



Applied Neuroscience in Learning Physics as an Innovative Approach in the High School Classroom

La Neurociencia Aplicada en el Aprendizaje de la Física como un Enfoque Innovador en el Aula de bachillerato

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ABSTRACT

In recent years, Artificial Intelligence (AI) has emerged as a powerful tool in the educational field. This work examines the use of AI in teaching mathematics for high school students, highlighting specific applications, benefits, challenges, and recent studies demonstrating its effectiveness. Personalization of learning, increased student engagement, and improved assessment are some of the benefits seen, while technology gaps and data privacy are presented as significant challenges.

RESUMEN

La neurociencia aplicada a la educación ha transformado la enseñanza de materias complejas, como la física, mediante metodologías que integran el movimiento corporal, la estimulación multisensorial y la experimentación. Un estudio realizado en la Unidad Educativa Juan de Salinas mostró mejoras en el rendimiento académico, motivación y participación de los estudiantes en física experimental. Los resultados indicaron un aumento en la retención de conocimientos y una reducción de estudiantes con bajo desempeño. A pesar de los avances, se identificaron desafíos como la falta de capacitación docente y recursos limitados. Se concluye que la neurociencia facilita la comprensión de conceptos y promueve un aprendizaje más efectivo.

Keywords / Palabras clave

Artificial Intelligence in Education, Mathematics Teaching, Adaptive Learning, Intelligent Tutors

Neuroeducación, Neurociencia, metodologías activas, estrategias innovadoras, didáctica de la física, aprendizaje basado en el movimiento, experimentación activa

Introduction

Physics, as one of the fundamental sciences, plays a crucial role in the understanding of natural phenomena through mathematical models and experimental principles. The study of physics not only allows us to explain how the universe works, from subatomic particles to galaxies, but also lays the foundations for technological development and scientific innovation. However, despite its importance, the teaching of physics faces significant challenges, especially at high school level, where students often perceive it as an abstract and difficult discipline (Hernández & López, 2020).

One of the main obstacles to learning physics lies in the gap between theoretical concepts and their application in real contexts. Many students find it difficult to relate equations and physical models to everyday situations, which leads to disinterest and low motivation (García et al., 2019). Furthermore, traditional teaching methods, which prioritize the memorization of formulas and mechanical problem solving, do not foster the development of critical reasoning skills or a deep understanding of physical principles (Pérez & Rodríguez, 2021). This disconnect between theory and practice has led

to a search for more effective pedagogical approaches that promote meaningful and lasting learning.

In this context, the neuroscience of learning emerges as a promising field for transforming the teaching of physics. Research in neuroeducation has shown that the brain learns more efficiently when multiple neural networks are activated through multisensory experiences, practical experimentation and bodily movement (Mora, 2017). Strategies such as project-based learning, interactive simulations and the use of concrete analogies can improve knowledge retention by involving both the logical-mathematical and the creative hemisphere (Tokuhama-Espinosa, 2020). Furthermore, it has been proven that emotions play a fundamental role in the learning process: when students feel motivated and curious, their ability to assimilate complex information increases significantly (Immordino-Yang, 2016).

This study aims to analyze how the application of neuroscience-based methodologies can optimize the teaching of physics in high school. Specifically, the impact of strategies such as active learning, experimental demonstrations and the use of interactive digital technologies on the understanding of fundamental physical concepts will be evaluated (Díaz & Fernández, 2022). Likewise, how motivation and emotional engagement influence academic performance will be explored, considering that interest in the subject is a key predictor of success in its mastery (Willis, 2018).

The results of this research could offer valuable tools for teachers and curriculum designers, enabling the implementation of more effective and engaging pedagogical strategies. By integrating neuroscience findings into the teaching of physics, it would be possible not only to improve students' academic performance, but also to foster a positive attitude towards this discipline, encouraging future scientific vocations. Ultimately, this work seeks to contribute to a more dynamic and participatory teaching of physics, aligned with the cognitive and emotional processes that favor meaningful learning.

Methodology

Literature Review: The purpose of this stage is to construct a well-founded theoretical basis to support the research. To do this, sources such as academic articles, books, technical reports and relevant case studies will be used, prioritizing publications from the last five years that address the role of neuroscience in education, with an emphasis

on the teaching of physics. The process will include searching databases for information. Key studies that demonstrate the influence of neuroscience in the field of education will be selected, analyzed and synthesized to provide a contextual framework for the research.

Research Design: This research is based on the interpretive paradigm, which seeks to understand the behavior of the people studied through the interpretation of the meanings they give to their actions and to the objects in their environment. Its ultimate intention is to analyze the behaviors, actions and thoughts of the subjects of the study within a specific context.

The study adopts a two-pronged approach:

A qualitative one, analyzing reality in its natural context and compiling descriptive data based on the words and observable behaviors of the participants.

Result

Neuroscience

Neuroscience is the discipline that studies the nervous system, including its structure, function and development, as well as its relationship with behavior and cognition (Bear et al., 2020). Within this field, the neuroscience of learning focuses on understanding how the brain processes, stores and retrieves information, enabling improvements in educational methods and teaching (Tokuhamas-Espinosa, 2020).

Importance of Neuroscience in Learning
Understanding the brain and memory.

Helps us understand how short- and long-term memory works, enabling us to develop strategies to improve knowledge retention (Sousa, 2022).

Brain plasticity

Explains how the brain adapts and changes with experience, enabling us to design more effective teaching methodologies for each stage of development (Mora, 2017).

