Journal of Educational Technology and Learning Creativity
Vol. 3, No. 2, December 2025, pp. 512~527
ISSN: 3021-7865, DOI: 10.37251/jetlc.vxix.x

Enhancing Cognitive Independence and Creativity in Higher Education Through Neuroeducation: An Empirical Study

Albina Volkotrubova[1], Jie Liu[2], Oleksandr Andrusenko[3], Yevheniia Provorova[4], Olga Vnukova[5]
[1]Department of Linguistics, International University of Kyrgyzstan, Bishkek, Kyrgyzstan
[2]Kyrgyz State University named after I. Arabaev, Bishkek, Kyrgyzstan
[3]Department of Systems Engineering and Information Technology, Sumy State University, Shostka, Ukraine
[4]Department of Vocal Performance, Anatolii Avdiievsky Faculty of Arts, Mykhailo Dragomanov State University of Ukraine, Kyiv, Ukraine
[5]Department of Physical Education and Health, Institute of Law and Modern Technologies, Kyiv National University of Technologies and Design, Kyiv, Ukraine

Article Info

Article history:

Received Oct 12, 2025
Revised Nov 29, 2025
Accepted Dec 19, 2025
Online First Dec 29, 2025

Keywords:

Cognitive Autonomy
Creativity
Higher Education
Neurodidactics
Neuroeducation

ABSTRACT

Purpose of the study: The research aims to empirically examine the effectiveness of integrating neuroeducation into higher education by analyzing how an integrated neurodidactic model enhances students' cognitive independence and creativity within technology-enhanced learning environments.

Methodology: The methodological underpinning was the system-activity approach. A quasi-experimental pre-test/post-test control group design was employed to assess the effectiveness of the neurodidactic intervention.Among the employed methodologies were questionnaires utilizing the MSLQ scale, creativity assessments developed by D. Johnson, S. Mednick, and E. Torrance, the expert evaluation method, as well as statistical analysis, including the Mann–Whitney U-test and Spearman's coefficient.

Main Findings: A total of 294 students participated in the pedagogical experiment, with 147 assigned to the control group and 147 to the experimental group. The findings revealed that the expert assessment of creativity in the experimental group (EG) averaged 26.32 points, compared to 22.60 points in the control group (CG); regarding the motivational criterion, the EG scored 4.1, while the CG scored 3.4. A marked enhancement in the measures of independence and creativity was observed within the experimental group. These improvements were statistically significant and confirmed the effectiveness of the neurodidactic intervention compared with traditional instruction.

Novelty/Originality of this study: The scientific novelty of the study lies in the empirical validation of an integrated neurodidactic model that systematically combines multiple cognitively grounded strategies within higher education. Unlike previous studies focusing on isolated neuroeducational techniques, this research demonstrates simultaneous improvements in cognitive independence and creativity through a technology-enhanced learning framework.

Corresponding Author:
Albina Volkotrubova,
Department of Linguistics, International University of Kyrgyzstan,
17A/1 Lev-Tolstoy Str., Bishkek, 720007, Kyrgyzstan
Email: 091019591nb@gmail.com

1. INTRODUCTION

Higher education is currently undergoing a transformation driven by digitalization and the imperative to update pedagogy in line with the advancements in cognitive science [1]. In this study, neuroeducational strategies are conceptualized and implemented within the framework of educational technology and technology-enhanced learning (TEL), where digital learning technologies such as learning management systems, multimedia content, and interactive assessments—function as mediators of cognitively grounded instructional design. In light of the increasing complexity of the professional landscape, cognitive autonomy and creativity have emerged as key features indispensable for a 21st-century specialist [2]-[4]. Traditional higher education, which predominantly emphasizes the reproduction of knowledge, frequently falls short in fostering flexible thinking and a creative mindset [5]-[7]. In response to these challenges, neuroeducation is gaining significance as an interdisciplinary domain that amalgamates neuroscience, psychology, and pedagogy to facilitate natural cognitive growth [8], [9]. Neurodidactics is based on a nuanced understanding of brain function during the learning process, considering sensory modalities, hemispheric asymmetry, memory, motivation, and emotional engagement. It employs methodologies such as gamification, interleaving, visualization, spaced repetition, retrieval practice, dual coding, and other innovative techniques.

These strategies significantly enhance the effective assimilation of knowledge and the cultivation of advanced cognitive skills [10]-[12]. Despite the growing interest in neuroeducation, there remains a lack of empirical research that thoroughly assesses the efficacy of neurodidactics within higher education, particularly regarding the enhancement of cognitive autonomy and creativity [13]-[15]. Furthermore, there is a pressing need to tailor neuroeducational strategies to specific national contexts and evaluate the preparedness of educators to implement such approaches [16]-[18]. The effectiveness of such implementation is closely related to teachers' digital literacy and their ability to meaningfully integrate technology into instruction.

In this regard, exploring the mechanisms for fostering essential cognitive qualities in students through the integration of neuroeducation assumes substantial significance for both educators and educational program developers. Recent studies demonstrate that neurodidactic principles are increasingly integrated into digital learning environments; however, such integration remains fragmented and methodologically limited. Empirical evidence also suggests that information technology–based learning environments play a significant role in fostering students' cognitive independence, autonomy, and self-regulation. In particular, Endra and Villaflora demonstrated that ICT-supported instructional models contribute to the development of students' responsibility for learning outcomes and independent cognitive engagement. Pérez Sánchez, Calle-Alonso, and Vega-Rodríguez [19], emphasize that, despite advances in learning analytics and neurodidactics, "no prior studies have combined machine learning, learning analytics, and neurodidactics within a unified empirical framework". This indicates that existing research primarily focuses on isolated technological or neuroscientific components rather than evaluating comprehensive neurodidactic models in authentic higher education settings. Consequently, there is a clear research gap concerning empirically validated, multi-component neurodidactic frameworks that simultaneously address cognitive independence and creativity through technology-enhanced learning environments.

The urgency of addressing this gap is intensified by the rapid digital transformation of higher education. Systematic reviews indicate that the effectiveness of contemporary instruction increasingly depends on the adoption of educational technology and TEL frameworks [20], [21]. In the context of Education 4.0, digital platforms, immersive technologies, and data-driven instructional design are no longer supplementary but central to fostering higher-order cognitive skills, autonomy, and creativity. Therefore, investigating neurodidactic mechanisms within technology-enhanced learning environments represents a timely and necessary response to current educational challenges.

A distinctive contribution of the present study lies in empirically validating a comprehensive neurodidactic model simultaneously targeting creativity and cognitive independence through multi-component intervention, which has not been systematically tested in prior research. Cognitive independence is defined as a multidimensional construct that integrates: motivational readiness for autonomous learning, cognitive-operational skills such as analysis, planning, argumentation, and independent problem-solving, and volitional self-regulation, persistence, and internal control in academic tasks. In this study, cognitive independence is operationalized through three validated components of the MSLQ scale: the motivational, content-operational, and volitional dimensions.

Based on the identified research gap, this study formulates several research questions aimed at examining the effectiveness of neuroeducational approaches in higher education. Specifically, the study investigates whether the integration of neuroeducational strategies significantly enhances students' cognitive independence compared with traditional instructional approaches, whether the implementation of a neurodidactic model contributes to improvements in key creativity indicators—namely fluency, flexibility, and originality—and whether statistically significant differences exist between experimental and control groups at both pre-test and post-test stages. In addition, the study explores which neurodidactic mechanisms are perceived by educators as the most effective in supporting student learning. Correspondingly, the study hypothesizes that neurodidactic intervention positively influences students' cognitive independence and creativity, and that improvements in cognitive independence are positively associated with academic performance.

The primary aim of this study is to empirically examine the impact of integrating neuroeducational methodologies into higher education learning environments on the development of students' cognitive autonomy and creativity. To achieve this aim, the study seeks to design and implement a neurodidactic model that integrates cognitively grounded instructional strategies, including gamification, spaced repetition, dual coding, and retrieval practice. Furthermore, the study analyzes students' levels of cognitive autonomy and creativity following the formative phase of instruction by comparing outcomes between the experimental and control groups using validated diagnostic instruments, namely the Motivated Strategies for Learning Questionnaire (MSLQ), D. Johnson's questionnaire, and the Mednick and Torrance creativity tests. In addition, the study evaluates educators' implementation of the neurodidactic model to determine its pedagogical effectiveness and practical applicability within higher education contexts.

