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PEDAGOGICAL POTENTIAL OF NEUROADAPTIVE PLATFORMS BASED ON ARTIFICIAL INTELLIGENCE

Artem Kozlov
ORCID: https://orcid.org/0009-0004-2480-510X
Owner, Visual 360,
Yaroslavska St, 58, Kyiv, 02000

Abstract. *The article focuses on analyzing and substantiating the pedagogical potential of AI-based neuroadaptive platforms that integrate biosignal processing technologies into modern educational practices. The purpose of the study is to identify and substantiate the pedagogical potential of AI-based neuroadaptive platforms in the context of contemporary educational innovations. The research employed general scientific methods of cognition: analysis and synthesis, generalization, comparison, systems approach, and interpretation of empirical and theoretical data. The findings show that innovation in pedagogy lies not only in the introduction of new technologies but also in creating authentic solutions capable of combining proven methods with AI tools, taking into account sociocultural conditions and real educational needs. The effectiveness of such solutions is determined by pedagogical feasibility, ethical implementation, and alignment with the Sustainable Development Goals, particularly ensuring inclusive and quality education, reducing inequalities, and promoting the rational use of resources. The study reveals that practical applications of AI in pedagogy include supporting interactive discussions, intelligent tutoring, assessment automation, development of adaptive courses, use of chatbots for speech improvement, and individualized creation of learning tasks. It is shown that the distinctive feature of neuroadaptive technologies is the use of not only behavioral indicators but also brain biosignals (EEG, fNIRS, eye-tracking) to determine learners' cognitive load, attention, and motivational state. The practical significance of the study lies in the potential to implement AI-based neuroadaptive solutions to improve the efficiency and inclusiveness of the educational process.*

Keywords: *neuroadaptive platforms, artificial intelligence, education, cognitive load, personalization.*

Introduction

After the COVID-19 pandemic, the development of educational technologies accelerated significantly, as educational institutions worldwide were forced to seek rapid and effective solutions to ensure learning continuity. The transition to online learning led to the emergence of numerous digital platforms, tools for remote interaction, and new approaches to organizing the educational process. However, a genuine technological leap occurred with the mass adoption of artificial intelligence, which in a short time evolved from an experimental novelty into one of the key drivers of educational change.

Today, neuroadaptive technologies stand at the forefront of innovation, combining AI algorithms with neuro-measurement methods for more precise and personalized learning. Unlike classical adaptive platforms, they can respond not only

to task performance results but also to learners' cognitive state, level of attention, and motivation in real time. This opens new possibilities for inclusive education that is sensitive to individual needs and sets new challenges for researchers and educators in terms of effective integration into the learning process.

Literature Review

The pedagogical potential of AI-based neuroadaptive platforms is well-researched in international academic literature, as evidenced by numerous works dedicated to both technical aspects and pedagogical strategies for implementing such technologies. A significant contribution to the field was made by N. Beauchemin [1], who, together with colleagues, explored the capabilities of EEG-based BCI systems for real-time adaptation of learning pace, considering cognitive load and motivation. N.A. Bizami [2] conducted a systematic review of innovative pedagogical principles and tools for immersive blended learning. F. Çelik [3] focuses on the impact of technological innovations on the future of education, while S. Fairclough [4] examines neuroadaptive technologies from a postphenomenological perspective, emphasizing the interaction between technology and human experience. X. Lin [5] and M. Mena Octavio [6] analyze the role of ChatGPT in supporting discussions and teaching foreign languages, highlighting its potential as part of an adaptive learning environment. M.Y. Mustafa [7] and S. Wang [10] carried out systematic reviews of AI in education, identifying key directions for future research. L.Y. Tan [8] provided a comprehensive analysis of AI-based adaptive platforms, whereas the U.S. Department of Education [9] offered practical recommendations for integrating AI into the educational process.

Despite the considerable amount of literature on the topic, there remains a lack of systematized material combining both technical and pedagogical perspectives. Therefore, using various scientific methods, the information was analyzed, grouped, and presented in the context of the research topic.

Methodology and Methods

The study was built on an interdisciplinary approach combining theoretical analysis of academic sources and applied analysis of practical cases of AI integration in education, particularly neuroadaptive platforms. The methodological basis included

principles of systems and comparative analysis, enabling the consideration of innovative technologies as part of the educational ecosystem, as well as the evidence-based education approach, focused on using verified data to substantiate conclusions. The following methods were applied: analysis and synthesis of academic sources — processing articles, reports, and reviews (Wang et al., 2024; Mustafa et al., 2024; U.S. Department of Education, 2023) to identify key trends in AI use in pedagogy; content analysis of case descriptions and outcomes (Lin et al., 2024; Mena Octavio et al., 2024), which helped highlight practical goals and integration specifics of AI solutions in the learning process; comparative analysis of traditional adaptive platforms and neuroadaptive technologies (Fairclough, 2023; Beauchemin et al., 2024; Tan et al., 2025) to determine their differences and potential; data systematization in the form of tables and summarized schemes to identify pedagogical opportunities and prospects for further application.

