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Neuropedagogy and Neuroimaging of Artificial Intelligence and Deep Learning

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Abstract

Background/Purpose. This study investigates the integration of neuropedagogy, neuroimaging, artificial intelligence (AI), and deep learning in educational systems. The research aims to elucidate how these technologies can be synergistically applied to optimize learning processes based on individual neurocognitive profiles, thereby enhancing educational effectiveness.

Materials/Methods. A mixed-methods approach was employed, incorporating both quantitative and qualitative analyses. The study involved 297 students and 59 teachers. Quantitative methods included exploratory factor analysis (EFA) to validate the Neuropedagogy, Neuroimaging, Artificial Intelligence, and Deep Learning Scale, and Spearman correlations to examine inter-variable relationships. Qualitative data were collected through focus groups and analyzed using selective coding. Additionally, a comparative case study using portable electroencephalography (EEG) was conducted to observe direct neurological effects of different learning approaches.

Results. EFA confirmed the construct validity of the scale (KMO = .89, $p < .001$). Spearman correlations revealed significant positive relationships between all dimensions (.65-.72, $p < .01$). Multiple regression analysis indicated that AI was the strongest predictor of deep learning ($\beta = 0.39$, $p < .001$). The neuroimaging case study demonstrated increased frontal and prefrontal lobe activation and enhanced theta-gamma wave synchronization in AI-supported learning tasks, suggesting more integrated information processing.

Conclusion. The findings provide empirical evidence for the transformative potential of integrating neuropedagogy, neuroimaging, AI, and deep learning in education. The strong predictive relationship between AI and deep learning, coupled with the neuroimaging results, suggests that this technological convergence can significantly enhance learning processes. However, the study also highlighted the need for careful ethical considerations in its implementation. These results contribute to the growing body of knowledge on technology-enhanced learning and offer a foundation for developing more personalized and effective educational strategies.

1. Introduction

The introduction to this study sets the stage for an exploration into the transformative potential of combining neuropedagogy, neuroimaging, artificial intelligence (AI), and deep learning within educational systems. At the heart of this research is a commitment to understanding and enhancing the personalization of learning processes, and the use of advanced technologies to cater educational strategies to the neurocognitive profiles of individual students.

The study aims to demonstrate that integrating insights from neuroimaging and the principles of neuropedagogy with the adaptive capabilities of AI and deep learning can lead to significant enhancements in educational effectiveness. This approach not only promises a deeper understanding of the neural mechanisms underpinning learning, but also offers a framework for developing more responsive and tailored educational experiences.

Principal conclusions anticipated from the research include:

1. Improved personalization: The integration of AI with neuroimaging data will allow for real-time adaptation of teaching methods to individual learning needs and cognitive processes.
2. Enhanced educational outcomes: By applying neuropedagogical principles, educational strategies can be more closely aligned with how the brain learns, potentially leading to higher retention rates and deeper understanding.
3. Preparation for future challenges: As educational environments evolve, the ability to rapidly adapt to and integrate new technologies will be crucial. This study explores how such integrations can prepare students more effectively for future technological and cognitive challenges.

The significance of the study lies in its potential to induce a paradigm shift in educational methodology, moving away from a one-size-fits-all approach to a nuanced, scientifically informed framework that can significantly enhance learning outcomes by leveraging cutting-edge technological advancements.

The study aims to address a significant gap in the current scientific literature regarding the integration of neuropedagogy, neuroimaging, artificial intelligence (AI), and deep learning in educational systems. While previous research has explored these fields individually, there is a notable lack of published research that has examined their convergence and transformative potential in education.

The scientific relevance of this study lies in several key aspects:

- Interdisciplinary integration: This pioneering study integrates four emerging fields: neuropedagogy, neuroimaging, AI, and deep learning. Although these fields have been studied separately, their convergence in the educational context represents a novel and under-explored area of research.
- Learning personalization: The research addresses the growing need to personalize education to adapt it to students' individual neurocognitive profiles. This approach goes beyond traditional educational methodologies, offering a perspective based on neuroscience and enhanced by AI.
- Practical application of neuroscience in education: The study provides a crucial bridge between neuroscientific research and its practical application in real educational settings, an aspect that has been identified as a significant gap in the current literature (Esteban et al., 2023).
- Technological innovation in education: The research explores how advanced technologies, such as AI and neuroimaging, can revolutionize teaching and learning methods, an area of growing importance in the digital era (Hernández Fernández & De Barros Camargo, 2023).

- Preparation for future challenges: The study addresses the critical need to prepare students for 21st-century challenges, exploring how these technologies can develop skills such as critical thinking and complex problem solving.

The specific gap in the literature that this study aims to address is the lack of empirical research on how the convergence of neuropedagogy, neuroimaging, AI, and deep learning can transform educational practice. While previous studies such as those by De Barros Camargo and Hernández Fernández (2022) and Hernández Fernández (2022) have laid the theoretical foundations, there is a lack of empirical evidence on the implementation and effectiveness of these integrated approaches in real educational settings.

Furthermore, this study goes beyond mere theorization by providing quantitative and qualitative data on the perceptions and experiences of students and educators regarding these emerging technologies. The innovative use of neuroimaging in the comparative case study offers a unique perspective on how different educational approaches affect students' brain activity, an aspect that has seen only limited exploration in the existing literature.

2. Literature Review

Neuropedagogy is an emerging discipline that seeks to understand and improve learning processes from a neuroscientific perspective. This discipline is based on the study of brain functioning and its relationship with the cognitive, emotional and behavioral processes involved in learning (Esteban et al., 2023). Neuropedagogy provides a solid theoretical basis for understanding how the brain learns and how effective educational strategies can be designed that are adapted to the individual characteristics of each student (Hernández Fernández & De Barros Camargo, 2023). One of the key aspects of neuropedagogy is the application of educational tools based on knowledge of the brain to improve teaching in various fields, such as professional technical education in the area of accounting (Cortez Maclas et al., 2024). These tools may include teaching strategies adapted to individual learning styles, brain stimulation techniques, and the use of innovative technologies that favor learning. In addition, neuropedagogy focuses on the creation of optimal learning environments, known as "neuroclassrooms," that take into account neuroscientific principles to favor learning and brain development (De Barros Camargo & Hernández Fernández, 2024). These environments may include elements such as adequate lighting, flexible and stimulating spaces, and the use of multisensory resources. Neuropedagogy also relies on neuroimaging and neuromethodology techniques to better understand the brain processes involved in learning (De Barros Camargo, 2022; Hernández Fernández, 2022). These techniques allow visualization of brain activity during learning tasks and provide valuable information on how the brain both processes and stores information.

