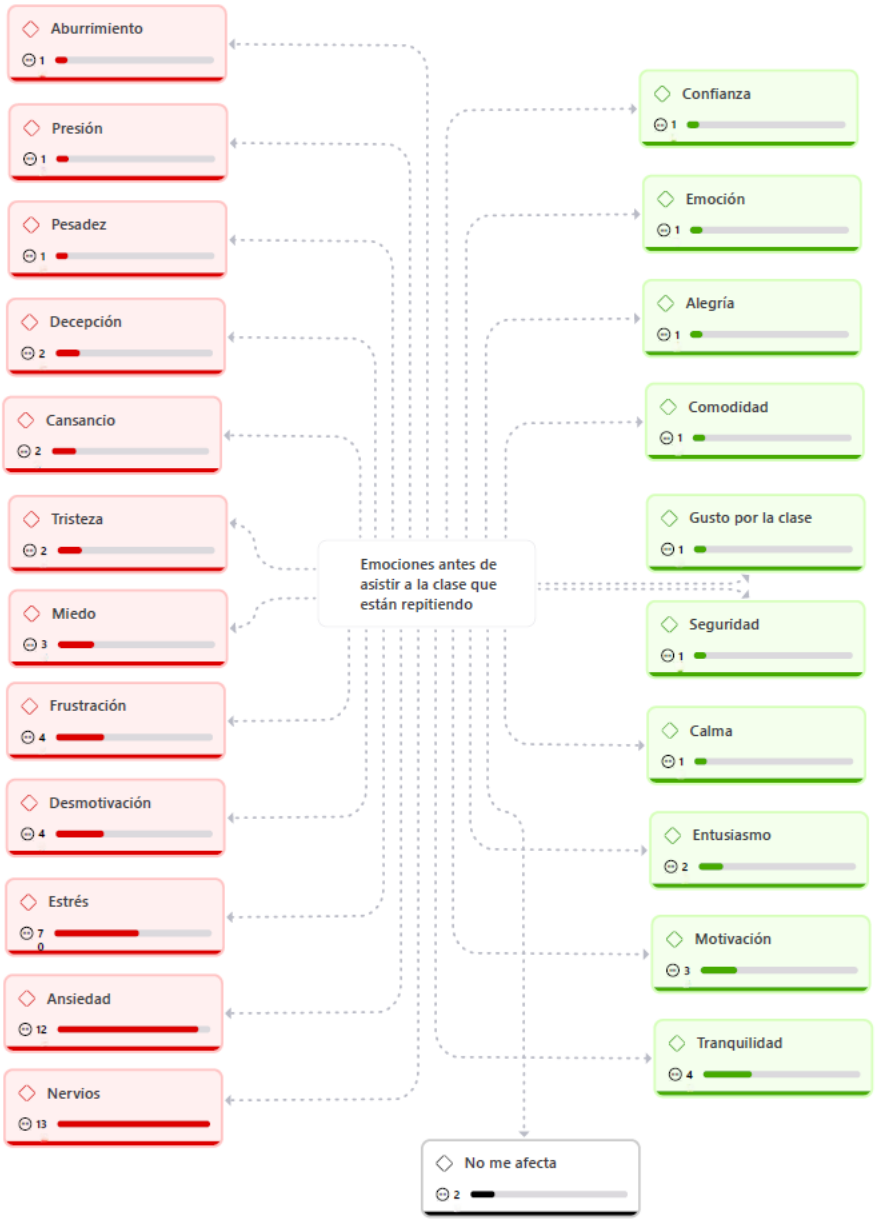


Figura 5. Emociones experimentadas antes de asistir a la clase en repetición.

During the exams, students again reported a predominance of negative emotions, mainly nervousness, anxiety, stress, and fear. Positive emotions were considerably less frequent, demonstrating a high emotional burden associated with the course assessment (Figure 6).



Figura 6. Emociones experimentadas durante el examen de la asignatura en repetición.

Regarding the comments made by the teachers, the participants indicated that those of a positive nature favored their motivation and willingness to continue learning; in contrast, the negative comments were perceived as a demotivating factor that affected their confidence and their attitude towards the subject (figure 7).

Finally, sleep habits during the exam period showed that most students slept between 23:00 and 01:00 hours; however, some participants reported going to sleep even after 02:00 hours or staying awake all night to study, reflecting rest patterns that are unfavorable for learning (Figure 8).

