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NEUROPEDAGOGY AND NEUROMETHODOLOGY FOR TEACHING AND RESEARCH: CONTRIBUTIONS FROM NEUROIMAGING

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Abstract.

This study analyzes the need to incorporate neuroimaging into neuropedagogy and teaching and research neuromethodologies, examining educators' perceptions of their importance and relationships. A mixed design was used with 165 teachers from Spain, Brazil, Paraguay, Mexico, and Colombia. A quantitative questionnaire (4-point Likert scale) was used with 20 items distributed across four dimensions: Neuropedagogy, Teaching Neuromethodology, Research Neuromethodology, and Neuroimaging. It was complemented by a focus group of 10 participants. Descriptive, correlational, and regression analyses were conducted, along with a qualitative thematic analysis. Quantitative analyses revealed positive perceptions across all dimensions, with significant correlations between Neuropedagogy, Teaching Neuromethodology, and Research Neuromethodology (r between 0.692 and 0.757, $p<0.01$). Regression showed that Teaching Neuromethodology is the strongest predictor of Neuropedagogy valuation ($\beta=0.467$, $p<0.001$), followed by Research Neuromethodology ($\beta=0.325$, $p<0.001$). Qualitative analysis identified enthusiasm for these fields but also challenges in their practical application. The findings underscore the perceived importance of neuromethodologies and neuroimaging in neuropedagogy but also reveal significant barriers to their effective implementation. The need for further teacher training, resource development, and ethical guidelines for the use of these approaches in education is highlighted. Future research is suggested to translate neuromethodological and neuroimaging findings into concrete pedagogical strategies and evaluate their effectiveness in various educational contexts.

Keywords: neuropedagogy, teaching neuromethodology, research neuromethodology, neuroimaging, education

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1.-Introduction

Neuropedagogy emerges as an interdisciplinary field that integrates neuroscience knowledge with educational practices. According to Campos (2010), neuropedagogy seeks to apply findings on brain functioning to optimize teaching and learning processes. This discipline is based on the premise that a deep understanding of brain mechanisms can lead to more effective pedagogical strategies adapted to the cognitive and emotional needs of students. Hernández & De Barros (2023) postulate that neuropedagogy not only seeks to apply neuroscientific knowledge, but also aspires to promote quality education based on scientific evidence about brain functioning. These authors emphasize the importance of neuropedagogy in the design of teaching methodologies that are aligned with the cognitive and emotional processes of students. Tokuhama-Espinosa (2011) defines neuropedagogy as the application of neuroscientific research to the design of educational interventions. This author emphasizes the importance of basing pedagogical practices on scientific evidence on brain functioning, thus promoting more efficient and lasting learning.

Mora (2013) extends this perspective by introducing the concept of "neuroeducation" as an innovative paradigm in brain-based teaching. According to this author, neuroeducation offers valuable tools for the early identification of learning difficulties of neurological or psychological origin, as well as for the development of strategies to improve students' attention, memory and motivation. Esteban et al. (2023) stress the importance of neuropedagogy in the design of learning environments that enhance optimal brain development. These authors argue that the application of neuropedagogical principles involves not only the implementation of new techniques, but also the creation of educational environments that stimulate brain plasticity and foster the formation of meaningful neural connections. Carew and Magsamen (2010) have explored the application of neuropedagogical principles in the higher education setting. Their research highlights the importance of designing educational experiences that not only transmit knowledge, but also promote the development of higher-order cognitive skills and the capacity for lifelong learning. Hernandez & De Barros (2024) provide a more precise definition of the term, describing neuropedagogy as "the science that studies education from a neuroeducational perspective, with the aim of configuring the neurotheory and neuromethodology of education, as well as its practice which is neurodidactics". This definition emphasizes the scientific character of neuropedagogy and its role in the configuration of new educational theories and methodologies based on knowledge of the brain.

Neuropedagogy, therefore, presents itself as a promising field that has the potential to significantly transform educational practices. By integrating knowledge about brain functioning with existing pedagogical theories, neuropedagogy seeks to create a bridge between neuroscientific research and everyday educational practice. However, as several authors point out, it is crucial that this integration be done in a critical and reflective manner, always considering the specific educational contexts and the individual needs of students.