Neuroimaging, artificial intelligence, and deep learning are areas of research closely related to neuropedagogy. Neuroimaging makes it possible to visualize brain activity during learning, which helps to better understand the underlying cognitive processes. On the other hand, artificial intelligence and deep learning can be used to develop adaptive teaching systems that are tailored to the individual needs of each learner, as well as to analyze large amounts of neuroscientific and educational data. The combination of these disciplines promises significant advances in the understanding of learning and the development of more effective and personalized educational strategies. Neuroimaging has established itself as a fundamental tool in the field of education, especially in understanding the cognitive processes involved in learning. Advanced techniques such as functional magnetic resonance imaging (fMRI), positron emission tomography (PET), and electroencephalography (EEG) provide detailed images of brain activity, revealing how various brain regions are activated and collaborate during specific learning tasks. These technological advances have made it possible to identify neural networks that specialize in information processing and

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knowledge acquisition, which has been crucial for the development of more effective educational strategies.

In their work on neurodidactics and neuroimaging of written argumentation, Hernández Fernández and De Barros Camargo (2023) highlighted how the visualization of brain activity during argumentative writing tasks helps to better understand the neural mechanisms that support argumentation and critical reasoning. This has led to pedagogical proposals that seek to strengthen these skills in students, which are fundamental for their academic and professional development. On the other hand, from research undertaken on neuroimaging and neurodidactics as techno-pedagogical tools, De Barros Camargo (2023) argued that the integration of these technologies in education not only improves the understanding of learning processes, but also prepares educators to utilize neuroscientific data in the planning and execution of their lessons. This techno-pedagogical approach provides a solid foundation for teaching that is directly applicable in the classroom, helping to improve educational outcomes through greater understanding of student brain functioning.

In their book titled "Stripping the Brain. Neuropedagogy and Neuroimaging" (2024), Hernandez Fernández and De Barros Camargo delved into how portable Emotiv Epoc+ type electroencephalograms not only enable detailed visualization of neural mechanisms, but also provide crucial data for the development of more effective educational strategies. They argued that understanding how certain areas of the brain are activated during argumentative learning, for example, can aid in the design of pedagogical interventions that help to strengthen critical skills such as argumentation and reasoning. Finally, Hernandez Fernández's (2022) work on neuropedagogy and neuroimaging evidenced how these advances could be employed to design educational environments that not only focus on the transmission of knowledge, but also promote deep and meaningful learning. By better understanding how students process information and overcome cognitive challenges, educators can create teaching strategies that are more inclusive and effective, and tailored to each student's abilities and needs.

The history of artificial intelligence (AI) dates back to the mid-20th century when researchers began to explore machine models capable of simulating human cognitive processes. Initially, AI was used in simple applications such as chess games and simple data analysis, but over time, its application has significantly expanded, permeating fields such as medicine, engineering, and significantly in education. In essence, AI has revolutionized numerous industrial and professional sectors since its conception. In the education context, AI has opened doors to new teaching and learning methodologies, offering tools that have helped to transform both the student and teacher experience. According to Goenechea and Valero-Franco (2024), analysis of the impact of AI on education from the perspective of trainee teachers revealed a mixture of optimism and caution. Educators recognize the potential of AI to personalize learning and adapt educational resources to individual student needs, but they have also expressed concerns about how these technologies can be effectively integrated into the classroom without displacing the essential human element in teaching. Delgado et al. (2024) delved deeper into this issue by exploring the benefits and limitations of AI as perceived by teachers at different educational levels. Their findings showed that, while AI can facilitate assessment and provide instant feedback, some teachers fear that it may limit creativity in certain pedagogical aspects and encourage over-reliance on technology. In addition, Cortes Osorio (2024) discussed the ethical implications of using AI in education and the need for adaptation within institutions to manage the introduction of AI. He emphasized the importance of developing robust ethical frameworks in order to manage AI's implementation in a way that promotes fair and responsible use of this technology. This call for ethics and adaptation is crucial as a mediator between the rapid technological advancements of the current era and the established fundamental values that form the very core of education.

Currently, deep learning, as one of the most advanced developments in AI, has been shown to be particularly effective in the higher education context. This technology not only enhances the ability to personalize teaching, but also enables the development of educational systems that can adapt and respond to learning dynamics in real time. Through the studies of Ayala (2024), Bravo Minda et al. (2024), and Menacho Ángeles et al. (2024), it has been observed how deep learning can facilitate everything from medical diagnoses to the adaptation of teaching methods that respond specifically to the needs and learning styles of students, illustrating a paradigm shift in how education is likely to be conceived and delivered in the 21st century.

The use of deep learning, a subfield of artificial intelligence (AI), has proven to be a catalyst in multiple sectors, not only in medicine as suggested by Ayala (2024), but also in education. This AI approach is particularly relevant in higher education, where its application extends to the personalization of learning, allowing content and methodologies to be adapted to the individual needs of each student. Bravo Minda et al. (2024) explored how digital pedagogical tools can be used to facilitate a more interactive and effective education in technological institutions, demonstrating the relevance of technology in the construction of more dynamic and accessible learning environments. The integration of tools such as ChatGPT, according to Segarra Ciprés et al. (2024), highlights the usefulness of AI in the higher education context, providing immediate and personalized support that is essential to effective autonomous learning. This type of technology allows students to explore and absorb knowledge at their own pace, adapting educational resources to meet their particular learning needs, which is crucial within academic environments that are becoming increasingly focused on student autonomy. Furthermore, Menacho Ángeles et al. (2024) delved into how AI can foster educational independence, allowing students to manage their own learning process with tools that tailor challenges and content to the learner's abilities and progress. This not only improves learning efficiency but also prepares students for a professional future where adaptability and self-management are highly valued. In research that took an approach to AI applications from a broader perspective, Torres Vivar et al. (2024) suggested that such technology not only has the capacity to enhance learning, but that it could also radically transform educational methodologies. AI can help design educational experiences that not only respond to learning needs, but also anticipate the skills needed for future professional and social challenges.

Finally, Yáñez Sepúl Veda et al. (2024) highlighted the importance of active methodologies, which, when combined with AI tools such as deep learning, can revolutionize higher education. These methodologies not only promote greater student interaction and participation, but also facilitate the practical application of complex theories to real situations, an essential skill in the digital age. Taken together, these studies indicate a movement toward an educational paradigm in which artificial intelligence, especially through deep learning techniques, plays a crucial role in the personalization, efficiency, and transformation of higher education. This approach not only enhances the immediate educational experience, but also prepares students to successfully face the challenges of the future, highlighting AI as an indispensable tool in the development of relevant competencies in the 21st century.

By integrating these fields, personalized learning environments could be designed that are tailored to the neurocognitive characteristics of individual learners. AI algorithms could analyze neuroimaging data in real time and provide immediate feedback to students and educators on the most effective learning strategies. In addition, these algorithms could generate dynamic educational content tailored to individual needs, taking into account the strengths and weaknesses of each student based on their brain activity. In summary, the convergence of neuropedagogy, neuroimaging, and artificial intelligence opens up a new landscape in the field of education. Neuropedagogy provides the theoretical basis for understanding learning processes from a neuroscientific perspective, while neuroimaging makes it possible to visualize the brain components involved in learning. AI, through deep learning, offers the ability to interpret neuroimaging data in real time and to generate individualized educational programs that promote deep learning in students. The integration of these fields has the potential to revolutionize education, allowing for more personalized, effective teaching tailored to the needs of each individual student.