2. THE COMPREHENSIVE THEORETICAL BASIS

The authors of numerous scholarly publications underscore the imperative of integrating neuroscience discoveries into pedagogical methodologies within higher education. Goldberg [22] emphasizes that, owing to the brain's inherent plasticity during youth, it is worth adopting "brain-friendly" learning practices rooted in the natural mechanisms of memory, attention, emotions, and motivation. A similar perspective is expressed by Gkintoni et al. [23], who draw a parallel between the significance of educational neuroscience for pedagogy and the foundational role of biology in medicine - as a scientific underpinning for innovation. They underscore the necessity of comprehending the fundamental processes of cerebral function when designing the educational experience. Notably, Pradeep et al. [24] characterize neuroeducation as a "transformative force" within pedagogy, facilitating the development of effective, inclusive learning paradigms aligned with brain functioning.

The cultivation of creative thinking stands as one of the key goals of education in the 21st century. Neuroscience correlates creativity with the interaction of cerebral networks. In this light, Lopata et al. [25], invoking the concept of "dual mode," contend that creativity emerges from the synergy between passive state networks (idea generation) and executive networks (decision selection), which education should intentionally activate. Accordingly, Dietrich and Zakka [26] accentuate the necessity of acknowledging diverse types of creativity, as neglecting them diminishes the efficacy of educational programs.

Other researchers also underscore the diverse manifestations of creativity. In the field of medical education, Shumylo et al. [27] characterize creativity as a multifaceted attribute that encompasses awareness, independent thinking, reflectiveness, goal orientation, and self-organization. To cultivate this quality, they advocate for techniques such as brainstorming, the use of focal objects, role-playing exercises, project-based learning, and the resolution of unstructured problems. A similar methodology is followed by Yaya Copaja and Egoavil Vera [28], who describe neuro-oriented strategies such as gamification, VR/AR, and the flipped classroom as mechanisms to enhance creativity, engagement, and student accountability. Yaya Copaja's insights align with Shumylo's advocacy for experiential learning, collaborative problem-solving, and project-based work. Thus, scholars from diverse nations agree that active neuro-oriented are effective for cultivating students' creative thinking.

Goldberg [22] advocates for instructing students in the fundamental principles of neuroscience, in particular brain architecture, memory processes, attention, and stress management, with the objective of fostering awareness and self-regulation. Empirical evidence substantiates the efficacy of this approach: Canadian educators who have participated in neuroeducation courses have begun incorporating mini-lectures on brain function, observing a marked increase in student interest. However, as Fragkaki et al. [29] report, while 92% of educators profess support for creativity, some regard it as irrelevant to their subject matter or struggle to allocate time for creative tasks. This perspective stands in stark contrast to contemporary pedagogical research, which posits creativity as an essential competency. Lopata et al. [30] emphasize that all students should cultivate creative thinking pertinent to their fields, mindful of industry-specific nuances. Fragkaki et al. [31] challenge the widespread myth about "right-brained" and "left-brained" students, asserting that creativity engages both hemispheres and intricate neural networks. Nevertheless, numerous educators persist in believing in such neuromyths. As Wilcox et al. [32] observe, this may be attributed to the deficiency of reliable neuroscientific information within the field of education The authors propose that the solution is the teachers' professional development of in the field of neuroeducation.

Mystakidis et al. [33] have developed an online neuroeducation course for university educators and a community of practitioners, equipping participants from various countries with scientifically grounded insights into the brain and learning processes. A survey revealed high levels of satisfaction and a willingness to adopt novel approaches, although the authors underscore the necessity of mentorship for enduring transformation. Bhargava and Ramadas [34] caution that in the absence of adequate pedagogical training, neuroscientific advancements may remain unexploited or misapplied. On the other hand, García-Valdecasas et al. [35] regard neuroeducation as pivotal to the professionalization of educators in the context of online learning, a consideration that is particularly salient in the post-pandemic landscape as well as amid the ongoing conflict in Ukraine.

Recent Ukrainian and Kyrgyz research corroborates the effectiveness of integrating neuroeducational approaches into higher education, which is consistent with our findings. Ukrainian scholarly literature predominantly concentrates on the practical dimensions of neurodidactics. For instance, Kruhlii et al. [36] and Ishchenko et al. [37] demonstrate that distance learning platforms, when utilized in accordance with neurodidactic principles, facilitate students' autonomous mastery of course material. What is more, Yermakova et al. [38] discovered that tailoring the educational environment to align with brain functioning enhances students' socialization and cognitive developmentA broader perspective on contemporary pedagogical transformation is provided by Suyo-Vega et al. [39], whose systematic review synthesizes evidence on innovative instructional practices in higher education. The authors demonstrate that learner-centered, technology-supported, and cognitively engaging pedagogical models are consistently associated with higher levels of student autonomy, self-regulation, and creative engagement. However, the review also highlights that many innovative practices remain methodologically fragmented and are rarely grounded in an explicit neurocognitive framework. Complementary empirical findings are reported by Maygeldiyeva et al. [40], who examined the role of information technology in supporting students' cognitive independence and self-regulated learning. Their results indicate that technology-mediated instruction enhances learners' autonomy and responsibility for learning outcomes, although without explicitly integrating neurodidactic mechanisms.

On the whole, Kyrgyz scholars support the idea that incorporation of neuroeducation within higher education fosters students' cognitive independence and creativity. Specifically, Volkotrubova et al. [37] underscore that to cultivate cognitive independence, it is imperative to establish conditions that encourage active student participation in learning and the pursuit of new knowledge. They highlight the significance of motivation, self-organization, and intentional development of students' creative capacities. Likewise, Motukeeva et al. [38] adopt a similar stance, illustrating that a neuro-educational environment invigorates students' creative thinking. Creativity in this study is conceptualized as a multidimensional construct encompassing fluency, flexibility, and originality, operationalized through Torrance and Mednick indicators.

Despite the growing body of literature confirming the pedagogical potential of neuroeducation, current research often demonstrates several methodological and conceptual limitations. First, many studies prioritise descriptive accounts of individual techniques (e.g., gamification, dual coding, spaced repetition) without examining their cumulative or interactive effects within a systemic instructional model. This leads to fragmented evidence and prevents drawing conclusions about the holistic influence of neurodidactic frameworks on student development. Second, a substantial proportion of publications rely on short-term interventions or small convenience samples, which restricts the generalisability of their findings and raises questions about the durability and scalability of observed effects. Third, creativity-related outcomes are frequently measured using heterogeneous tools, making cross-study comparison difficult and contributing to inconsistent empirical trends.

Another critical limitation of existing scholarship is the insufficient integration of neurobiological data. Although many authors invoke neuroscientific principles, relatively few studies incorporate objective neural indicators (such as EEG or fMRI) or even triangulate behavioural and neurocognitive evidence. As a result, the mechanisms through which neurodidactic strategies influence motivational, executive, and creative processes remain largely theoretical rather than empirically validated. Finally, only a limited number of studies address the role of teacher readiness, metacognitive accuracy, or institutional constraints, despite these factors being crucial mediators of instructional effectiveness. Collectively, these gaps underscore the need for comprehensive, empirically grounded models—such as the one proposed in this study—that integrate multiple neurodidactic mechanisms and evaluate their impact in authentic educational settings using multimodal evidence.

3. RESEARCH METHOD

The intervention was implemented through technology-enhanced learning environments utilizing digital platforms, online assessments, and multimedia tools within a quasi-experimental pre-test–post-test control group design. Both the experimental (EG) and control (CG) groups completed identical diagnostic assessments at two measurement points: a pre-test in September 2024 and a post-test in May 2025, assessing creativity (Johnson, Mednick, Torrance) and cognitive independence (MSLQ). This design enabled verification of baseline equivalence and evaluation of intervention effectiveness. The Mann–Whitney U-test confirmed no statistically significant differences between the EG and CG at the pre-test stage ($p > .05$), indicating comparable baseline conditions.