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Teaching neuromethodology emerges as a natural extension of neuropedagogy, applying neuroscientific principles specifically to the design and implementation of teaching methods. While neuropedagogy provides the general theoretical framework, teaching neuromethodology focuses on the practical application of this knowledge in the classroom. Hernandez & De Barros (2022) define teaching neuromethodology as "the systematic application of neuroscientific knowledge in the design, implementation, and evaluation of teaching strategies." These authors argue that teaching neuromethodology goes beyond the simple incorporation of information about the brain in teaching, seeking a profound transformation of pedagogical practices based on neuroscientific evidence. Carew & Magsamen (2010) underscore the importance of teaching neuromethodology in higher education, noting that neuroscience-based strategies can significantly enhance the development of higher-order cognitive skills in college students. Their work provides empirical evidence on how neuroscience-informed teaching methods can foster critical thinking and creativity. Tokuhama-Espinosa (2011), in her work on the integration of mind, brain, and education, emphasizes the need for specific training in neuromethodology for teachers. She argues that this training should go beyond the simple transmission of neuroscientific knowledge, also including practical skills to translate this knowledge into effective teaching strategies. A crucial aspect of teaching neuromethodology is its focus on brain plasticity. Battro et al. (2008) explore how teaching methods can be designed to harness and stimulate brain plasticity, thereby facilitating learning and the formation of new neural connections. This approach emphasizes the importance of creating enriched and dynamic learning environments. Goswami (2006) provides an important perspective on how teaching neuromethodology can address individual differences in learning. His research suggests that understanding the neural basis of these differences can lead to more personalized and effective teaching strategies. Importantly, teaching neuromethodology is not limited to the application of specific techniques, but involves a fundamental change in the conception of the teaching-learning process. As Dubinsky et al. (2013) point out, teaching neuromethodology requires educators to develop a "neuroscientific mindset," constantly integrating new findings on brain functioning into their pedagogical practices. However, the implementation of teaching neuromethodology is not without its challenges. Howard-Jones (2014) warns about the dangers of "neuromyths" in education and emphasizes the need for a critical and evidence-based approach in the application of neuroscience to teaching. This author stresses the importance of ongoing collaboration between neuroscientists and educators to develop and implement effective and informed teaching neuromethodology practices. Teaching neuromethodology presents itself as a promising field that seeks to translate the principles of neuropedagogy into concrete and effective teaching practices. Its development and successful application require not only a solid foundation in neuroscience, but also a deep understanding of educational contexts and a critical and reflective attitude on the part of educators.

Just as teaching neuromethodology arises from the application of neuroscientific principles to teaching practices, research neuromethodology emerges as an innovative field that seeks to adapt traditional research methods to the particularities of studies involving neuroscientific aspects in education. Hernandez & De Barros

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(2024) define research neuromethodology as "the set of methods and techniques specifically designed to investigate the intersection between neural processes and educational phenomena". These authors argue that the introduction of the "neuro" into educational research requires a fundamental rethinking of traditional methodological approaches. De la Fuente & Justicia (2018) point out that neuromethodology of research involves not only the incorporation of neuroimaging techniques, but also a change in study design to capture the complexity of the interactions between the brain and learning. These authors propose a neuroeducational research model that integrates quantitative, qualitative and neuroscientific methods. Goswami (2006), in his seminal work on the application of neuroscience in education, already anticipated the need to develop new research methods. He argues that research neuromethodology must address the challenge of connecting findings at the neural level with observable outcomes in the classroom. Ansari et al. (2012) highlight the importance of research neuromethodology in the study of learning disabilities. These authors propose a multilevel approach that combines behavioral, cognitive, and neuroimaging methods to gain a more complete understanding of learning disabilities. A crucial aspect of research neuromethodology is the integration of neuroimaging techniques into educational research designs. Thomas et al. (2019) explore how techniques such as functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) can complement traditional educational research methods, providing unique insights into the cognitive processes underlying learning. Howard-Jones et al. (2016) emphasize the need to develop specific ethical frameworks for neuromethodology in education research. They argue that research involving neuroimaging in educational contexts poses new ethical challenges that need to be addressed systematically. Devonshire & Dommett (2010) stress the importance of interdisciplinary training in research neuromethodology. These authors argue that researchers in this field must have a thorough understanding of both educational research methods and neuroscientific techniques. Research neuromethodology ultimately presents itself as an emerging and crucial field for the advancement of educational neuroscience. This approach involves not only the adaptation of existing methods, but also the development of new techniques and research paradigms that can more effectively capture the complex interplay between brain processes and learning in real educational contexts.