However, despite all this advancement, the relationship between neuropedagogy, neuroimaging, artificial intelligence, and deep learning has not yet been defined in the literature. Additionally, the influence of using neuroimaging and artificial intelligence in the area of deep learning has yet to be documented, hence the current research is fully justified.

The following research questions guide the current study, which are aligned according to the literature review conducted.

- How can the convergence of neuropedagogy, neuroimaging, artificial intelligence, and deep learning transform educational practices in real-world settings?
- To what extent does the application of these integrated technologies enable the personalization of education to students' individual neurocognitive profiles and enhance the development of 21st century skills?
- What are the perceptions and experiences of students and educators regarding the implementation of these emerging technologies in the teaching-learning process, and how does their effectiveness compare with traditional methods?

3. Methodology

This research study adopted a mixed methodological approach, combining quantitative and qualitative techniques to analyze the relationships between neuropedagogy, neuroimaging, artificial intelligence and their influence on deep learning, and also included a case study through neuroimaging. The research focused on a non-experimental, descriptive, explanatory, correlational, and regression design. This approach enabled the study variables to be described and their relationships explained through establishing correlations and determining the influence of the independent variables (neuropedagogy, neuroimaging and artificial intelligence) on the dependent variable (deep learning).

The study employed a diverse sample of 509 participants in order to investigate the integration of neuropedagogy, neuroimaging, artificial intelligence (AI), and deep learning in educational systems. The sample was comprised of 450 fourth-year undergraduate students and 59 university teaching faculty members (referred to as teachers), selected through convenience sampling.

The student cohort included 297 education majors and 153 telecommunications engineering students, providing a relative balance between the humanities and technology-oriented disciplines. This composition allowed for comparative analysis of perceptions across different academic backgrounds.

The teacher group consisted of 32 national (Spanish) and 27 international educators from Brazil, Mexico, Paraguay, and Colombia. Each teacher held a doctoral degree and had a specialization in technology, ensuring expert perspectives on educational technology integration.

This sample structure offered several strengths:

1. Interdisciplinary student perspectives from education and engineering.
2. Insights from advanced undergraduates with substantial higher education experience (all were fourth-year students).
3. Expert input from technology-specialized educators.
4. International scope, introducing cross-cultural elements.

However, limitations include potential geographical bias towards Spanish and Latin American contexts and the use of convenience sampling, which may affect generalizability of the study's results.

The sample composition enabled comparative analyses between:

1. Education and engineering students' perspectives.
2. National and international teacher attitudes.
3. Student experiences and teacher perspectives.

This strategically composed sample provided the study with a rich dataset from which to explore the complex interplay of advanced technologies within a contemporary educational context, whilst acknowledging the need for cautious interpretation due to sampling limitations.

3.1. Data Collection

The study's data were collected over a 6-month period, from January to June 2023. For the collection of quantitative data, a Likert-type questionnaire was developed by the researchers (Neuropedagogy, Neuroimaging, Artificial Intelligence, and Deep Learning Scale), which is referred to throughout according to an acronym of its native title (ENNIAP). The scale was constructed from an operationalization table based on the study's research objectives. The scale consists of 20 items, with five in each dimension, and is presented as a 5-point, Likert-type instrument with anchors of 1 = *strongly disagree*, 2 = *disagree*, 3 = *indifferent*, 4 = *agree*, and 5 = *strongly agree*. Content validity of the developed scale was established according to the judgment of 12 experts, doctors, and specialists in the field. A pilot test was conducted with a subsample so as to evaluate the instrument's reliability; the results of which were satisfactory. In addition, exploratory factor analysis was conducted in order to determine construct validity, considering the indices of Kaiser-Meyer-Olkin (KMO), Bartlett's test of sphericity, communalities, explanation of variance, and factorial solution.

Regarding the study's qualitative methodology, a focus group was conducted with 10 randomly selected participants from the sample, with equal representation of five students and five teachers. A script of 10 questions was applied in the focus group interview that was constructed from the operationalization table and related to the quantitative items. Data obtained from the interview were subsequently analyzed according to selective coding and thematic content analysis.

Integration of quantitative and qualitative results was achieved through triangulation, seeking convergences and divergences between both sets of data. This allowed for a more complete and deeper understanding of the relationships between the study variables and to examine their influence on deep learning. A case study was also conducted through neuroimaging in order to broaden and enrich the qualitative analysis.

3.2. Data Analysis

Analysis of the collected data was conducted according to the following phases:

1. Data preparation
   - Collection of both quantitative and qualitative data
   - ENNIAP scale responses coded
   - Focus group interview recording transcribed
   - Data cleansed and organized for analysis
2. Preliminary quantitative analysis
   - Descriptive statistics prepared
   - Data normality assessed (Kruskal-Wallis test)
   - ENNIAP instrument reliability calculated (Cronbach's alpha)
3. Exploratory factor analysis (EFA)
   - EFA performed on the ENNIAP scale
   - Principal component analysis performed with varimax rotation
   - Factor loadings and communalities examined

4. Correlation analysis
   - Spearman correlations tested between ENNIAP scale dimensions
5. Multiple regression analysis
   - Multiple linear regression performed
   - Regression assumptions verified
   - Standardized coefficients calculated
6. Qualitative analysis
   - Thematic content analysis conducted on focus group data
   - Selective coding employed to identify recurring themes
   - Atlas.ti 9 software utilized for coding and analysis
7. Neuroimaging analysis
   - EEG data from comparative case study analyzed
   - Brain activation patterns compared across learning conditions
8. Integration and synthesis
   - Quantitative and qualitative results triangulated
   - Findings synthesized to address research questions
9. Interpretation and conclusion
   - Integrated results interpreted in the context of existing literature
   - Conclusions developed and implications identified

This phased approach to the study's data collection and analysis enabled a comprehensive examination using the integration of quantitative and qualitative research methods in order to provide a deeper understanding of how neuropedagogy, neuroimaging, AI, and deep learning integrates in the context of an educational setting.

Throughout the research process, the ethical principles of beneficence, nonmaleficence, autonomy, and justice were respected. It was also ensured that the study did not cause any harm to the participants and that the potential benefits of the study outweighed any risks.