The intervention was implemented through technology-enhanced learning environments utilizing digital platforms, online assessments, and multimedia tools. A quasi-experimental pre-test/post-test control group design was applied. Both the experimental group (EG) and the control group (CG) completed identical diagnostic procedures at two measurement points:

The investigation into the effects of integrating neuroeducational mechanisms on the enhancement of cognitive independence and creativity among students was conducted within the framework of the system-activity approach and the principles of pedagogical experimentation. During the assessment stage, a comprehensive survey of educators was executed in their authentic educational environment, with the objective of determining their preparedness for the implementation of neurodidactic methodologies as part of the pedagogical experiment's formative stage. This stage was fundamentally supportive, aimed at establishing conditions supporting the primary objective of the research, namely to facilitate qualitative transformations in student learning.

The formative stage of the pedagogical experiment sought to reevaluate the content of education and establish effective pedagogical conditions for fostering cognitive independence and creativity among students. The focal point of influence during this stage was primarily the students themselves, while the training of educators was regarded as an essential resource for actualizing novel approaches within the student learning environment. Special emphasis was placed on familiarizing teachers with the foundational principles of neuroeducation. The knowledge acquired by educators was seamlessly integrated into the educational process, not only within the framework of classroom instruction but also in extracurricular activities. The developed model of teacher training, grounded in neurodidactic principles, encompasses the utilization of diverse methods and strategies aimed at enhancing students' cognitive abilities, taking into account sensory perception, individual learning styles, as well as mechanisms for the consolidation of knowledge in long-term memory.

The neurodidactic intervention was implemented through a set of technology-enhanced learning tools, including learning management systems (LMS), online quizzes, multimedia presentations, and interactive digital simulations. These platforms supported spaced repetition, retrieval practice, and dual coding by enabling repeated access to learning materials, immediate feedback, and multimodal content delivery. Similar approaches have been identified as effective mechanisms for supporting self-regulated learning and cognitive autonomy in digital environments [41]-[43].

All pedagogical interventions implemented during the formative stage were designed to transform the students' learning experiences and ensure positive developments in their levels of autonomy, self-regulation, and creative thinking. Table 1 presents a generalized overview of the key neurodidactic methods and techniques employed throughout the formative stage of the study. Each of these methodologies was intended to promote the growth of cognitive independence and creativity.

Table 1. Characteristics of neurodidactic methods used during the formative stage of the experiment

No.	Name of the method	Fundamental concept and operational mechanism	Frequency of use	Form of implementation	Expected cognitive effect
1	Gamification	Use of game elements to simulate situations that stimulate learning	1 time/week	Intellectual games, quests, online quizzes	Increased motivation, engagement in learning
2	Frame-based technologies	Visual-auditory environment with adaptive learning blocks	2 times/month	Presentations, video lectures, interactive simulations	Facilitating the perception of complex material
3	Group discussions, debates	Discussion of problems, substantiation of opinions, exchange of arguments	Weekly	Seminars, case studies	Development of critical thinking, language skills
4	Alternating practice	Switching between topics to strengthen neural connections in long-term memory	1-2 times/week	Tasks on various topics within one session	Versatility of knowledge, improvement of long-term memorization
5	Search practice	Reproduction of the studied material without prompts or notes	After each module	Self-testing, open questions	Strengthening long-term memory, self-control
6	Interval repetitions	Repetition of the material with increasing time intervals	3–4 times per course	Online platforms, mind maps	Creating lasting traces in memory

7	Dual-coding learning	Combining text and images/videos to form dual traces in memory	Regularly	Lectures with visual inserts, graphics, videos	Synchronizing verbal and visual thinking
8	Elaboration	Explaining new information using examples from previous experience	Throughout all classes	Practical examples, mini-discussions	Fortifying the connections between knowledge and profound comprehension.

** Author's own development*

The application of these neurodidactic methodologies during the formative stage of the study facilitated the establishment of a dynamic and adaptable educational environment, primarily oriented towards addressing students' cognitive needs, cultivating their capacity for autonomous learning, and promoting unconventional thinking. The integration of these approaches within the educational framework significantly contributed to enhanced attention, elevated levels of comprehension, and the development of competencies for enduring retention and proficient utilization of information. This educational paradigm holds considerable promise for higher education against the backdrop of the ongoing digital transformation within the learning landscape.

During the evaluative stage of the study, to substantiate the efficacy of the proposed model in both the EG and the CG, independent experts conducted a thorough analysis of the alterations in students' cognitive development, particularly focusing on their cognitive autonomy and creativity by the end of the third academic year in both groups.

Thus, all stages of the study are logically interconnected: the initial awareness level of educators served as the foundational point, from which, through their training and the proactive dissemination of innovative methodologies within the student environment, substantial positive transformations in students' outcomes were realized.

Additionally, following the completion of the professional development program centered on the integration of neuroeducational technologies into the pedagogical process, a survey was administered to educators to evaluate which specific mechanisms for fostering cognitive independence and creativity among students were implemented in practice, as well as to ascertain these instruments' subjective effectiveness.

3.1. Research Methods

The pedagogical experiment aimed to evaluate the effectiveness of the neurodidactic model and was conducted in three stages: a pre-test (September 2024), an eight-month formative intervention (October 2024–April 2025), and a post-test (May 2025). During the intervention, the experimental group engaged in cognitively grounded strategies, including spaced repetition, dual coding, retrieval practice, and gamification. Psychometric instruments were used to assess creativity (Johnson, Mednick, Torrance) and cognitive independence (MSLQ) before and after the intervention. Teacher surveys examined educators' readiness to implement neurodidactic approaches. Quantitative data were analyzed using descriptive statistics and inferential tests, including the Mann–Whitney U-test, Wilcoxon signed-rank test, and Spearman's rank correlation coefficient.

3.2. Study Sample

A total of 294 third-year students from three higher education institutions in Ukraine and Kyrgyzstan participated in the study. Using cluster sampling, participants were evenly assigned to a control group (CG) and an experimental group (EG), each consisting of 147 students. The experimental group was taught using a neurodidactic model integrating interactive, creative, and project-based strategies, while the control group followed traditional instruction. The intervention aimed to enhance cognitive independence and creativity and was supported by nine participating educators. The sample size ensured sufficient statistical power for reliable intergroup comparisons.

3.3. Research Tools

The following instruments were used to assess the levels of creativity and cognitive independence: D. Johnson's Creativity Questionnaire (20 minutes); S. Mednick's Remote Associates Test (40 minutes); E. Torrance's subtest "Incomplete Figures" - an evaluation of non-verbal creativity (12 minutes); E. Torrance's subtest "Unusual Use" - an evaluation of verbal creativity (10 minutes); D. Marlowe - D. Crown's Approval Motivation Scale (5 minutes); and the Motivated Strategies for Learning Questionnaire (MSLQ) - utilized to assess students' cognitive independence (60 minutes). The Motivated Strategies for Learning Questionnaire (MSLQ) was adopted in its original validated form from Pintrich et al. and has been widely used to assess motivational, cognitive, and self-regulatory components of learning in higher education contexts. The creativity assessment tools developed by D. Johnson, S. Mednick, and E. Torrance were also employed in their original standardized versions without modification. According to previous validation studies, the internal consistency of the MSLQ scales is reported to be acceptable to high, with Cronbach's alpha values typically ranging from $\alpha = 0.70$ to 0.90. In the present study, the instrument was used based on its established psychometric properties reported in the literature.

The author's questionnaire was administered to evaluate educators, encompassing knowledge of neuropsychological foundations (attention, memory, motivation); comprehension of neurodidactic principles; and proficiency in the application of cognitively effective strategies (such as dual coding and retrieval practice).

The analysis of the results was conducted using the IBM SPSS Statistics Version 21 software. Given the deviations from normal data distribution, non-parametric criteria were employed: the Mann-Whitney U-test for the analysis of independent samples and Spearman's rank correlation coefficient (rs) for examining the

4. RESULTS AND DISCUSSION

Figure 1 illustrates the distribution of the outcomes from the educators' assessment, quantified by the percentage of correct responses, in order to ascertain the degree of preparedness among teachers for the implementation of neurodidactic methodologies.