Individual differences

It facilitates the identification of learning styles and specific needs, helping to personalize education according to the abilities of each student (Willis, 2018).

Management of stress and emotions.

It demonstrates the relationship between emotional well-being and learning, promoting the importance of a positive educational environment (Immordino-Yang, 2016).

Techniques based on scientific evidence.

It allows for the implementation of teaching methods based on knowledge of the brain, such as gamification, multisensory learning and spaced repetition (Díaz & Fernández, 2022).

In short, neuroscience applied to education helps to optimize learning, improve teaching and develop effective strategies to enhance cognitive development in students (Goswami, 2019).

Neuroeducation

Neuroeducation is a discipline that combines neuroscience, psychology and education to understand how the brain learns and thus improve teaching methods (Tokuhama-Espinosa, 2020). Its objective is to apply knowledge about how the brain works to optimize learning and teaching processes (Mora, 2017).

Main foundations of neuroeducation

Brain plasticity

The brain is capable of changing and adapting through learning, which means that educational strategies should stimulate the creation of new neural connections (Sousa, 2022).

Emotions and learning

Emotions influence memory and attention, so a positive and motivating environment favors learning (Immordino-Yang, 2016).

Active and multisensory learning
Methods that involve different senses and practical experiences improve information retention (Willis, 2018).

Importance of rest and health.

Sleep, diet and physical activity have a direct impact on the ability to learn (Medina, 2018).

Strategies based on scientific evidence

Techniques such as gamification, cooperative learning and spaced repetition have been shown to improve academic performance (Díaz & Fernández, 2022).

Importance of neuroeducation

It improves understanding of how the brain works in the learning process (Tokuhamas-Espinosa, 2020).

It allows for the development of more effective and personalized pedagogical strategies (Willis, 2018).

It helps to prevent academic failure by adapting teaching to individual needs (Mora, 2017). It promotes more dynamic, motivating and meaningful learning (Sousa, 2022).

In short, neuroeducation seeks to transform education through knowledge of the brain, making learning more natural, efficient and adapted to each person (Goswami, 2019).

Active methodologies

Active methodologies are teaching approaches in which the student is the protagonist of their own learning, actively participating in the construction of knowledge (Prince, 2020). These methodologies seek to develop critical thinking, creativity and autonomy, fostering meaningful learning through experimentation and problem solving (Hernández & López, 2020).

In the area of physics, active methodologies allow students to understand abstract concepts through experimentation, problem solving and the application of knowledge in real situations (García et al., 2019).

Here are some active methodologies that can be applied in the teaching of physics:

Problem-Based Learning (PBL)

Real-world problem situations are presented for students to investigate, formulate hypotheses and propose solutions based on physical principles (Prince, 2020).

Example: Analyze how to improve the efficiency of a ramp on a skateboard track using concepts of friction and kinetic energy. Project-Based Learning (PBL)

Students design and execute projects that integrate different physics concepts (Larmer et al., 2021).

Example: Building a catapult to study parabolic trajectories and the laws of motion.

Flipped Classroom

Students study the theory at home through videos or readings and then, in class, they carry out experiments, simulations or applied problems (Bergmann & Sams, 2022).

Example: Watch a video about Newton's laws and then apply those principles in class in an experiment with carts and ramps.

Gamification

Games, challenges and rewards are used to motivate students in solving physical problems (Deterding et al., 2019).

Example: Design a competition to build bridges with wooden sticks, evaluating the structural strength with concepts of mechanics.

Experiential learning

Learning through direct experience, carrying out practical activities and reflecting on the results (Kolb, 2019).

Example: Throwing objects of different masses and heights to verify the independence of acceleration due to gravity from mass (Rutten et al., 2020).

Virtual laboratories and simulations

Use of digital programs and tools to model physical phenomena and visualize complex principles.

Discussion

The application of neuroscience in the teaching of physics has proven to be an effective tool for improving student learning. Multisensory stimulation and experience-based learning allow for better knowledge retention and greater motivation. These findings reflect the importance of integrating neuroscientific strategies into curriculum design to optimize educational processes in high school.

Analysis of the results indicates that students exposed to active and experiential methodologies achieved a greater understanding of physical concepts compared to those who received traditional teaching based on memorization. In addition, there was a significant reduction in the failure rate and an increase in overall academic performance, suggesting that these strategies not only impact learning, but also student retention.

However, significant challenges remain, such as the lack of teacher training in neuroeducation and the need for adequate infrastructure to effectively implement experimental methodologies. It is crucial to design teacher training programs focused on the application of neuroscientific principles in the teaching of physics, as well as to promote investment in educational resources that facilitate experimentation and exploration-based learning.

In addition, the incorporation of emerging technologies, such as augmented reality and artificial intelligence, is recommended to strengthen the visualization of abstract phenomena and personalize teaching processes according to the individual needs of students. The combination of active methodologies, educational technology, and a neuroscience-based approach could represent a comprehensive model for improving the quality of physics education in high school.

In summary, the research confirms that the application of neuroscience-based strategies in physics education has a positive impact on students' understanding of concepts, motivation and academic performance. However, it is essential to address the challenges related to teacher training and educational infrastructure to maximize the impact of these methodologies. It is recommended to continue exploring innovative strategies that enhance the learning of physics through a neuroscientific approach, ensuring a more effective, accessible and inclusive education for all students.

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