3.2 Quantitative Phase

Of the 43 students included in the initial assessment, 41 completed the final measurement, divided into a control group ($n = 26$) and an intervention group ($n = 15$). Scores obtained before and after the neuroeducational intervention were compared in the dimensions of study techniques, study habits, and emotions. and academic performance (Table 1). In addition to tests of statistical significance, effect sizes were calculated using Hedges' g and 95% confidence intervals for pretest-posttest comparisons within each group.

In the study techniques dimension, no statistically significant differences were observed between the pre-test and post-test evaluations in either group (control group: $p = 0.852$; intervention group: $p = 0.705$). Furthermore, the effect sizes were trivial in both the control group (Hedges' $g = -0.04$) and the intervention group (Hedges' $g = 0.09$), indicating changes of little practical relevance. Similarly, comparisons between the two groups showed no significant differences either before ($p = 0.406$) or after the intervention ($p = 0.280$).

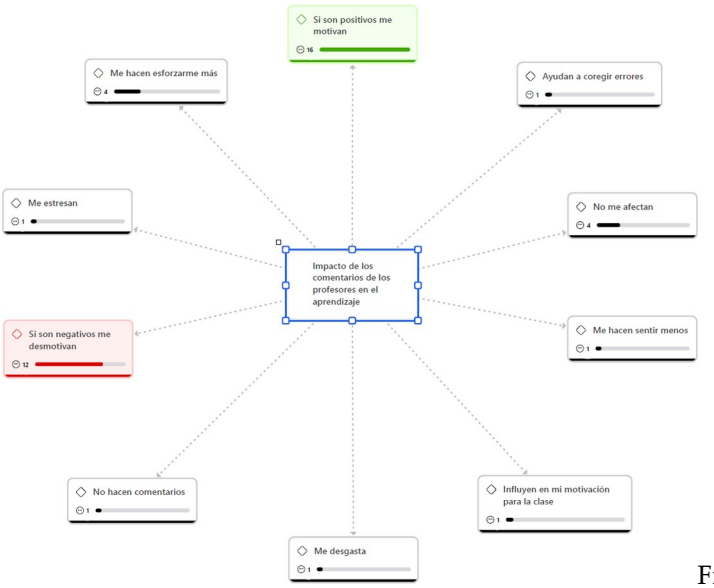
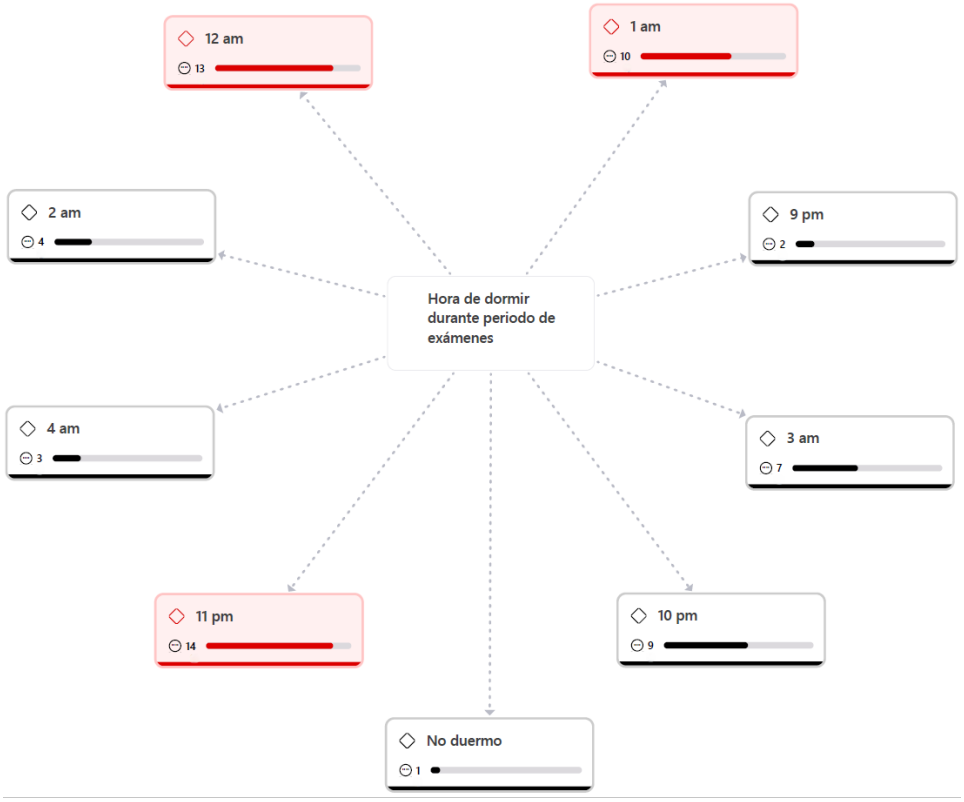


Figura 7. Impacto de los comentarios de los docentes en el aprendizaje.