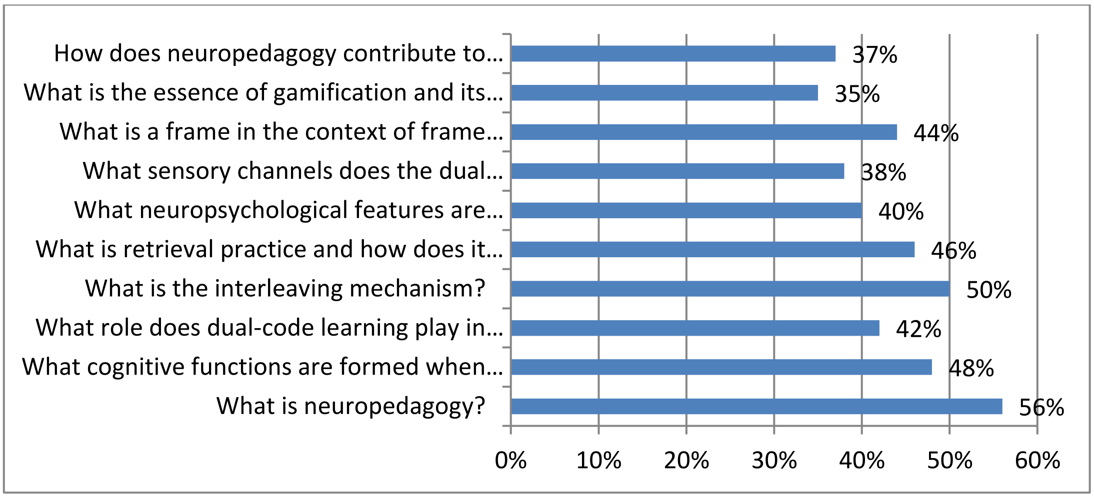

Figure 1. Percentage of the teachers' correct answers to the questions of the test on neuro-pedagogy
* Author's own development

The graph illustrates the percentage of correct responses provided by educators to each of the ten test inquiries. The topics that were least comprehended include: gamification in education (35%); the impact of neuro-pedagogy on long-term memory retention (37%); and dual coding alongside sensory channels (38%). These findings suggest a significant deficit in the practical understanding of the mechanisms underpinning neuro-education. Educators exhibit a greater proficiency in grasping overarching concepts, such as the definition of neuroeducation (56%), yet they display a lack of familiarity with the intricate processes involved in cognitive learning.

Table 2 presents the summarized test outcomes in the form of scores, percentages of the maximum possible value, and the corresponding levels of knowledge.

Table 2. Test results for teachers' awareness of neuroeducation principles

Teacher	Max. points	Points scored	% of maximum	Knowledge level
Teacher A	20	8	40.0%	Low
Teacher B	20	9	45.0%	Low
Teacher C	20	7	35.0%	Low
Teacher D	20	10	50.0%	Low
Teacher E	20	6	30.0%	Low
Teacher F	20	11	55.0%	Low
Teacher G	20	13	65.0%	Average
Teacher H	20	12	60.0%	Average
Teacher I	20	14	70.0%	Average

** Author's own development * Elucidation: low level: less than 60% correct answers; average level: from 60% to 79%; high level: exceeding 80% (there was none in this sample).*

It should be noted that the modest outcomes achieved by educators during the initial phase were anticipated, as the majority had not previously undergone systematic training in neuroeducation. Engaging with neurodidactics necessitates not only an acquaintance with terminology but also a thorough understanding of cognitive mechanisms, which inherently requires time. Consequently, the experimental design incorporated an initial training for teachers, structured as an innovative professional development program spanning one year, which was conducted concurrently with the gradual integration of the acquired knowledge into the educational framework. Thus, the initial phase established a baseline, that is the existing level of knowledge that warranted enhancement.

In the course of exploring the students' creativity, a favorable environment was cultivated, facilitating the recognition of these abilities among the participants. At the same time, dialogues concerning the content orientation of the employed methods were deliberately avoided, allowing students to articulate their thoughts in a distinctive manner through activities that unusual for them.

To verify the initial equivalence of the experimental (EG) and control (CG) groups, a comparative analysis of pre-test indicators was performed. Table 3 presents the baseline scores for creativity and cognitive independence.

Table 3. Pre-test results for creativity and cognitive independence

Indicator	EG (M ± m)	CG (M ± m)	U-test	p-value
Johnson expert evaluation	22.10 ± 0.71	21.90 ± 0.75	10612.0	.742
Torrance fluency	10.20 ± 0.92	10.00 ± 0.89	10701.0	.693
Torrance flexibility	7.40 ± 0.52	7.30 ± 0.54	10822.5	.611
Originality	1.12 ± 0.28	1.10 ± 0.27	10855.0	.598
Motivational criterion	3.35 ± 0.05	3.31 ± 0.05	10822.5	.611
Operational criterion	3.21 ± 0.06	3.18 ± 0.07	10931.0	.563
Volitional criterion	3.39 ± 0.04	3.36 ± 0.04	11002.5	.540

** Author's own development*

These results directly address Objective 2, which required establishing baseline comparability of cognitive autonomy and creativity levels between groups. The absence of significant differences confirms the preliminary assumption embedded in Hypothesis H1, namely that the experimental and control groups were initially comparable at the pre-test stage ($p > .05$). This provides a valid foundation for evaluating the true effect of the neurodidactic intervention.

The average values of verbal and non-verbal creativity indicators for the two groups examined, obtained from the study, are presented in Table 4.

Table 4. Average values of creativity indicators obtained during the study

Creativity indicators	EG			CG		
Expert assessment of creativity in the D. Johnson questionnaire	26,32	0,57	3,33	22,60	0,92	4,62
Self-assessment of creativity in the D. Johnson questionnaire	28,76	0,74	4,26	28,92	0,97	4,83
Index of uniqueness in the S. Mednick test	4,56	0,51	2,95	4,64	0,66	3,32
Index of originality in the S. Mednick test	0,49	0,03	0,15	0,47	0,03	0,15
Number of responses in the S. Mednick test	19,38	0,39	2,24	18,64	0,63	3,13
Index of uniqueness in the E. Torrance subtest "Incomplete figures"	2,91	0,17	0,97	2,88	0,19	0,93
The originality index in the E. Torrance subtest "Incomplete figures"	0,79	0,02	0,10	0,77	0,02	0,11
Fluency in the E. Torrance subtest "Unusual use"	14,88	1,13	6,60	9,72	0,93	4,64
Flexibility in the E. Torrance subtest "Unusual use"	9,44	0,55	3,23	7,16	0,59	2,93
Originality in the E. Torrance subtest "Unusual use"	1,59	0,34	1,97	1,04	0,26	1,27

** Author's own development*

The average expert evaluation of students' creative manifestations, obtained from the D. Johnson creativity questionnaire, yielded a score of 26.32±0.57 points in the EG, whereas the CG achieved a score of 22.60±0.92 points. The disparities between the groups in this metric are statistically significant ($p<0.05$, Mann–Whitney criterion), signifying a favorable influence of neuroeducation integration on the enhancement of students' creative potential. That being said, the self-assessment levels of creativity in both groups remained elevated:

28.76±0.74 points in the EG and 28.92±0.97 points in the CG. These findings suggest a tendency among students to overestimate their own creativity, as their self-evaluations surpass expert assessments in both cohorts. A statistically significant positive correlation was identified between self-assessment and expert evaluation of creativity in both groups: in the EG, rs = 0.374, $p<0.05$, and in the CG, rs = 0.397, $p<0.05$. The uniqueness index, a crucial metric for evaluating creative potential within this assessment, registered at 4.56±0.51 points for the EG and 4.64±0.66 points for the CG.

Although the difference between these indicators is statistically insignificant, the overall level of verbal creativity among students in both groups can be regarded as quite high, as only 20–40% of respondents from the reference sample achieved superior results.

In E. Torrance's subtest "Incomplete figures", the indices of non-verbal creativity were examined, specifically focusing on the uniqueness and originality indices. In the EG, these values were recorded at 2.91±0.17 and 0.79±0.02 points, respectively, while in the CG, they were 2.88±0.19 and 0.77±0.02 points. The comparison with percentile scales indicates that fewer than 20% of individuals in the EG exhibit higher results, reflecting a high level of non-verbal creativity in both groups.