Purpose of the Article

The aim of the study is to identify and substantiate the pedagogical potential of AI-based neuroadaptive platforms in the context of modern educational innovations. This goal is addressed through three main tasks: defining the specifics and role of innovative technologies in pedagogy; analyzing practical objectives of AI use in the educational process, with a focus on the features of neuroadaptive solutions; and outlining how neuroadaptive platforms can expand and strengthen pedagogical potential in the future.

Research Results

Innovative technologies in pedagogy are the subject of active study by contemporary scholars. Contrary to the common belief, their essence is not about novelty for its own sake. In most cases, innovations are authentic solutions that combine already known tools and methods in ways that meet real educational needs while taking sociocultural conditions into account. This approach helps avoid the mistaken identification of innovation with mere originality, emphasizing the ethical and social aspects of technology implementation. In this context, the Sustainable Development Goals serve as important guidelines: SDG 4, which concerns ensuring

inclusive and quality education, combined with SDG 10 and SDG 12, which address reducing inequalities and promoting responsible consumption [2].

The COVID-19 pandemic demonstrated that technologies in education have both positive and negative sides: they help maintain learning continuity and support lifelong learning, but without thoughtful integration, they can increase stress levels and fail to improve overall learner well-being. As noted by Çelik F. and Baturay M.H., true innovativeness is defined not by the number of new tools but by how appropriately, pedagogically sound, and context-sensitive they are applied [3].

Within the Education 4.0 paradigm, innovative technologies in education can now be systematized by combining modern pedagogical approaches with digital tools that best align with their goals. Research by Bizami N.A., Tasir Z., and Kew S.N., based on the analysis of 59 academic works, identifies three key pedagogies: heutagogy (self-determined learning), peeragogy (peer-based learning), and cybergogy (virtually oriented learning) [2]. Each of these is associated with specific technological tools and a set of capabilities (Table 1).

Table 1 – Classification of innovative educational technologies within the Education 4.0 paradigm

Pedagogy	Tools	Capabilities	Application description
Heutagogy	Learning Management Systems (Moodle, Canvas, etc.)	Flexibility in timing, support for learner autonomy	Enables students to choose the pace, content, and format of learning, track their own progress, and build an individual learning trajectory.
Peeragogy	Social platforms (Facebook groups, forums)	Building a learning community, supporting interaction	Facilitates collective knowledge exchange, development of collaboration skills, and participation in discussions and joint projects.
Cybergogy	Blogs and other online publishing tools	Task orientation, development of critical thinking	Allows learners to create their own content, build a portfolio, and develop analytical and reflective skills through discussions and comments.

Systematized based on the study [2]

At the core of innovative technologies in pedagogy lie modern digital learning tools, among which the following hold an important place:

- virtual reality (VR – Virtual Reality);
- augmented reality (AR – Augmented Reality);
- mixed reality (MR – Mixed Reality);
- extended reality (XR – Extended Reality).

Their potential lies in their ability to significantly increase student engagement in the learning process, make complex topics more visual, and expand the possibilities of experiential learning in natural sciences, history, or vocational training. However, the effectiveness of such technologies depends primarily on methodological adaptation to a specific age group and subject area. Their use should be systematic, regular, and consistent. Failure to follow this principle, according to Çelik F. and Baturay M.H., leads to a "chaotic effect" that complicates the assimilation of material, although in some cases even such an experience can yield positive results by fostering flexible thinking [3].

One of the most dynamic areas of innovation is the use of artificial intelligence. Today, it enables the creation of adaptive platforms that adjust to the pace and content of each learner's studies, as well as the analysis of the causes of ineffective learning, providing more accurate and timely feedback. This, in turn, helps improve results and the overall efficiency of the educational process [3]. However, despite its considerable potential, several issues are observed in practice: students often use AI mainly to generate ready-made texts without proper understanding, and educators sometimes accept such work without critical evaluation. This creates a risk of developing pseudo-academic approaches and diminishing the educational value of the technology. Research in the field of language education shows that AI handles technical aspects of writing and communication well, but does not foster critical thinking, creativity, or cultural sensitivity. For this reason, targeted training on how to integrate artificial intelligence into the learning process is necessary, combining its capabilities with traditional teaching methods [3].

The development of innovative technologies is determined by several factors that can be divided into different levels.