Regarding study habits, the control group showed a significant decrease between the initial and final assessments ($p = 0.025$), with a small effect size (Hedges' $g = -0.45$). In contrast, the intervention group showed no significant changes ($p = 0.974$), and the effect size was trivial (Hedges' $g = -0.01$). Furthermore, comparisons between the two groups showed no statistically significant differences before ($p = 0.842$) or after the intervention ($p = 0.228$).

In contrast, academic emotions showed a significant increase in the intervention group after participating in the neuroeducational course ($p = 0.005$), accompanied by a large effect size (Hedges' $g = 0.82$). On the other hand, the control group showed no statistically significant changes ($p = 0.513$), and the effect size was trivial (Hedges' $g = 0.13$). Furthermore, comparisons between the two groups showed no significant differences before ($p = 0.482$) or after the intervention ($p = 0.303$).

Regarding academic performance, both groups had similar scores on the first and second midterm exams. However, the intervention group showed a significant increase in the third midterm score compared to the first ($p = 0.026$) and compared to the second ($p = 0.035$), while the control group did not show significant differences between the assessments (Table 2).

Table 1. Scores for study techniques, study habits, and academic emotions according to study group.

Variable	Control group *n* = 26			Intervention Group *n* = 15			
	Average	OF	Hedges' *g* (95% CI)	Average	OF	p	Hedges' *g* (95% CI)
Study Techniques							
Pre	33.15	4.95	-0.04 (-0.41	34.53	5.28	0.406	0.09 (-0.39
Post	32.96	5.91	to 0.34)	35.15	6.47	0.280	to 0.57)
p	0.852			0.705			
Study Habits							
Pre	39.38	6.16	-0.45 (0.84	39.80	6.74	0.842	-0.01 (-0.49
Post	37.15	6.60	to -0.06)	39.73	6.31	0.228	to 0.47)
p	0.025			0.974			
Academic emotions							
Pre	35.27	6.12	0.13 (-0.25	33.93	5.23	0.482	0.82 (0.25
Post	36.00	6.71	to 0.50)	38.40	7.75	0.303	to 1.38)
p	0.513			0.005			

Data are mean ± standard deviation (SD). Rows identified as " p " indicate the pretest-posttest comparison within each group. Statistical significance was considered when $p < 0.05$.

Table 2. Grades obtained according to study group.

Ratings	Control group *n* = 26			Intervention Group *n* = 15		
	Average	OF	p	Average	OF	p
Partial 1	5.61	0.85	—	5.35	0.86	0.720
Partial 2	5.35	0.95	—	5.43	1.38	0.744
Partial 3	5.59	1.29	—	6.03	1.62	0.291
Partial (2 vs 1)	-0.19	1.03	0.356	0.08	1.15	0.897
Partial (3 vs 1)	-0.02	1.43	0.944	0.68	1.08	0.026
Partial (3 vs 2)	-0.24	1.16	0.420	0.60	1.08	0.035

Data are presented as mean ± standard deviation (SD). Empty cells indicate that no statistical comparison applies in that position.

4. Discussion

This research analyzed the impact of a neuroeducational intervention on factors related to academic performance using a mixed-methods approach that integrated a qualitative and a quantitative phase. The combination of both approaches allowed, on the one hand, the identification of factors that students associated with failing the course and, on the other hand, the evaluation of the effect of an intervention based on neuroscience principles on dimensions related to learning and academic performance. Overall, the results show that the intervention was associated with an increase in scores on academic emotions and with an improvement in academic performance, while no statistically significant changes were observed in study techniques or habits.

The qualitative phase confirmed that course failure is a multifactorial phenomenon involving both extrinsic (academic and contextual) and intrinsic (student-related) factors. Students primarily reported difficulties related to organization, time management, study strategies, stress, and anxiety—results that align with research conducted on medical students describing course failure as a consequence of the interaction of multiple academic, personal, and institutional factors (1-3). Similarly, Chavera Rondón et al. documented that both intrinsic and extrinsic factors jointly influence the academic performance of health sciences students (5).