Particular attention should be directed towards the results of E. Torrance's subtest "Unusual use". Statistically significant differences were discerned between the EG and CG regarding fluency and flexibility, both with $p<0.01$ (Mann-Whitney criterion). Participants in the EG demonstrated higher results: fluency at 14.88±1.13 points (in contrast to 9.72±0.93 in the CG) and flexibility at 9.44±0.55 points (compared to 7.16±0.59 in the CG). Fluency in this context signifies the ability to generate a substantial number of verbal ideas, while flexibility denotes the capacity to approach problems from diverse perspectives and employ various problem-solving strategies.

In terms of responses' originality in the same subtest, the scores were also elevated in the EG (1.59±0.34 points) compared to the CG (1.04±0.26 points). These findings confirm Hypothesis H1, demonstrating that the neurodidactic intervention resulted in significantly higher creativity indicators in the experimental group compared with traditional instruction (Mann–Whitney U-test, $p < .05$). This suggests that the integration of neuroeducational strategies positively influenced the development of creative thinking. These post-test data fully correspond to Objective 2, which required analysing and comparing the levels of creativity after the formative stage. The statistically significant intergroup differences demonstrated in Table 4 provide direct confirmation of Hypothesis H1, showing that the intervention produced measurable gains in creative performance.

To assess the efficacy of the proposed neurodidactic model, a comparative analysis of the cognitive independence levels of students in the EG and CG was conducted across three criteria: motivational, content-operational, and volitional (Table 5).

Table 5. Results of evaluating the students' cognitive independence according to the criteria

Creativity indicators	EG			CG		
Motivational (instrumental educational values)	4,1	0,04	0,48	3,4	0,06	0,58
Content-operational (development of general intellectual skills, GIS)	3,9	0,05	0,50	3,2	0,07	0,62
Voluntary (corresponds to the MSLQ component)	4,2	0,03	0,45	3,3	0,06	0,57

** Author's own development*

The average value pertaining to the motivational criterion (instrumental educational values) among students was recorded at 4.1±0.04 points for the experimental group, whereas the control group scored 3.4±0.06 points. The disparities observed between the groups are statistically significant ($p<0.05$, Mann-Whitney U test), underscoring the affirmative influence of the implemented neurodidactic model on the cultivation of conscious educational motivation and achievement orientation.

In terms of the content-operational criterion (level of development of general intellectual skills), students in the EG demonstrated superior performance with scores of 3.9±0.05 points, compared to 3.2±0.07 points in the CG group. This highlights an enhancement in the EG students' capabilities to plan, analyze, argue, and independently resolve educational challenges, which is directly correlated with the proactive application of interactive and project-based methodologies within the educational framework.

Regarding the voluntary criterion, which corresponds to the assessment of self-regulation levels according to the MSLQ scale, a pronounced advantage for EG students was also recorded - 4.2±0.03 points, in contrast to 3.3±0.06 points in the CG group. This signifies a heightened capacity to navigate difficulties, maintain goal orientation, and exert internal control over educational endeavors among participants who engaged with the updated program.

Statistically significant positive correlations were established between individual criteria of cognitive independence and the level of academic success in the EG group (Spearman's correlation coefficients rs ranging from 0.29 to 0.34, $p<0.05$), whereas in the CG group, such correlational dependencies are either absent or appear at a lower level. These correlation results provide direct empirical confirmation of Hypothesis H2, which predicts that higher levels of cognitive independence are positively associated with better academic performance.

Thus, the findings corroborate the efficacy of integrating neuroeducation into higher education as a strategic instrument for the intentional cultivation of essential components of cognitive independence among students, encompassing motivational engagement, operational autonomy, and volitional regulation of learning. The results presented in Table 5 directly address Objective 2, which involved assessing the levels of cognitive independence after the intervention. The significant differences in motivational, operational, and volitional components between EG and CG confirm Hypothesis H1, demonstrating that the implemented neurodidactic model effectively increased students' cognitive autonomy.

To assess changes within the experimental group across the academic year, the Wilcoxon signed-rank test was applied (Table 6).

Table 6. Wilcoxon test results for the experimental group (pre-test → post-test)

Indicator	Z-value	p-value
Motivational component	-8.12	< .001
Operational component	-7.94	< .001
Volitional component	-8.25	< .001
Torrance fluency	-7.88	< .001
Torrance flexibility	-7.44	< .001
Torrance originality	-6.91	< .001

* *Author's own development*

All indicators demonstrated statistically significant improvements within the EG ($p < .01$), confirming the intra-group component of Hypothesis H1, which predicts significant improvements within the experimental group after the intervention. These intra-group results fulfil Objective 2 by demonstrating positive dynamics across all measured components within the experimental group. As shown in Table 6, the significant pre–post gains further confirm Hypothesis H1, demonstrating consistent pre–post improvement within the experimental group.

Table 7 delineates the average scores from teachers' responses to each of the ten inquiries following the completion of the course. Each question reflects the extent of practical implementation within a specific neurodidactic mechanism or an evaluation of its impact on the quality of the educational process. The acquired data reflect a high subjective effectiveness of the program. The most elevated ratings (4.56) pertain to teachers' confidence and the course overall influence. The methodologies of dual coding, spaced repetition, and gamification received slightly lower ratings (ranging from 3.1 to 3.5), indicating a necessity for further methodological support to facilitate their effective implementation.

Table 7. Results of the post-course survey of teachers

Assertion	Teacher A	Teacher B	Teacher C	Teacher D	Teacher E	Teacher F	Teacher G	Teacher H	Teacher I
1. Which part of the course have you applied in your practice?	4	5	3	4	3	4	5	4	4
2. How often have you used the gamification method?	3	4	2	3	2	4	4	3	3
3. How effective was the interleaving method in working with students?	4	4	3	4	2	3	5	4	4
4. Have you used spaced repetition to consolidate knowledge?	2	3	2	4	3	4	5	3	3
5. How successfully was dual coding applied in teaching?	3	4	2	4	3	4	5	4	3
6. How much did students' cognitive independence improve?	4	4	3	5	3	4	5	4	4
7. How much did students' creativity improve?	4	4	3	4	3	5	5	4	3
8. How much has your confidence in using neurodidactics increased?	5	5	4	5	4	5	5	4	4
9. How much will your future teaching practice change?	4	4	3	5	3	5	4	4	4
10. Overall assessment of the course's impact on the quality of the educational process	5	5	4	5	4	5	5	4	4

* *Author's own development*

The results of the individual survey of educators reveal an overarching positive perception and integration of neurodidactic methodologies into pedagogical practice subsequent to the completion of the course. Educators B, D, F, and G consistently exhibit the highest scores (5), signifying considerable motivation and effective application of the knowledge acquired. However, the responses from certain educators (for example, C and E) reflect a moderate level of implementation of specific techniques, in particular gamification, spaced repetition, and dual coding. This observation may suggest a necessity for supplementary methodological support, supervision, or mentoring to consolidate and expand their practical toolkit. The data in Table 7 address Objective 3, which required evaluating educators' readiness and practical use of neurodidactic mechanisms. The reported improvements in confidence, perceived effectiveness, and frequency of implementation indicate that teachers became more prepared to incorporate neurodidactic strategies into their daily practice. These findings highlight the supportive instructional environment created during the experiment and help explain the favourable conditions under which students' cognitive changes occurred.

A deeper analysis of the survey responses enables us to draw explicit conclusions regarding the relative effectiveness of individual neurodidactic mechanisms. According to teachers' evaluations, the most consistently effective strategies were interleaving, gamification, and dual coding — all three were applied with higher frequency and received stable scores indicating noticeable improvements in student engagement and cognitive autonomy. These methods appear to be more intuitively understood by educators and easier to integrate into existing lesson structures. In contrast, spaced repetition and retrieval practice were used less systematically, which may be attributed to several factors: insufficient methodological training, the perception that these techniques require additional preparation time, and the absence of ready-made tools for their seamless integration into course materials. Teachers also noted difficulties in maintaining regular cycles of repetition within rigid academic schedules. Thus, while all mechanisms demonstrated pedagogical value, the effectiveness of each depended on the level of teacher preparedness, the complexity of implementation, and the degree to which the method aligned with established teaching routines. This finding reinforces the need for extended methodological support to ensure balanced application of all neurodidactic strategies, rather than selective reliance on the most accessible ones.