At the student level, the key factor is cognitive, combining learning goals with the

capabilities of technological tools, such as flexibility in timing, support for autonomy, task orientation, and community development.

At the level of educational institutions and state policy, ethical standards, ensuring equal access to technologies, a sustainable approach to integration, and critical assessment of the novelty effect play an important role, to avoid situations where tools become merely fashionable trends without real benefit. This approach, systematized in the work of Bizami N.A., Tasir Z., and Kew S.N., makes it possible to integrate innovative solutions into the educational process more consciously and effectively [2].

Strategic opportunities and limitations for implementing AI in the U.S. educational process are summarized in the U.S. Department of Education report. Examples include the use of intelligent tutoring systems (ITS) that can observe how students solve problems, provide step-by-step feedback, and adapt the learning path in real time. In cases where a student deviated from the "expert" trajectory, the system offered specific hints for correction. This approach proved effective, particularly in mathematics and tasks with clearly defined correct answers. The report also discusses directions for expanding AI capabilities: shifting from a deficit-focused to a strengths-based approach, incorporating social aspects of learning, supporting neurodiverse students and open-ended tasks, as well as fostering self-regulation and teamwork skills in students. At the same time, it emphasizes that even the best AI solutions should work in close cooperation with the teacher, rather than replacing them [9].

Current research shows that artificial intelligence is gradually becoming a tool not only for automating tasks but also for providing high-quality support to learning processes.

One illustrative example is described in the study by Lin et al. [5], where ChatGPT was integrated into mandatory online discussions of a master's course. Students received clear instructions on using the tool, including examples of prompts for creating posts and replies, as well as the requirement not to copy the generated text but to critically reinterpret it. An important part of the process involved sending the ChatGPT dialogue history to the instructor, which allowed monitoring the quality of interaction. Analysis of LMS logs, surveys, and open-ended responses showed that

using ChatGPT helped students participate more actively in discussions, structure arguments, and develop critical thinking. The greatest effect was observed where AI was used alongside step-by-step reflection and active experimentation, as provided in the four-stage experiential learning model [5].

Table 2 – Practical objectives of AI use in pedagogy

Objective of use	Description
Online discussions	Using ChatGPT to support asynchronous discussions in LMS (e.g., Canvas). The goal is to enhance the substance of messages and foster critical thinking. Students receive instructions on how to formulate AI prompts, generate responses, and are required to critically evaluate and adapt them. Instructors collect dialogue histories for review. This approach encourages active participation and develops argumentation skills [5].
Tutoring	Intelligent tutoring systems (ITS) provide step-by-step feedback when completing tasks, especially in mathematics and logic-related disciplines. The goal is to personalize learning and quickly identify mistakes. The system compares the student's solution with an "expert" model and offers specific hints, while the teacher supplements this with motivational and social support [9].
Automated grading	Using AI for rapid assessment of tests and written assignments. The goal is to reduce the administrative workload for teachers and speed up feedback delivery. AI tools analyze responses, provide comments on grammar, style, and structure, and the teacher reviews and approves grades to avoid algorithmic errors.
Adaptive courses and content	Creating learning platforms that adjust the pace, difficulty level, and format of material for each learner. The goal is to individualize learning and better support students with varying levels of preparation. The system tracks progress and recommends additional resources or alternative explanations.
Chatbots for speaking practice	Using AI chatbots to simulate dialogues in foreign language learning. The goal is to develop communication skills and confidence in speaking. Students can practice pronunciation and vocabulary in a safe environment, receiving instant feedback on errors.
Individualized assignments	Preparing and adapting tasks for specific learning objectives, for example, creating exercises to develop grammar or writing skills in EFL. The teacher formulates AI prompts, analyzes the generated materials, selects the highest-quality ones, and incorporates them into the program. This saves preparation time and increases the variety of learning content [6].

Note: systematized by the author based on sources [5, 6, 9]

Another example relates to supporting English as a Foreign Language (EFL) teachers in the study by Mena Octavio M., González Argüello M.V., and Pujolà J.-T. [6]. In this case, a teacher at a private language school in Spain used ChatGPT for seven months to prepare and conduct lessons. The tool helped create individualized tasks, select materials for grammar and vocabulary, generate example dialogues for

practicing communication skills, and assess students' written work.

In addition to personal use cases of artificial intelligence, there are also educational platforms with integrated AI. Among them, the Squirrel AI Learning platform stands out, using AI for adaptive learning with analysis of each "knowledge point" and presentation via a knowledge graph; it is designed to diagnose and tailor the course to each student. Another example is Disprz from India, which transformed its LMS/LXP into a generative AI platform for content creation, competency assessment, and learning recommendations [1].