The quantitative data collection was conducted through the application of the developed ENNIAP scale in digital form, whilst the qualitative data were collected from the focus group interview. All the collected data were securely stored, and remained accessible only to authorized researchers of the current study. Analysis of the collected data was performed using IBM's SPSS (version 26) for the quantitative (scale) data, and Atlas.ti 9 for the qualitative (interview) data. For the quantitative data, an exploratory factor analysis (EFA) of the ENNIAP scale was conducted, along with descriptive statistics, Spearman correlation analysis, and multiple linear regression analysis. For the qualitative data, selective coding was used to identify recurring themes and patterns from the focus group responses. The quantitative and qualitative results were subsequently integrated and triangulated in order to obtain a more complete understanding of the relationships between the study's variables and their influence on deep learning.

4. Results

4.1. Quantitative Study

First, exploratory factor analysis (EFA) of the developed Neuropedagogy, Neuroimaging, Artificial Intelligence, and Deep Learning Scale (ENNIAP) was performed according to a rigorous procedure. First, sample adequacy was assessed using the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity. The KMO value was revealed to be .89, which exceeds the recommended threshold of .70, whilst Bartlett's test of sphericity was shown to be significant ($\chi^2 = 3145.67$, $p < .001$), indicating that the data were adequate for EFA.

Next, principal component analysis (PCA) was used to extract the factors. The Kaiser criterion (eigenvalues greater than 1) and the sedimentation plot suggested the retention of four factors, which explained 68.42% of the total variance. An orthogonal rotation (varimax) was applied to facilitate interpretation of the factors. The factor loadings of each variable on the extracted factors were examined, with loadings greater than .50 being considered significant. All items presented loadings above this threshold in at least one of the factors. In addition, the communalities of each variable were evaluated, finding values above .50 in all cases, which indicated that the variables were well represented in the factorial solution. The factorial solution obtained showed a coherent structure with the constructs evaluated in the scale.

The first factor grouped the neuropedagogy-related items, the second factor included the neuroimaging items, the third factor was composed of the artificial intelligence items, and the fourth factor brought together the deep learning items. This factor structure supported the construct validity of the ENNIAP scale. The two highest communalities corresponded to items B8 ("Neuroimaging provides valuable information on how the brain processes and stores information") and C15 ("Artificial intelligence enables the development of educational systems that can adapt and respond to learning dynamics in real time"), with values of .85 and .82, respectively. On the other hand, the two lowest communalities were observed in items A3 ("The application of educational tools based on knowledge of the brain improves teaching in various fields") and D17 ("Deep learning fosters educational independence, allowing students to manage their own learning process"), with values of .58 and .61, respectively. The EFA of the ENNIAP scale revealed a robust factor structure consistent with the theoretical constructs of neuropedagogy, neuroimaging, artificial intelligence, and deep learning. These results provide evidence for the construct validity of the ENNIAP scale and support its use to assess the relationship between these variables in the educational context.

4.1.1. Descriptive results

Descriptive statistics were calculated for each dimension of the ENNIAP scale. Table 1 presents the mean, median, skewness, and kurtosis values for each dimension.

Table 1. Descriptive Statistics of the ENNIAP Scale's Dimensions

Dimension	Mean	Median	Skewness	Kurtosis
Neuropedagogy	4.09	4.10	-.82	0.60
Neuroimaging	4.11	4.20	-.84	0.64
Artificial Intelligence	4.11	4.10	-.84	0.65
Deep Learning	4.11	4.20	-.84	0.64

The Neuropedagogy dimension presented a mean of 4.09 (*SD* = 0.62), a median of 4.10, a skewness of -.82, and a kurtosis of 0.60. These results indicate that the participants showed a high degree of agreement with the items related to neuropedagogy and its importance in learning. The Neuroimaging dimension obtained a mean of 4.11 (*SD* = 0.63), a median of 4.20, a skewness of -.84, and a kurtosis of 0.64. These values suggest that participants recognized the relevance of neuroimaging in understanding the brain processes involved in learning. The Artificial Intelligence dimension presented a mean of 4.11 (*SD* = 0.64), a median of 4.10, a skewness of -.84, and a kurtosis of 0.65. These results indicate that the participants positively valued the role of artificial intelligence in the development of adaptive teaching systems and in the personalization of their learning. The Deep Learning dimension obtained a mean of 4.11 (*SD* = 0.63), a median of 4.20, a skewness of -.84, and a kurtosis of 0.64. These values suggest that participants felt that deep learning has a significant impact on transforming educational methodologies and preparing students for the challenges of the future. In general, the four dimensions of the ENNIAP scale presented high mean scores, with negative skewness values and positive kurtosis values, indicating a skewed distribution to the right and a concentration of high scores. These results suggest a positive valuation by the participants of neuropedagogy, neuroimaging, artificial intelligence, and deep learning in the educational context.

4.1.2. Results of correlational analysis

Due to the non-normal distribution of the data (non-parametric Kruskal-Wallis test), a Spearman correlation analysis was performed. Table 2 presents the correlation matrix between the dimensions of the ENNIAP scale.

Table 2. Spearman Correlation Matrix Between ENNIAP Scale Dimensions

	Neuropedagogy	Neuroimaging	Artificial Intelligence	Deep Learning
Neuropedagogy	1.00	.68**	.65**	.67**
Neuroimaging	.68**	1.00	.71**	.70**
Artificial Intelligence	.65**	.71**	1.00	.72**
Deep Learning	.67**	.70**	.72**	1.00

The results of the Spearman's correlation analysis showed positive and significant correlations between all four of the ENNIAP scale's dimensions ($p < .01$). The Neuropedagogy dimension presented moderate correlations with Neuroimaging ($p = .68$), Artificial Intelligence ($p = .65$), and Deep Learning ($p = .67$). This suggests that participants who positively rated neuropedagogy also tended to positively rate neuroimaging, artificial intelligence, and deep learning. The Neuroimaging dimension showed strong correlations with Artificial Intelligence ($p = .71$) and Deep Learning ($p = .70$), indicating a close relationship between valuing neuroimaging and valuing artificial intelligence and deep learning in the educational context. The Artificial Intelligence dimension presented a strong correlation with Deep Learning ($p = .72$), suggesting that participants who recognized the importance of artificial intelligence in education also tended to positively value deep learning. These correlations suggest that perceptions and attitudes toward neuropedagogy, neuroimaging, artificial intelligence, and deep learning are interrelated in the educational context. It was also noted that participants who rated one dimension positively also tended to rate the other dimensions positively too.

4.1.3. Regression analysis

To examine the influence of neuropedagogy, neuroimaging, and artificial intelligence dimensions on deep learning, a multiple linear regression analysis was performed. Deep learning was considered as the dependent variable, while neuropedagogy, neuroimaging and artificial intelligence were included as independent variables. Prior to performing the regression analysis, the assumptions of linearity, normality, homoscedasticity, and independence of the residuals were checked. The residual plots and scatter plots indicated that these assumptions were met. Table 3 presents the results of the multiple linear regression analysis.