Therefore, the program has demonstrated efficacy in cultivating readiness for the implementation of neuroeducational strategies; however, to achieve enduring and systemic transformation, it is advisable to provide ongoing professional support for educators through the facilitation of practical seminars or individualized methodological tutorials.

We share the conclusions of Williams et al. [44], which revealed that, despite their interest in the subject, the majority of educators exhibited a low level of awareness as regards fundamental neuroscience principles: fewer than 25% had received pertinent training. In our investigation, merely 3 out of 9 educators demonstrated an average level of understanding (60–70% correct responses), while the remainder scored significantly lower (30–55%). This finding corroborates the global trend, which is also evident in the research conducted by Caballero and Llorent [45], where 82% of participants supported neuromyths.

Mello-Carpes et al. [46] illustrated that, notwithstanding their lack of knowledge, 100% of teachers expressed a willingness to adopt innovative approaches. Likewise, in our study, following the training, 8 out of 9 educators highly valued the impact of the course and their confidence in employing the methods (4.56 points out of 5). Conversely, the findings of Şişman et al. [47], which indicate that teachers with greater knowledge more frequently supported neuromyths, give reason to a careful evaluation of the information quality. This underscores the necessity to cultivate critical thinking alongside the acquisition of knowledge.

The observed improvements in creativity indicators are consistent with previous findings on the role of digital tools in fostering creative thinking. Wang and Li [48] demonstrated that technology-supported pedagogical models create optimal conditions for creative expression, particularly in fluency and flexibility. Similarly, Cojocariu et al. [49] emphasize that digital creativity in higher education is closely associated with learner autonomy, motivation, and cognitive flexibility. The present findings extend these results by demonstrating that creativity gains are maximized when digital tools are systematically integrated with neurodidactic principles rather than used as isolated instructional enhancements. The results of the experiment indicate a notable enhancement in creativity within the experimental group. For instance, fluency according to the Torrance test was recorded at 14.88 points (in contrast to 9.72 in the control group, CG), flexibility at 9.44 (compared to 7.16), and originality at 1.59 (versus 1.04). These results substantiate the findings of Rahimi and Shute [50], which reported a learning effect of $d = 0.45$. We agree with Zaremohzzabieh et al. [51] that educational technologies exert a moderate influence on creativity ($g \approx 0.60$), particularly concerning fluency, flexibility, and originality. We also substantiate the assertion regarding the efficacy of interactive methods. However, as noted in the work of Rahimi and Shute [29], individual indices exhibited uneven changes (only flexibility demonstrated improvement), which partially aligns with our findings: specifically, the uniqueness index in the Mednik test was nearly identical for both groups (4.56 in EG, 4.64 in CG). We find further validation in the research of Zhan et al. [52], which indicated that the application of associative methods fosters creativity. We hold that the effective implementation of analogous neurodidactic methods yields comparable results.

Despite the overall positive dynamics, certain creativity indicators remained weak or showed minimal change, which reveals structural limitations of the applied neurodidactic model. In particular, the stability of the Mednick uniqueness index and the negligible differences in several non-verbal creativity measures suggest that associative and divergent thinking may require longer interventions or more specialized techniques than those included in our program. These results imply that while the model effectively enhances fluency, flexibility, and originality in task-oriented contexts, it may be less sensitive to deeper cognitive processes responsible for remote association generation. Another important aspect concerns the discrepancy between students' high self-assessments and more moderate expert evaluations. This gap likely reflects the well-documented phenomenon of metacognitive overestimation among learners, especially in creative domains where subjective confidence does not always correlate with actual performance. It also suggests that the model, although beneficial for cognitive autonomy, may not sufficiently develop students' reflective accuracy or metacognitive calibration. Therefore, the findings highlight both the strengths and constraints of the neurodidactic model, indicating the necessity for extended, targeted interventions and explicit metacognitive training to support more stable gains across all dimensions of creativity.

The present study recorded a statistically significant enhancement across all three criteria, namely motivational, operational, and volitional: for instance, the volitional criterion achieved a score of 4.2 for EG compared to 3.3 for CG. This aligns with Cazan's [53] findings, demonstrating that training in metacognitive strategies over the course of a year fosters sustained self-regulation development. We also concur with Galal et al. [54] that self-efficacy positively influences academic achievement, whereas emotional instability (test anxiety) detrimentally impacts performance. Our data reveal a positive correlation between self-regulation and academic success ($r_s = 0.29$–0.34, $p < 0.05$). However, as Privitera [55] observes, the long-term effects of such programs require further investigation. Our findings contribute to the empirical foundation supporting the efficacy of neurodidactics in cultivating student autonomy.

A deeper interpretation of the obtained results allows us to specify how particular neurodidactic mechanisms generated improvements in motivational, operational and volitional components of cognitive independence. Gamification increased the motivational component by activating reward-based learning, enhancing dopamine-driven engagement, and fostering students' achievement orientation through immediate feedback and progress tracking. Spaced repetition and retrieval practice, grounded in the consolidation dynamics of long-term memory, directly strengthened the volitional component, as repeated self-testing required sustained effort, self-monitoring, and persistence, thereby stimulating executive control and self-regulation. Dual coding and elaboration techniques contributed primarily to the operational component, as the integration of verbal and visual information enhanced analytical processing, planning, and cognitive flexibility, enabling students to construct more stable mental models and independently transfer knowledge across tasks. Finally, interleaving and alternating practice strengthened both operational and volitional aspects by forcing students to switch between tasks, inhibit habitual responses, and develop adaptive problem-solving strategies. Thus, each of the implemented neurodidactic mechanisms had a differentiated yet complementary effect, collectively contributing to the systematic gains observed in motivational readiness, intellectual autonomy, and self-regulatory behavior.

Meta-analytical evidence suggests that technology-enhanced learning produces meaningful educational effects only when technologies are aligned with pedagogically purposeful learning activities. Sailer et al. [56] conclude that digital tools alone do not improve learning outcomes unless they actively scaffold cognitive processes and learner engagement. The present study confirms this conclusion by showing that neurodidactic mechanisms embedded within structured TEL activities result in statistically significant improvements in cognitive independence and creativity.

The findings of this study provide practical implications for the design of educational technology and technology-enhanced learning environments. In line with recent research on inclusive and culturally responsive digital assessment, the proposed neurodidactic model demonstrates how technology-based tools can be structured to support cognitive autonomy, creativity, and equitable learning outcomes. Furthermore, advances in educational neuroscience and artificial intelligence indicate that adaptive digital systems can further enhance personalization and self-regulation [57]-[60]. Integrating neurodidactic principles into TEL design enables the development of learning environments that are not only technologically advanced but also cognitively optimized, providing a foundation for sustainable innovation in higher education.

The scientific novelty of this research lies in the development and empirical validation of an integrated neurodidactic model, which differs fundamentally from existing approaches described in the literature. Previous studies typically examine isolated neuroeducational techniques (e.g., dual coding, spaced repetition, gamification, interleaving) or explore teachers' attitudes toward neuroscience without testing a systemic instructional model. In contrast, this study is the first to combine four core neurocognitive mechanisms into a unified multi-component pedagogical system implemented over eight months in real learning environments across three higher education institutions.

From the perspective of the Educational Technology field, this study contributes an empirically validated framework demonstrating how neurodidactic principles can be systematically embedded into technology-enhanced learning design to support cognitive autonomy and creativity.

For the first time, the study demonstrates statistically significant simultaneous improvements in all three components of cognitive independence (motivational, operational, volitional) and in key creativity indicators (fluency, flexibility, originality), validated through a quasi-experimental design using Mann–Whitney and Wilcoxon tests. Additionally, the research provides novel empirical evidence of a positive correlation between cognitive independence components and academic achievement (rs = .29–.34), a relationship insufficiently addressed in prior neuroeducation studies. A further innovative contribution is the evaluation of teachers' neuroeducational readiness and the validation of a year-long professional development program as an effective mechanism for sustaining neurodidactic implementation.