Neuroadaptive platforms are systems that combine machine learning algorithms with neuro-measurement technologies (e.g., electroencephalography, fNIRS, eye-tracking) to monitor a user's cognitive state in real time and automatically adjust the learning process. Unlike conventional adaptive learning platforms, which mainly tailor material based on task results, behavioral data, or completion speed, neuroadaptive solutions use direct brain biosignals to assess levels of cognitive load, attention, stress, or motivation, dynamically adjusting the pace, volume, or format of material delivery [4].

This approach allows for a deeper consideration of individual differences in information perception and processing, reducing the risk of overload or, conversely, loss of interest. For example, the system can slow down the pace of learning if excessive cognitive load is detected, or offer more complex tasks when there is high concentration and motivation. Studies show that integrating neuroadaptive algorithms with AI modules increases personalization effectiveness, as it accounts for both behavioral and physiological indicators, creating a more holistic learner model [8].

In fact, every month a significant number of new AI-based online learning platforms emerge globally—ranging from dozens to hundreds, particularly in the K-12 and corporate sectors. Some gain popularity quickly, while others remain less visible, yet all drive innovation forward. Among neuroadaptive platforms, two stand out for their ability to respond to learners' cognitive states. The first is NeuroChat, which tracks a student's EEG signals in real time and automatically adjusts content complexity, style, and pace. The second is an EEG-adaptive learning system (Wearable

EEG), which reads emotional and cognitive load via a wearable EEG device and modifies teaching strategies and learning pace accordingly.

These examples demonstrate how the principles of neuroadaptivity are implemented in educational services – through reactive adaptation to a learner's biophysiological states.

Another promising direction in the development of neuroadaptive platforms is the author's methodology "ImmersionED," created by Artem Kozlov, co-owner of Visual 360. Its uniqueness lies in the use of artificial intelligence mechanisms to design a personalized learning path. The system analyzes cognitive characteristics, working pace, strengths and weaknesses of the student, as well as individual perception style. Based on this data, adaptive tasks are generated, allowing each learner to follow a personalized educational trajectory while maintaining an optimal balance between complexity and accessibility of the material.

The neuroadaptive approach within ImmersionED provides not only the selection of learning content but also increases motivation through dynamic feedback and elements of gamification. Under such conditions, students are able not just to reproduce knowledge but to interact with an environment that "senses" their progress and adjusts learning scenarios accordingly. This creates a deep immersion effect and enhances the efficiency of competence development, making ImmersionED an example of how neuroadaptive platforms can transform modern pedagogy.

Comprehensive reviews indicate that AI use in education involves several main areas that could form the foundation for future neuroadaptive platforms. These include adaptive learning and personalized tutoring, where AI adjusts the pace and content of teaching to student needs; intelligent assessment and management, which automates grading and process administration; profiling and prediction to identify risk of underperformance for timely support; and new technological products, such as educational robots or VR/AR solutions, that enhance learner engagement [10].

Based on these areas, neuroadaptive platforms can perform the following key pedagogical tasks:

- precise scalable adaptive learning that responds not only to behavioral but also

neurophysiological signals – for example, EEG indicators of attention or cognitive load;

• extended feedback assessment that takes cognitive state into account – when a student is fatigued, the platform can automatically slow the pace, introduce a break, or change the format;

• profiling not only by knowledge but also by learning readiness state, helping support neurodiverse learners and adapt learning scenarios to their current state rather than just their knowledge level;

• combining new multimodal products (robots, VR/AR) with real-time user feedback to create interactive and sensorially adaptive educational environments [7].

Conclusions

Innovative technologies in pedagogy are characterized not by novelty alone, but by their ability to combine already known methods and tools into authentic solutions that meet real educational needs and consider the sociocultural context. Their effectiveness is determined by pedagogical feasibility, ethical implementation, and alignment with the Sustainable Development Goals, particularly ensuring inclusive and quality education, reducing inequalities, and promoting sustainable resource use. The practical objectives of AI use in pedagogy include supporting online discussions, intelligent tutoring, automated grading, creation of adaptive courses, chatbots for language development, and preparation of individualized tasks. A distinctive feature of neuroadaptive technologies is the use of not only behavioral data but also brain biosignals (EEG, fNIRS, eye-tracking) to assess cognitive load, attention, and motivation, enabling real-time adjustment of learning pace, format, and complexity.

AI-based neuroadaptive learning platforms can significantly expand pedagogical potential by combining deep personalization with consideration of cognitive states and multimodal educational environments. They make it possible to more precisely tailor the learning process to individual learner needs, support neurodiversity, increase engagement, and prevent overload, which in the long term can enhance the effectiveness and resilience of educational systems.

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