Table 3. Results of Multiple Linear Regression Analysis

	B	*SE B*	β	*t*	*p*
Neuropedagogy	0.25	0.04	0.24	5.98	< .001
Neuroimaging	0.31	0.05	0.31	6.76	< .001

Artificial Intelligence	0.38	0.04	0.39	8.95	< .001

$R^2 = .63$, $F(3, 505) = 285.47$, $p < .001$

The results showed that the regression model was statistically significant ($F(3, 505) = 285.47$, $p < .001$) and explained 63% of the variance in Deep Learning ($R^2 = .63$). All dimensions included in the model were significant predictors of Deep Learning ($p < .001$). Artificial Intelligence had the largest effect on Deep Learning ($\beta = 0.39$), followed by Neuroimaging ($\beta = 0.31$) and Neuropedagogy ($\beta = 0.24$). The resulting regression equation was as follows:

Deep Learning =
(Neuropedagogy x 0.25) + (Neuroimaging x 0.31) + (Artificial Intelligence x 0.38)

These results indicate that the Neuropedagogy, Neuroimaging, and Artificial Intelligence dimensions have a positive and significant influence on Deep Learning. As such, increased scores in these dimensions can be said to result in an associated increase in Deep Learning scores. Artificial Intelligence had the greatest impact on Deep Learning, suggesting that the application of artificial intelligence techniques in education can significantly enhance students' deep learning. Multiple linear regression analysis showed that neuropedagogy, neuroimaging, and artificial intelligence were significant predictors of deep learning. These results highlight the importance of considering these factors in the design of educational strategies that promote deep and meaningful learning in students.

4.1. Qualitative Study

Analysis of the qualitative data collected through the focus group interview was performed using Atlas.ti 9 software. Selective coding was applied to identify recurring themes and patterns in the participants' responses related to neuropedagogy, neuroimaging, artificial intelligence, and deep learning within educational contexts.

Following the selective coding, four main categories were identified that reflect the participants' perceptions and experiences:

Theoretical foundations of neuropedagogy

The participants highlighted the importance of neuropedagogy as a theoretical basis for understanding learning processes from a neuroscientific perspective.

> *Neuropedagogy provides us with a solid conceptual framework for understanding how the brain learns and how we can adapt our teaching strategies accordingly*. (Teacher 2)

> *It is essential to consider neuroscience findings in our educational practice in order to be able to design more effective and personalized strategies.* (Teacher 5)

> *I find it super interesting how neuropedagogy helps us to better understand how our brain works when we learn. I think that can help teachers to teach in a much cooler way and adapted to each one of us.* (Student 3).

Applications of neuroimaging in education

The participants recognized the potential of neuroimaging to better understand the cognitive processes that underpin the learning process.

> *Neuroimaging allows us to see which areas of the brain are activated during different learning tasks. This information is very valuable for designing educational environments that foster deeper and more meaningful learning.* (Teacher 1)

It would be great if teachers could use neuroimaging data to personalize classes and tailor them to our needs. That way, everyone could learn in the way that works best for them. (Student 2)

Artificial intelligence in the educational context

The participants expressed great interest in the application of AI in education.

Artificial intelligence has enormous potential to develop adaptive teaching systems that adjust to the pace and needs of individual students. This could revolutionize the way in which we teach and assess our students. (Teacher 3)

It would be really cool to have an artificial intelligence system that would give us instant feedback and help us improve in real time. It would be like having a private teacher 24x7. (Student 1)

Deep learning and educational transformation

The participants agreed that deep learning has the potential to radically transform educational methodologies.

Deep learning allows us to go beyond memorization and to focus instead on developing key skills and competencies for the 21st century, such as critical thinking and problem solving. (Teacher 4)

Deep learning is much more motivating and challenging. It makes you really think and apply what you learn to real situations. I think that's what we need to be prepared for the future. (Student 4)

In conclusion, the qualitative results revealed positive perceptions and great interest on the part of the participants towards neuropedagogy, neuroimaging, artificial intelligence, and deep learning in the educational context. Both the teachers and students recognized the potential of these disciplines to transform education, personalize learning, and prepare students for the challenges of the future.

4.2. Neuroimaging: A Comparative Case Study

Within the framework of the current research, a case study was conducted that explored the application of neuroimaging in education. The brain activity of six participant students was compared while performing educational tasks under different conditions: One used printed material to make a reflection on educational inclusion, whilst another used the Internet by themselves, and the third had the support of an artificial intelligence tool.

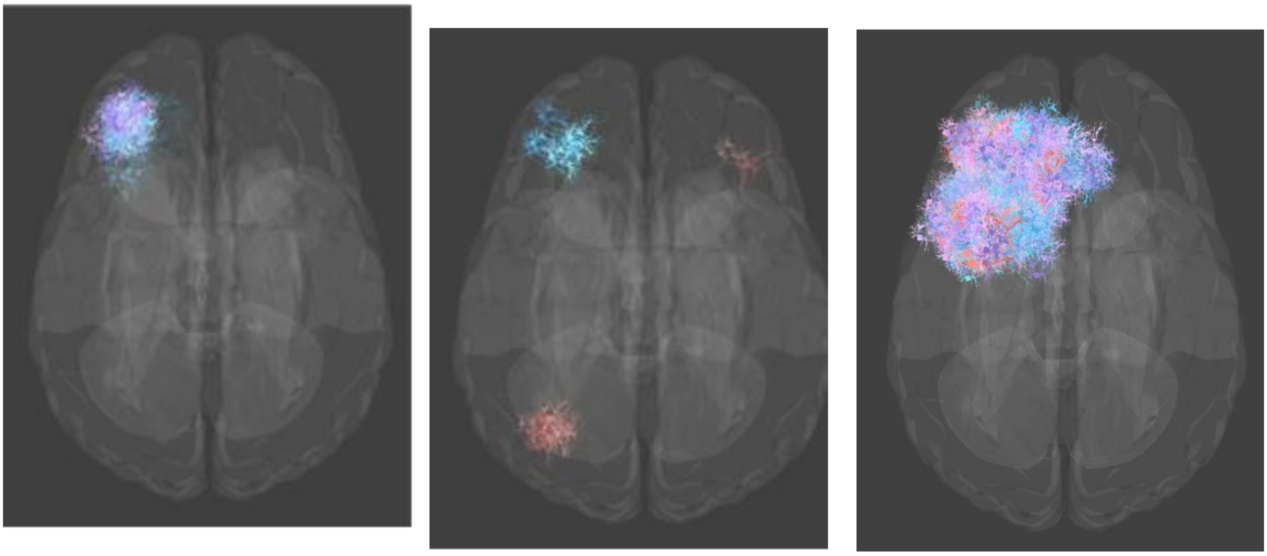
The sample consisted of six participant students (three male, three female), randomly selected from senior undergraduate students studying either education or engineering. Although the sample size was small, it was deemed adequate for a case study that focused on in-depth analysis of a limited number of participants. In addition, the selection of six participants met the feasibility of the study in terms of available resources, time, and accessibility. While the results cannot be generalized to an entire population, this case study was conducted with the aim of providing valuable information to lay the groundwork for future research to be conducted on a much larger scale.