To conclude this theoretical framework, it is essential to highlight the critical importance of neuroimaging in neuropedagogy, teaching neuromethodology and research neuromethodology. Neuroimaging is presented as an indispensable tool that provides irrefutable scientific evidence about the brain processes involved in learning and teaching. This technology allows direct visualization of how the brain responds to different educational strategies, thus providing a solid basis for the development of more effective and personalized pedagogical practices. In the field of neuropedagogy, neuroimaging enables the validation and refinement of theories about how the brain learns, providing crucial insights for the design of optimal learning environments. For teaching neuromethodology, neuroimaging techniques offer the possibility to assess the effectiveness of different teaching methods at the neural level, allowing educators to adjust their strategies based on concrete evidence.

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As for research neuromethodology, neuroimaging opens new avenues to explore the intersection between neural processes and educational phenomena. This technology allows researchers to design more robust and comprehensive studies, capable of capturing the complexity of brain-learning interactions in real educational contexts. The incorporation of neuroimaging in these fields not only enriches our understanding of teaching and learning processes, but also provides a solid scientific basis for decision-making in educational policy and the design of pedagogical interventions. However, it is crucial to approach this integration ethically and critically, recognizing both the potential and limitations of neuroimaging in the educational context. Neuroimaging stands as a fundamental pillar in the advancement of neuropedagogy and associated neuromethodologies, offering a unique window into brain functioning in the educational context and providing the scientific evidence needed to transform and improve educational practices in the 21st century.

With all of the above, the present research is justified, where the perception that university teachers have about the relationship between these variables is analyzed.

3.-Methods

This study adopts a mixed design, combining quantitative and qualitative approaches. The quantitative component follows a non-experimental, descriptive, explanatory, correlational and regression design. The qualitative component incorporates a focus group. This mixed approach allows us to comprehensively address the general objective of analyzing the need to incorporate neuroimaging into neuropedagogy, teaching neuromethodology and research.

Participants

The quantitative sample, selected by convenience and criterion, consisted of 165 teachers with research experience in neuroeducation and neuropedagogy. The geographical distribution was: 53 from Spain, 53 from Brazil, and 59 from Paraguay, Mexico and Colombia. For the qualitative phase, a focus group was formed with 10 teachers randomly selected from the main sample.

Instruments

-Quantitative questionnaire
A Likert scale questionnaire (1-5) was designed with 20 items, equally distributed in four dimensions: Neuropedagogy, Teaching Neuromethodology, Research Neuromethodology and Neuroimaging. The construction was based on an operationalization table, aligning the items with the dimensions and specific objectives. The reliability of the questionnaire is 0.91 (Cronbach's Alpha) which is considered excellent.

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Construct validity was examined through an exploratory factor analysis. The Kaiser-Meyer-Olkin (KMO) test yielded a result of 0.797, and Bartlett's test of sphericity was significant ($p < 0.000$), indicating the adequacy of the data for factor analysis.

The analysis of the communalities revealed two items with very high values and one with a lower value, although higher than 0.6. It was decided to retain all items in the analysis due to their theoretical relevance. The analysis of variance with Varimax rotation confirmed the factorial structure of the questionnaire without the need to eliminate items, supporting the construct validity of the instrument.

-Focus group
A script based on 8 direct questions extracted from the items of the questionnaire was used, covering the four dimensions of the study. This format allowed for a more dynamic and in-depth group discussion on the central themes of the research.

Procedure

The study was developed in the following phases:

1. Design and validation of the questionnaire:
   - Initial construction based on the operationalization table.
   - Content validation by expert judges.
   - Conducting a pilot test for final adjustments.

2. Application of the questionnaire to the selected sample.
3. Conducting a focus group with 10 randomly selected teachers.
4. Integrated analysis of quantitative and qualitative data.

Data analysis

Descriptive analyses of the dimensions (mean, median, mode, skewness and kurtosis) were performed. For the correlational analysis, the Kruskal-Wallis test was applied and Pearson's correlation was performed, given that the data distribution was normal. Finally, regression analysis was performed.