Together, these findings position the proposed model as a conceptually and empirically distinct contribution to neuroeducation research, extending current theoretical frameworks and offering a reproducible system for higher education. Several limitations should be acknowledged. First, although the sample size ensured sufficient statistical power, the study included only third-year students from three institutions, which may limit the generalizability of the findings. Second, the assessment relied on self-report questionnaires and expert evaluations, which may introduce subjective bias. Third, the experiment lasted eight months; therefore, long-term effects of the neurodidactic model remain unknown. Future research should examine longitudinal dynamics, extend the model to other educational contexts, and incorporate objective neurocognitive measurements.

Additionally, the composition of the sample introduces several important constraints. Although the total number of participants ensured sufficient statistical power, the selection was limited to third-year students in humanitarian and pedagogical fields from only three institutions. This restricts the representativeness of the findings and prevents broader extrapolation to other academic years, disciplines or educational systems. The duration of the intervention — eight months — also imposes limitations, as certain cognitive and creative outcomes, particularly associative originality and metacognitive calibration, typically require longer exposure to instructional innovation. Therefore, the study may not fully capture delayed or cumulative effects of neurodidactic strategies.

Another limitation concerns the measurement instruments. The study relied primarily on psychometric questionnaires and creativity tests (Johnson, Mednick, Torrance), which, while validated, focus on behavioural and self-report indicators. These tools cannot fully reflect underlying neurocognitive processes, nor do they capture fine-grained fluctuations in executive control, emotional states or attentional regulation. The absence of neurophysiological measurements (such as EEG, fNIRS, or eye-tracking) prevented the authors from verifying whether changes in cognitive independence were accompanied by measurable alterations in neural activation patterns. Including multimodal data in future research would considerably strengthen the explanatory power and allow triangulation of behavioural and neurobiological evidence.

5. CONCLUSION

The results of the pedagogical experiment demonstrated a positive effect of the neurodidactic model on students' cognitive autonomy and creativity. Statistically significant improvements were observed in the experimental group (n = 147), including higher scores in creativity (expert evaluation: 26.32 vs. 22.60), motivational (4.1 vs. 3.4) and volitional components (4.2 vs. 3.3), as well as in fluency (14.88 vs. 9.72), flexibility (9.44 vs. 7.16), and originality (1.59 vs. 1.04) compared to the control group. These findings confirm the effectiveness of the implemented neurodidactic model integrating dual coding, spaced repetition, retrieval practice, and gamification. The study contributes novel empirical evidence by validating a comprehensive neurodidactic framework that systematically enhances motivational, operational, and volitional aspects of cognitive autonomy in higher education. The model also demonstrated strong practical value, as reflected in the successful implementation of a professional development program for educators, which received a mean effectiveness rating of 4.56 out of 5. Statistical analysis confirmed both research hypotheses: significant improvements in cognitive independence and creativity ($p < .05$), as well as positive correlations between cognitive autonomy and academic performance (rs = .29–.34, $p < .05$). These findings support the scalability of the proposed neurodidactic model for broader application in higher education contexts. Future research is recommended to examine the long-term impact and cross-disciplinary applicability of the neurodidactic model across diverse educational contexts and learner populations, including longitudinal and mixed-methods approaches.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the preparation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried **out** entirely by the authors without the assistance of AI-based technologies.

REFERENCES

[1] C. J. Kazanjian and C. A. Rossatto, "Critical culturally relevant synergism in higher education: Equitable educational experiences through neuroscientific curricula," in *Teaching and Learning for Social Justice and Equity in Higher Education*, S. R. Shapiro, Ed. Cham, Switzerland: Springer, 2020, pp. 199–218, doi: 10.1007/978-3-030-44939-1_11.

[2] S. Alkhassawneh and H. Al Sharif, "Perspectives of brain research (educational neuroscience) on the design and implementation of teaching strategies in educational technology," *J. Neuroeducation*, vol. 5, no. 2, pp. 14–24, 2025, doi: 10.1344/joned.v5i2.47695.

[3] M. M. Jackson and A. A. O. Alfaki, "Advancing sustainable development goal 6: Innovations, challenges, and pathways for clean water and sanitation," *Integr. Sci. Educ. J.*, vol. 6, no. 3, pp. 224–231, 2025, doi: 10.37251/isej.v6i3.2114.

[4] A. Nisah, Q.-U. Jatoi, and G. Tleumuratov, "Procedure text writing skills using silent film media in grade VII students of state junior high school 10 South Tangerang," *J. Lang. Lit. Educ. Res.*, vol. 2, no. 1, pp. 1–9, 2025, doi: 10.37251/jolle.v2i1.1574.

[5] M. M. Hardiman and R. M. JohnBull, "Exploring changes in teacher self-efficacy through neuroeducation professional development," *The Teacher Educator*, vol. 59, no. 2, pp. 175–195, 2023, doi: 10.1080/08878730.2023.2214555.

[6] F. Fetmirwati, L. G. Franco, and M. T. G. Tadena, "Exploring the guided inquiry learning model in biology practicum: Its impact on students' scientific attitudes and cognitive knowledge," *J. Acad. Biol. Biol. Educ.*, vol. 2, no. 1, pp. 26–34, 2025, doi: 10.37251/jouabe.v2i1.1642.

[7] A. A. Kambuna, Q.-U. Jatoi, and M. Jlassi, "Language function of selected cosmetics advertisement in online media," *J. Lang. Lit. Educ. Res.*, vol. 2, no. 1, pp. 71–84, 2025, doi: 10.37251/jolle.v2i1.1836.

[8] L. Elouafi, V. Ait Abdellah, and M. Janah, "Progress report in neuroscience and education: Experiment of four neuropedagogical methods," *Educ. Sci.*, vol. 11, no. 7, Art. no. 373, 2021, doi: 10.3390/educsci11080373.

[9] A. Ghalby and L. A. Malaluan, "Safety first? Exploring occupational health and safety knowledge levels of chemistry education students in laboratory settings," *J. Chem. Learn. Innov.*, vol. 2, no. 1, pp. 12–22, 2025, doi: 10.37251/jocli.v2i1.1562.

[10] J. A. Barán Vinces, F. F. Ponce Vera, and J. M. Zambrano Acosta, "Neuroeducation, mediation applied to comprehensive human development from a university context," *Rev. Filosofía*, vol. 38, no. 97, pp. 428–439, 2022, doi: 10.5281/zenodo.4891872.

[11] M. H. Al-Obaidy, Z. Abdulah, and P. Ratti, "Preventive insights: The role of education in enhancing hypertension patients' knowledge on heart disease," *J. Health Innov. Environ. Educ.*, vol. 2, no. 1, pp. 11–18, 2025, doi: 10.37251/jhiee.v2i1.1722.

[12] E. Nurjanah and R. P. Laguatan, "Enhancing plant diversity learning with an ethnobotany-based e-booklet: A focus on the Pandeglang community," *J. Acad. Biol. Biol. Educ.*, vol. 2, no. 1, pp. 58–68, 2025, doi: 10.37251/jouabe.v2i1.1989.

[13] S. Huangal-Scheineder, J. Cieza-Sánchez, M. Diaz-Paredes, M. Arriaga-Delgado, and A. Marchena-Tafur, "Neuroeducation and impact on higher education: A systematic review," *Int. J. Eval. Res. Educ.*, vol. 13, no. 6, Art. no. 29170, 2024, doi: 10.11591/ijere.v13i6.29170.

[14] N. N. Le and M. Z. Aye, "The effect of integrating green sustainable science and technology into STEM learning on students' environmental literacy," *Integr. Sci. Educ. J.*, vol. 6, no. 3, pp. 232–239, 2025, doi: 10.37251/isej.v6i3.2116.

[15] A. I. Ilyas, J. P. T. Pocaan, and K. Tanasavate, "Feminism reflected in *7 Hati 7 Cinta 7 Wanita* by Robby Ertanto Soediskam: A literary feminist analysis," *J. Lang. Lit. Educ. Res.*, vol. 2, no. 1, pp. 25–32, 2025, doi: 10.37251/jolle.v2i1.1663.