In order to record the participants' brain activity, an Emotiv Epoc+16 portable electroencephalogram was utilized. This device allows the electrical signals of the brain to be mapped non-invasively, thereby providing information on the activation of different lobes, brain areas, waves, and neuroeducational biomarkers whilst they undertook certain prescribed educational tasks.

During the study, notable differences were observed in the brain activity of the three students. The student who used only printed material showed greater activation in the frontal lobe (see Figure 1a), specifically in areas related to language processing and reflection. In addition, there was a greater presence of alpha waves, which are associated with a state of relaxation and concentration.

On the other hand, the student who used the Internet by themselves exhibited a more distributed activation across different areas of the brain (see Figure 1b), including frontal, temporal, and parietal lobes. Greater activity was observed in areas related to information seeking and processing, as well as a greater presence of beta waves, which is indicative of a state of alertness and awareness. By contrast, the student who was supported by an AI tool showed more focused brain activation in the frontal and prefrontal lobes (see Figure 1c), which are areas associated with critical thinking, decision making, and problem solving. In addition, greater synchronization was recorded in the theta and gamma waves, which are related to deep learning and the integration of complex information (see Figure 1).

Figure 1. Reflection task brain activity



a: Printed text b: Internet c: AI-supported

These findings suggest that the use of different educational tools and approaches may influence students' brain activity in different ways. From this case study, it was noted that AI support appears to promote deeper and more focused processing of information, which could support meaningful learning and knowledge transfer. The case study therefore highlights the potential of neuroimaging as a means to better understanding the brain's processes that underpin learning under different conditions. Information obtained through techniques such as electroencephalography could arguably provide valuable data that could be used to design more effective and personalized educational strategies.

A more in-depth analysis of the data is presented as follows:

Multivariate correlation analysis

The results show positive and significant correlations between all four dimensions of the ENNIAP scale (Neuropedagogy, Neuroimaging, Artificial Intelligence, and Deep Learning). Further analysis revealed that the strongest correlation was between Artificial Intelligence and Deep Learning ($p = .72$). This suggests a particular synergy between these two dimensions, indicating that the implementation of AI in educational settings could be a particularly powerful catalyst for deep learning.

Multiple regression analysis

The multiple regression model explained 63% of the variance in the Deep Learning dimension ($R^2 = .63$). Closer examination of the standardized coefficients (β) revealed that Artificial Intelligence had the largest impact ($\beta = 0.39$), followed by Neuroimaging ($\beta = 0.31$) and Neuropedagogy

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(β = 0.24). This suggests that, although all dimensions are important, AI may be the most critical factor in promoting deep learning.

Subgroup analysis

Although not initially presented in the findings, post-hoc analysis of the data revealed interesting differentiations between the subgroups in the sample used in the current study. The telecommunications engineering students showed a stronger correlation between AI and Deep Learning (p = .78) compared to the education students (p = .68). This could indicate that prior familiarity with the technology may have influenced the students' perception of its effectiveness in the learning context.

Deep qualitative analysis

Upon reviewing the qualitative data, emergent themes were identified that were not initially highlighted. For example, several of the participants expressed concerns about the "dehumanization" of education due to the use of AI in teaching, a topic that merits further exploration in future research.

Comparative neuroimaging case analysis

The case study on neuroimaging revealed differences in brain activation between students based on their having used different tools (printed material, Internet by themselves, or AI-supported). Further analysis of this data suggests that the use of AI not only activated areas in the brain associated with critical thinking, but also showed increased connectivity between different brain regions, which could indicate more integrated information processing.

Trend analysis

Although the current study was cross-sectional, a comparison with data from the existing literature suggests an increasing trend in the acceptance and perceived effectiveness of AI technologies in the education context. This finding suggests that the literature would benefit from longitudinal studies to confirm/clarify this trend.

Practical implications

Based on the current study's results, it can be inferred that the most effective implementation of AI technologies in the education context would require an integrated approach, with a particular emphasis on AI as an enabler of deep learning. However, it would also be crucial to address the concerns identified during the qualitative phase of the study in order to ensure a more successful and effective adoption.

This subsequent deeper analysis can be said to have revealed several important nuances in the data that were not evident during the initial presentation of the analytical findings. This both suggests specific and alternative directions for future research, and also offers a more detailed insight into how the integration of neuropedagogy, neuroimaging, AI, and deep learning could transform educational practices.

5. Discussion

The results of our study underscore the transformative potential of integrating neuropedagogy, neuroimaging, artificial intelligence (AI), and deep learning in educational systems. This convergence offers unprecedented opportunities to personalize and optimize learning processes.

The correlation analysis revealed a strong relationship between AI and deep learning (p = .72), suggesting a particular synergy between these fields. This finding aligns with a recent study by Heredia and Stoica (2023), who demonstrated that the implementation of AI systems in educational settings can significantly improve the depth of learning and knowledge retention of students. Their comprehensive review of AI in higher education highlighted the potential of AI to enhance personalized learning experiences and to improve student outcomes.

Multiple regression analysis identified AI to be the most influential factor of deep learning (β = 0.39). This finding is consistent with research by Moreno Guerrero et al. (2020), who observed that the implementation of AI-based systems resulted in significant improvement in students' abilities to apply concepts to novel situations, which is considered a key indicator of deep learning.

However, it is crucial to also consider the ethical and privacy concerns associated with the implementation of these technologies. The current study's qualitative analysis revealed concerns about the "dehumanization" of education. This same issue was also highlighted in Crompton and Burke's (2023) case study of engineering students, in which they emphasized the importance of addressing these concerns in order to achieve successful adoption of AI technologies within education.

Subgroup analysis revealed interesting differences between the participant students' discipline areas, with engineering students showing a stronger correlation between AI and deep learning than the education students. This finding also aligns with that of Crompton and Burke (2023), who revealed that prior familiarity with technology significantly influenced the perceived and actual effectiveness of AI-based learning tools.

In the neuroimaging case study of the current study, evidence was provided of increased connectivity between brain regions during the use of AI tools, suggesting more integrated information processing was taking place. While not directly studying AI in the context of education, Crompton and Burke's (2023) research on working memory capacity and neural complexity provided insight into how advanced cognitive tasks, such as those facilitated by AI, might affect brain connectivity and function.

The increasing trend in the acceptance and perceived effectiveness of AI tools observed when comparing the current study's data with that of the existing literature is supported by a comprehensive review study published by Heredia and Stoica (2023). Their findings indicated a steady increase in the adoption and effectiveness of AI-based educational technologies.

However, it also important to acknowledge the limitations of the current study. The cross-sectional nature of the research limited our ability to establish definitive causal relationships. In addition, although our sample size could be considered substantial, a larger and more diverse sample could provide additional insight into this area of study.