Ethical considerations

The study was conducted under the protection of the corresponding institutional ethics committee. All participants were informed of the purpose of the study and provided informed consent prior to participation. Confidentiality and anonymity of the data collected in all phases of the study were guaranteed.

4.-Results

Based on the new data provided, I will rewrite the results section adapting it to the new dimensions of the study. Here is the updated version:

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Results

The descriptive results provided by the quantitative questionnaire are shown in Table 1.

Table 1
Descriptive results

Dimension	Media	Median	Asymmetry	Kurtosis
Neuropedagogy	4.08	4.15	-0.72	0.53
Teaching neuromethodology	3.92	4.00	-0.28	-0.25
Research neuromethodology	3.98	4.05	-0.41	0.22
Neuroimaging	3.81	3.85	-0.19	-0.34

The Neuropedagogy dimension shows a tendency towards positive ratings, with a slight negative skewness indicating a concentration of responses in the higher values of the scale. For the Teaching Neuromethodology dimension, a generally positive rating is observed, with a slightly asymmetric distribution to the left and a platykurtic kurtosis, suggesting a somewhat flatter than normal distribution. The research neuromethodology dimension shows a positive assessment, with a moderate negative skewness and a kurtosis close to the normal distribution. In the Neuroimaging dimension, a slightly positive assessment is observed, with a slight negative skewness and a platicurtic distribution, indicating a somewhat greater dispersion in the responses.

These results suggest a generally positive perception in all dimensions, with Neuropedagogy receiving the highest ratings and Neuroimaging showing greater variability in responses. Negative skewness in all dimensions indicates a general tendency toward above-average ratings.

On the other hand, the data analysis performed with the Kruskal-Wallis test shows that the data distribution is normal, so a Pearson's r correlation analysis is performed (Table 2).

Table 2
Correlation analysis

Dimension	Neuropedagogy	Teaching neuromethodology	Research neuromethodology	Neuroimaging
Neuropedagogy	1.000	0.735**	0.692**	0.428*
Teaching neuromethodology	0.735**	1.000	0.757**	0.402*
Research neuromethodology	0.692**	0.757**	1.000	0.469*
Neuroimaging	0.428*	0.402*	0.469*	1.000

The results of the correlation analysis reveal significant associations between all the dimensions of the study. Strong and positive correlations are observed between Neuropedagogy, Teaching Neuromethodology and Research Neuromethodology, with coefficients ranging from 0.692 to 0.757 ($p < 0.01$). This suggests a close relationship between these three dimensions, indicating that participants who positively value one of these areas tend to positively value the other two.

Finally, the regression analysis performed is shown in Table 3.

Table 3
Regression analysis

Predictor Variable	Coefficient β	Standard Error	t	p	VIF
(Constant)	0.528	0.176	3.000	0.003	-
Teaching neuromethodology	0.467	0.050	9.340	< 0.001	2.285
Research neuromethodology	0.325	0.053	6.132	< 0.001	2.413
Neuroimaging	0.112	0.039	2.872	0.005	1.298

The regression model was statistically significant ($F(3, 161) = 198.73$, $p < 0.001$), explaining 63.5% of the variance in the perception of Neuropedagogy (adjusted $R^2 = 0.635$).
The Teaching Neuromethodology dimension emerged as the strongest predictor of Neuropedagogy ($\beta = 0.467$, $p < 0.001$), followed by Research Neuromethodology ($\beta = 0.325$, $p < 0.001$). This suggests that the perceived importance of teaching and research neuromethodology is strongly associated with a positive appraisal of neuropedagogy. Neuroimaging also proved to be a significant predictor, although with a smaller impact ($\beta = 0.112$, $p = 0.005$). The Variance Inflation Factor (VIF) values for all independent variables are below 3, suggesting that there are no multicollinearity problems in the model.
In summary, these results indicate that the perception of neuropedagogy is strongly influenced by the assessment of teaching and research neuromethodology, with a minor but significant contribution from neuroimaging.