One of the most relevant findings was that students reported using various study techniques, including underlining, summarizing, flashcards, and the Pomodoro Technique. However, the qualitative analysis showed that, in many cases, these strategies were implemented inadequately; for example, some participants underlined practically all of the material or created summaries by transcribing the content almost verbatim. This finding provides an important element for interpreting the quantitative results, since the absence of significant changes in study technique scores allows us to identify areas for improvement in the intervention course and the duration of each topic covered. It also suggests that the problem may lie in how students apply study techniques, as they do so without knowing or understanding them.

Regarding study habits, no statistically significant changes were identified after the neuroeducational intervention. These findings suggest that different dimensions related to learning exhibit varying rates of change in response to educational interventions. Although the course addressed aspects related to study planning, sleep, rest periods, and learning organization, the seven-week duration may not have been sufficient to generate detectable changes in habits that typically solidify over time. Therefore, future research with longer follow-up periods will determine whether these changes can manifest in the medium and long term.

In contrast, the observed increase in academic emotions scores suggests that interventions based on neuroscience principles can promote changes in dimensions related to how students approach the learning process. Neuroeducation posits that understanding the brain processes involved in learning, as well as the role of attention, memory, emotions, and sleep, fosters the development of evidence-based educational strategies (9-11). Furthermore, the effect size observed for this dimension was large (Hedges' $g = 0.82$), supporting the practical relevance of the intervention. In contrast, changes in study techniques and habits showed trivial and small effect sizes, respectively, suggesting that these dimensions might require longer-term interventions to produce more significant changes.

These results are consistent with recent international literature, which recognizes that neuroeducation constitutes an interdisciplinary approach that integrates knowledge from neuroscience, cognitive psychology, and educational sciences to design teaching strategies in accordance with the mechanisms involved in learning (15). In this context, it has been proposed that neuroeducational interventions usually produce initial changes in variables related to motivation, self-regulation, and academic emotions, while modifications in study habits or techniques may

require longer periods of implementation and follow-up (15-16). This perspective offers a plausible explanation for the results observed in the present study, where the main effect of the intervention was manifested in the emotional dimension, without significant changes in study techniques and habits during the evaluated period.

Before attending class and during exams, emotions such as anxiety, stress, and nervousness predominated, reflecting the high emotional burden experienced by students who are failing. Consequently, it is reasonable that an intervention aimed at understanding brain function during learning and strengthening self-regulation strategies showed changes primarily in this dimension, even though other study-related variables remained stable during the evaluation period.

Regarding academic performance, no statistically significant differences were observed between the groups in the grades obtained on each midterm exam. However, the intervention group showed a significant improvement in the within-group comparisons between the third midterm and the two previous midterms. These findings suggest a possible association between the neuroeducational intervention and the evolution of academic performance; however, due to the quasi-experimental design and the absence of interaction analysis between groups, the results should be interpreted with caution and do not allow for establishing a causal relationship.

One of the main strengths of this study was the integration of a mixed-methods approach, which allowed for addressing the phenomenon of academic performance from two complementary perspectives. The qualitative phase explored the academic experiences of failing students, while the quantitative phase evaluated the effect of a neuroeducational intervention implemented in a subsequent semester on dimensions related to learning and academic performance. Although the two phases were not directly methodologically dependent, their integration broadened the understanding of the phenomenon by comparing the students' reported experiences with the results obtained after the intervention.

Limitations of the study include the small sample size, particularly in the intervention group, the inclusion of students from a single institution, and the lack of random assignment of participants—conditions inherent to the quasi-experimental design employed. The use of pre-existing groups may have contributed to selection bias and limited the study's internal validity, due to the possible existence of unmeasured baseline differences between the groups. These characteristics may also have limited the statistical power to detect differences between groups and increased the risk of type II errors; therefore, the results should be interpreted with caution. The duration of the intervention may also have limited the identification of changes in variables related to study techniques and habits. Future research should incorporate larger samples, multicenter studies, random assignment where possible, and longer follow-up periods to confirm the findings and assess the permanence of the observed changes.

5. Conclusions

- The neuroeducational intervention was associated with a significant increase in academic positive emotions and a positive evolution in academic performance in the intervention group. In contrast, no significant changes were observed in study techniques or habits during the evaluation period. These findings suggest that interventions based on neuroscience principles can contribute to strengthening specific dimensions related to learning in medical students.
- Furthermore, this study provides evidence for the usefulness of a mixed-methods approach in integrating the exploration of factors associated with academic performance with the evaluation of educational interventions. However, due to the study's methodological

limitations, further research with larger samples, long-term follow-up, and designs with greater methodological control is needed to confirm these findings.

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