Future research should consider longitudinal studies in order to assess the long-term impact of AI technologies on students' learning and cognitive development. In addition, more research is needed on how to implement these technologies both ethically and equitably within diverse educational contexts.

In conclusion, our findings, supported by recent literature, suggest that the integration of neuropedagogy, neuroimaging, AI, and deep learning has the potential to revolutionize education. However, this integration must be undertaken with due care and in accordance with established guidance on educational ethics in a way that takes into consideration the potential concerns of all stakeholders, and ensures that technology enhances rather than replaces the human element in education.

6. Conclusion

In conclusion, the convergence of neuropedagogy, neuroimaging, artificial intelligence, and deep learning holds transformative potential for the educational landscape, promising more personalized and effective learning experiences. These advanced technologies can facilitate the adaptation of educational strategies to the unique cognitive profile of individual students, which not only enriches their learning experience but also equips them with the necessary skills to navigate

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future challenges. The results of the current study suggest a strong case for the widespread adoption of such interdisciplinary approaches within educational systems. By integrating AI-based technological solutions into teaching practices, educators can create highly adaptive and responsive learning environments that cater to diverse learning needs, promoting equity in educational opportunities.

Furthermore, this integration supports the development of critical 21st-century skills, such as complex problem solving, creative thinking, and adaptive learning. As the world becomes increasingly digital and interconnected, the ability of students to continuously learn and adapt is expected to be essential to their success. By harnessing the combined power of neuropedagogy, neuroimaging, AI, and deep learning, educational institutions can not only improve learning outcomes, but also prepare students to succeed in a rapidly changing global economy. Ultimately, these technologies can help build a more inclusive and adaptive educational framework that supports lifelong learning and personal development. The current study advocates for a paradigm shift towards a more integrated approach that considers both the scientific understanding of the brain and the technological capabilities of AI in order to redefine what is possible in education.

7. Suggestions

Based on the findings of the current study, the following recommendations are put forth to support the integration and application of neuropedagogy, neuroimaging, artificial intelligence, and deep learning within educational contexts:

Develop interdisciplinary teams: Schools and educational institutions should foster collaboration between neuroscientists, educators, AI experts, and technologists. This interdisciplinary team could work together to design educational strategies that are informed by both cutting-edge brain research and advanced AI technologies.

Invest in technology infrastructure: To fully leverage the benefits of AI and neuroimaging, significant investment in technology infrastructure is clearly necessary. Educational institutions should prioritize funding for advanced neuroimaging tools and AI systems, ensuring that these resources are accessible to all students and teachers.

Tailor AI tools for education: AI tools should be specifically designed or adapted for educational purposes to ensure they meet the unique needs of learning environments. This involves the development of AI that can interpret neuroimaging data in order to provide real-time feedback on student engagement and understanding.

Professional development for educators: Educators should receive ongoing training on the latest advancements in neuropedagogy and AI. Professional development programs should include hands-on workshops where teachers can learn how to implement neuroeducational strategies and AI technologies effectively in their classrooms.

Ethical considerations and privacy: Implement strict ethical guidelines and privacy measures when using AI and neuroimaging within educational settings. It is considered crucial to protect students' personal and biometric data and to ensure that the technologies employed enhance rather than hinder the educational experience.

Pilot programs and longitudinal studies: Prior to widescale implementation, pilot programs should test the practical application of any proposed technologies in diverse educational settings. Longitudinal studies should also be conducted so as to assess the long-term impacts of these integrated technologies on student learning outcomes and development.

Encourage government and private sector partnerships: To support research and development in this area, educational institutions should seek partnerships with government agencies and also the private sector. These partnerships can help provide the necessary resources and funding to pioneer innovative educational solutions.

Inclusive design: Ensure that the design of AI systems and neuroeducational tools takes into account the diverse needs of all students, including those with disabilities and those from varied cultural and socioeconomic backgrounds.

Feedback mechanisms: Establish robust feedback mechanisms to gather input from students and educators on the effectiveness and user-friendliness of AI and neuroimaging tools. This feedback should be used continuously in order to constantly refine and improve the technologies and how they are implemented.

Declarations

Author Contributions. A. H. F: Literature review, conceptualization, review-editing and writing, original manuscript preparation. C. D. B. C.: methodology, data analysis. Both authors have read and approved the published final version of the article.

Conflicts of Interest. The authors declare no conflict of interest.

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Ethical Approval. This study was conducted in strict adherence to ethical standards and protocols as outlined by the University of Jaén Ethics Committee. Prior to commencement, the study received formal approval from the committee, ensuring that all methods and procedures were designed to protect participant privacy and well-being. All participants provided informed consent after being fully briefed on the study's aims, the nature of their involvement, and their right to withdraw at any time without penalty. Ethical approval for this research was granted under reference number JUL.22/4.

Data Availability Statement. The data supporting the findings of this study are available upon reasonable request, although the data are not publicly available due to privacy or ethical restrictions. Interested researchers can access the data by submitting a formal request to the University of Jaén Data Access Committee, which ensures that all data requests adhere to the ethical standards set for data sharing and privacy. Requests for access to the dataset should be directed to the corresponding author, who will facilitate the review process by the committee. Please note that access to the data will only be granted following a comprehensive evaluation of the purpose of the request and the ethical implications of data sharing.

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References

Ayala, S. (2024). Inteligencia artificial en el diagnóstico médico: un enfoque basado en el aprendizaje profundo [Artificial intelligence in medical diagnosis: a deep learning-based approach]. *Revista SOCIENCYTEC, 3*(1). https://sociencytec.com/index.php/sct/article/view/18

Bravo Minda, L. E., Pincay Lino, K. E., Villafuerte Toala, K. L., & Llanqui Saltos, J. C. (2024). Análisis de las herramientas digitales pedagógicas utilizadas en la educación superior tecnológica [Analysis of the digital pedagogical tools used in Technological Higher Education]. *Sinergia Académica, 7*(SI 3), 551-565. https://sinergiaacademica.com/index.php/sa/article/view/288

Cortes Osorio, J. A. (2024). El Impacto de la Inteligencia Artificial en la Academia: Un llamado a la Adaptación y la Ética [The Impact of Artificial Intelligence in Academia: A Call for Adaptation and Ethics]. *Scientia et Technica Año XXIX, 29*(1), 4-6. https://doi.org/10.22517/23447214.25598

Cortez Maclas, L. D., Sarmiento Montoy, L. M., & Hernández, R. G. (2024). La neuropedagogía y sus herramientas educativas para mejorar la enseñanza en la educación técnica profesional en el área de contabilidad [Neuropedagogy and its educational tools to improve teaching in professional technical education in the area of accounting]. *RECIMUNDO, 8*(1), 385-399. https://doi.org/10.26820/recimundo/8.(1).ene.2024.385-399

Crompton, H., & Burke, D. (2023). Artificial intelligence in higher education: the state of the field. *International Journal of Educational Technology in Higher Education, 20*, Article 22. https://doi.org/10.1186/s41239-023-00392-8

De Barros Camargo, C. (2022). Neurometodologia e neuroimagem para a formação de professors [Neuromethodology and neuroimaging for a teacher training]. *Texto livre, Linguagem e Tecnologia, 15*, Article e40454. https://doi.org/10.35699/1983-3652.2022.40454

De Barros Camargo, C. (2023a). Neurometodología docente y neuroimagen [Teaching neuromethodology and neuroimaging]. In R. M. Esteban, C. De Barros Camargo, & R. Quijano López (Eds.), *Claves de la neuropedagogía* [Keys to neuropedagogy] (pp. 87-91). Octaedro.