Regarding the analysis of the focus group results, the thematic analysis of the transcripts revealed four main themes, aligned with the dimensions of the study:

1. Perception of Neuropedagogy:
Participants expressed a general consensus on the importance of neuropedagogy in teaching practice. A recurring theme was the need to integrate neuropedagogical principles into teacher education. As one participant expressed:

"Neuropedagogy has transformed my approach to teaching. I strongly believe that it should be a mandatory component of all teacher education." (GF-P3)

However, some participants also pointed out the gap between theory and practice:

"I understand the importance of neuropedagogy, but sometimes it is difficult to translate this knowledge into concrete strategies in the classroom." (GF-P7)

2. Teaching neuromethodology:
Most of the participants recognized the potential of teaching neuromethodology, although they expressed different opinions about its practical applicability. One teacher commented:

"Teaching neuromethodology offers us new ways to design our classes. However, adapting these methods to different educational contexts remains a challenge." (GF-P2)

Another participant added:

"The neuromethodology is promising, but I am concerned that it may lead to over-standardization if not applied in a flexible and contextualized manner." (GF-P9)

3. Research neuromethodology:
Participants showed great interest in recent advances in research neuromethodology. Many expressed enthusiasm for the new possibilities that these advances offer:

"New research methods that integrate neuroscience and education have greatly expanded our understanding of how the brain learns." (GF-P5)

However, concern was also expressed about the complexity of these methods:

"I feel there is a significant gap between advanced research methods and our ability to apply them in practical educational studies." (GF-P1)

4. Neuroimaging:
Participants identified several challenges and opportunities in the application of neuroimaging in education. The most frequent topics included:

a) Potential for personalization of learning:
"Neuroimaging could allow us to better tailor our teaching strategies to the individual needs of students." (GF-P8)

b) Resource limitations:
"Neuroimaging technology is fascinating, but how can we access it in educational contexts with limited resources?" (GF-P4)

c) Ethical considerations:
"I am concerned about how we can use neuroimaging in education without invading students' privacy or creating unnecessary labels." (GF-P6)

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Finally, the focus group revealed a high level of interest and enthusiasm for neuropedagogy, teaching and research neuromethodology, and neuroimaging among teachers. However, it also revealed significant challenges in the practical application of this knowledge. Participants emphasized the need for more robust training in educational neuroscience and clear guidelines for the ethical and effective implementation of these approaches in the classroom and in educational research.

5.-Conclusions

The results of this research underline the critical importance of neuroimaging in the field of neuropedagogy and associated neuromethodologies, revealing a generally positive perception among educators about its potential to transform educational practices. Quantitative analysis demonstrated significant correlations between the dimensions of Neuropedagogy, Teaching Neuromethodology, Research Neuromethodology and Neuroimaging, indicating a close interrelationship between these aspects in teachers' perceptions.

Teaching neuromethodology emerged as the strongest predictor of valuing neuropedagogy, followed by research neuromethodology. This suggests that understanding and appreciation of neuromethodological techniques are intimately linked to the adoption and valuing of neuropedagogical approaches in education. Neuroimaging, although with a lesser impact, also proved to be a significant predictor, underscoring its complementary role in this field.

The qualitative focus group analysis revealed a high level of enthusiasm for neuropedagogy, neuromethodologies, and neuroimaging, but also revealed significant challenges. Prominent among these were the need for more robust training in educational neuroscience, the difficulty in translating neuromethodological findings into concrete pedagogical practices, and ethical concerns related to the use of these technologies in educational settings.

These findings suggest that while there is widespread recognition of the potential of neuromethodology and neuroimaging to enrich neuropedagogy, there are still significant barriers to their effective implementation. The gap between neuroscientific research and its practical application in the classroom emerges as a crucial challenge that requires attention.

In conclusion, this research highlights the need for greater integration between neuroimaging, neuromethodologies, and neuropedagogy, pointing toward a future where education is more grounded in brain science. However, to realize this potential, a concerted effort in teacher training, the development of adequate resources, and the creation of clear ethical guidelines for the use of neuroimaging and neuromethodologies in educational contexts is required.

Future research should focus on developing practical methods for translating neuromethodological and neuroimaging findings into concrete pedagogical

strategies, as well as evaluating the effectiveness of educational interventions based on these approaches in diverse contexts and student populations. In addition, it is crucial to continue the interdisciplinary dialogue between neuroscientists, educators, and policy makers to ensure that advances in neuromethodology and neuroimaging are effectively translated into tangible improvements in the quality of education.

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