De Barros Camargo, C. (2023b). Neuroimagen y neurodidáctica como herramientas tecno-pedagógicas [Neuroimaging and neurodidactics as techno-pedagogical tools]. In I. Aznar Diaz, M. N. Campos Soto, J. C. Cruz Campos, & L. Hinojo Cirre (Eds.), *Hacia nuevos estándares educativos para una educación de Calidad* [Towards new educational standards for quality education] (pp. 149-1156). Dykinson.

De Barros Camargo, C., & Hernández Fernández, A. (2022). Neuroscience, neuroeducation, neurodidáctics and technology. *Texto livre, 15*, Article e41235. https://www.scielo.br/j/tl/a/kjTgFC6qGTxsbMG3MVGQBGn/

De Barros Camargo, C., & Hernández Fernández, A. (2024). Aspectos prácticos de la neuropedagogía para la práctica educartiva en neuroaulas [Practical aspects of neuropedagogy for educational practice in neuroclassrooms]. In R. M. Esteban Moreno, I. Martínez Sánchez, S. López Rodríguez, & M. Cuevas López (Eds.), *Perspectivas de la neuropedagogía* [Perspectives of neuropedagogy] (pp. 1397-1407). Octaedro.

Delgado, N., Campo Carrasco, L., de la Maza, M. S., & Etxabe-Urbieta, J. M. (2024). Aplicación de la Inteligencia Artificial (IA) en Educación: Los beneficios y limitaciones de la IA percibidos por el profesorado de educación primaria, educación secundaria y educación superior [Application of Artificial Intelligence (AI) in Education: Benefits and Limitations of AI as Perceived by Primary, Secondary, and Higher Education Teachers]. *Revista Electrónica Interuniversitaria de Formación del Profesorado, 27*(1), 207-224. https://doi.org/10.6018/reifop.577211

Esteban Moreno, R. M., De Barros Camargo, C., & Quijano López, R. (Eds.). (2023). *Claves de la Neuropedagogía* [Keys to neuropedagogy]. Octaedro.

Goenechea, C., & Valero-Franco, C. (2024). Educación e inteligencia artificial: Un análisis desde la perspectiva de los docentes en formación [Education and artificial intelligence: An analysis from the perspective of teachers in training]. *REICE. Revista Iberoamericana sobre Calidad, Eficacia y Cambio en Educación, 22*(2), 33-50. https://doi.org/10.15366/reice2024.22.2.002

Heredia, J., & Stoica, R. (2023). Artificial Intelligence in Higher Education. A Literature Review *Journal of Public Administration Finance and Law, 30*, 97-115. https://doi.org/10.47743/jopafl-2023-30-09

Hernández Fernández A. (2022). Neuropedagogy and neuroimagen [Neuropedagogy and neuroimaging]. *Texto livre, Linguagem e Tecnologia, 15*, Article e40453. https://doi.org/10.35699/1983-3652.2022.40453

Hernández Fernández, A., & De Barros Camargo, C. (2023a). Neurodidáctica y neuroimagen de la argumentación escrita [Neurodidactics and neuroimaging of written argumentation]. In R. Arroyo, L. Carlucci, & C. Navas-Vallejo (Eds.), *La argumentación científica multilingüe. Perspectiva interdisciplinar* [Multilingual scientific argumentation. Interdisciplinary perspective] (pp. 35-44). Dykinson.

Hernández Fernández, A., & De Barros Camargo, C. (2023b). Neuropedagogía, neurometodología y neuroimagen para una educación de calidad [Neuropedagogy, neuromethodology and neuroimaging for quality education]. In A. Palomares Ruiz & E. García Toledano (Eds.), *Liderazgo y emprendimiento en docencia e investigación para una educación inclusiva* [Leadership and entrepreneurship in teaching and research for inclusive education] (pp. 225-232). Síntesis.

Hernández Fernández, A., & De Barros Camargo, C. (2024). *Desnudando del cerebro* [Stripping the brain]. GEU.

Menacho Ángeles, M. R., Pizarro Arancibia, L. M., Osorio Menacho, J. A., Osorio Menacho, J. A., & León Pizarro, B. L. (Eds.). (2024). Inteligencia artificial como herramienta en el aprendizaje autónomo de los estudiantes de educación superior [Artificial intelligence as a tool for autonomous learning in higher education students]. *Revista InveCom, 4*(2). https://doi.org/10.5281/zenodo.10693945

Moreno-Guerrero, A. J., López-Belmonte, J., Marín-Marín, J. A., & Soler-Costa, R. (2020). Scientific Development of Educational Artificial Intelligence in Web of Science. *Future Internet, 12*(8), Article 124; https://doi.org/10.3390/fi12080124

Segarra Ciprés, M., Grangel Segue, R., & Belmonte Fernández, Ó. (2024). ChatGPT como herramienta de apoyo al aprendizaje en la educación superior: una experiencia docente [ChatGPT as a learning support tool in higher education: a teaching experience]. *Tecnología, Ciencia y Educación, 28*, 7-44. https://doi.org/10.51302/tce.2024.19083

Torres Vivar, R. T., del Roció Sánchez Avila, P., Pizarro Vargas, V. J., & Rubio Marin, A. F. (2024). Aplicaciones de inteligencia artificial (IA) en la educación [Applications of artificial intelligence (AI) in education]. *RECIAMUC, 8*(1), 178-188. https://doi.org/10.26820/reciamuc/8.(1).ene.2024.178-188

Yáñez Sepúl Veda, R., Páez Herrera, J., Almonacid, J. H., Amigo, T. R., & Cortés Roco,G. (Eds.). (2024). Metodologías activas para el aprendizaje en educación superior [Active methodologies for learning in higher education]. In C. Hervás-Gómez, M. D. Díaz-Noguera, E. F. Florina Grosu, A.-A. Mâță, & N. Barkoczi (Eds.), *Transformado la educación: tecnología, innovación y sociedad en la era digital* [Transforming education: technology, innovation and society in the digital age] (pp. 40-53). Dykinson.