[16] G. Leisman, "Neuroscience in education: A bridge too far or one that has yet to be built," *Brain Sci.*, vol. 13, no. 1, Art. no. 40, 2023, doi: 10.3390/brainsci13010040.

[17] M. S. Rahajo and A. Kumyat, "Analysis of driving factors for the implementation of clean technology to optimize green manufacturing in the Wiradesa batik small and medium enterprises (SMEs)," *Int. Sci. Educ. J.*, vol. 6, no. 3, pp. 258–268, Sep. 2025.

[18] F. R. Putri, C. A. Osunla, and R. A. Sen, "Bridging healthcare and technology: Management systems in radiology services," *J. Health Innov. Environ. Educ.*, vol. 2, no. 1, pp. 31–42, 2025, doi: 10.37251/jhiee.v2i1.1726.

[19] C. J. Pérez Sánchez, F. Calle-Alonso, and M. A. Vega-Rodríguez, "Learning analytics to predict students' performance: A case study of a neurodidactics-based collaborative learning platform," *Educ. Inf. Technol.*, vol. 27, no. 8, pp. 12061–12082, 2022, doi: 10.1007/s10639-022-11128-y.

[20] J. Feng, B. Yu, W. H. Tan, Z. Dai, and Z. Li, "Key factors influencing educational technology adoption in higher education: A systematic review," *PLOS Digit. Health*, vol. 4, no. 4, Art. no. e0000764, 2025, doi: 10.1371/journal.pdig.0000764.

[21] A. Haleem, M. Javaid, M. A. Qadri, and R. Suman, "Understanding the role of digital technologies in education: A review," *Sustain. Oper. Comput.*, vol. 3, pp. 275–285, 2022, doi: 10.1016/j.susoc.2022.05.004.

[22] H. Goldberg, "Growing brains, nurturing minds—Neuroscience as an educational tool to support students' development as life-long learners," *Brain Sciences*, vol. 12, no. 12, art. 1622, 2022, doi: 10.3390/brainsci12121622.

[23] E. Gkintoni, I. Dimakos, C. Halkiopoulos, and H. Antonopoulou, "Contributions of neuroscience to educational praxis: A systematic review," *Emerging Science Journal*, vol. 7, Special Issue, pp. 146–158, 2023, doi: 10.28991/ESJ-2023-SIED2-012.

[24] K. Pradeep, R. S. Anbalagan, A. P. Thangavelu, S. Aswathy, and V. G. Jisha, "Neuroeducation: Understanding neural dynamics in learning and teaching," *Frontiers in Education*, vol. 9, art. 1437418, 2024, doi: 10.3389/feduc.2024.1437418.

[25] J. A. Lopata, N. Barr, M. Slayton, and P. Seli, “Dual-modes of creative thought in the classroom: Implications of network neuroscience for creativity education,” *Translational Issues in Psychological Science*, vol. 8, no. 1, pp. 74–88, 2022, doi: 10.1037/tps0000317.

[26] A. Dietrich and S. Zakka, “Education, neuroscience, and types of creativity,” *Future in Educational Research*, vol. 1, no. 1, pp. 63–71, 2023, doi: 10.1002/fer3.7.

[27] M. Shumylo, I. Rassokha, O. Bieliaieva, and V. V. Petrovskyi, “Creativity as an essential aspect in medical education,” *Creativity Studies*, vol. 15, no. 1, pp. 179–192, 2022, doi: 10.3846/cs.2022.13320.

[28] C. A. Yaya Copaja and J. R. Egoavil Vera, “Neuroeducation strategies that promote participation in the classroom: A belief from the experience of university students in Peru,” *Edelweiss Applied Science and Technology*, vol. 9, no. 1, pp. 1173–1181, 2025, doi: 10.55214/25768484.v9i1.4367.

[29] M. Fragkaki, S. Mystakidis, and K. Dimitropoulos, “Higher education faculty perceptions and needs on neuroeducation in teaching and learning,” *Education Sciences*, vol. 12, no. 10, art. 707, 2022, doi: 10.3390/educsci12100707.

[30] G. Wilcox, A. R. Barbre, S. Owens, and K. Quigley, “Impact of educational neuroscience teacher professional development: Perceptions of school personnel,” *Frontiers in Education*, vol. 7, art. 912827, 2022, doi: 10.3389/feduc.2022.912827.

[31] S. Mystakidis, A. Christopoulos, M. Fragkaki, and K. Dimitropoulos, “Online professional development on educational neuroscience in higher education based on design thinking,” *Information*, vol. 14, no. 7, art. 382, 2023, doi: 10.3390/info14070382.

[32] V. Bhargava and V. Ramadas, “Implications of neuroscience/neuroeducation in the field of education to enhance the learning outcomes of the students,” *Journal of Positive School Psychology*, vol. 6, no. 6, pp. 6502–6510, 2022. Available: https://journalppw.com/index.php/jpsp/article/view/8636

[33] F. García-Valdecasas, I. Martínez Sánchez, D. González González, and J. Álvarez Rodríguez, “Role of neurodidactics in teacher professionalization for online teaching in higher education,” *Texto Livre: Linguagem e Tecnologia*, vol. 15, art. e40505, 2022, doi: 10.35699/1983-3652.2022.40505.

[34] O. Kruhlii, M. Zhulinska, L. Levytska, H. Shevtsiv, N. Pechko, and V. Tynnyi, “Neurodidactic aspects of teaching adults foreign languages,” *BRAIN. Broad Research in Artificial Intelligence and Neuroscience*, vol. 14, no. 4, pp. 199–211, 2023, doi: 10.18662/brain/14.4/500.

[35] Y. Ishchenko, D. Hubarieva, I. Soroka, D. Usyk, and L. Chemonina, “Emotional education as a means of developing social competence in primary school students in wartime,” *International Electronic Journal of Elementary Education*, vol. 17, no. 1, pp. 1–13, 2024, doi: 10.26822/iejee.2024.359.

[36] S. Yermakova, O. Ivanova, O. Horytska, V. Polishchuk, T. Polukhtovych, and T. Vivcharenko, “Influence of the neuro-educational environment on one’s socialization under total digitalization,” *BRAIN. Broad Research in Artificial Intelligence and Neuroscience*, vol. 14, no. 4, pp. 593–611, 2023, doi: 10.18662/brain/14.4/523.

[37] V. Volkotrubova and E. Zh. Zhoomartova, “Psychological and pedagogical aspects of the formation of cognitive independence of the Central Asian youth (Silk Road countries’ experience),” *BIO Web of Conferences*, vol. 120, art. 01015, 2024, doi: 10.1051/bioconf/202412001015.

[38] A. Motukeeva, A. Azhibaeva, D. Kulbachaev, Zh. Abdyrakunova, and M. Toloev, “Formation of creative thinking among students in the digital educational environment,” *E-Learning and Digital Media*, 2024, doi: 10.1177/20427530241307671.

[39] J. A. Suyo-Vega, V. H. Fernández-Bedoya, and M. E. Meneses-La-Riva, “Beyond traditional teaching: A systematic review of innovative pedagogical practices in higher education,” *F1000Research*, vol. 13, art. 22, 2024, doi: 10.12688/f1000research.143392.2.

[40] S. Maygeldiyeva, B. Bekzhanova, L. Zhamansarieva, S. Stamkulova, and G. Usenova, “The development of cognitive independence of students based on information technology,” in *Proc. E3S Web Conf. (ICBTE 2020)*, vol. 159, art. 09009, 2020, doi: 10.1051/e3sconf/202015909009.

[41] A. Faza and I. A. Lestari, “Self-regulated learning in the digital age: A systematic review of strategies, technologies, benefits, and challenges,” *Int. Rev. Res. Open Distrib. Learn.*, vol. 26, no. 2, pp. 23–58, 2025, doi: 10.19173/irrodl.v26i2.8119.

[42] K. Khaeratunnafisah and K. Lizbeth, “Utilization of telehealth in improving the quality of health services during the pandemic: Systematic review,” *Journal of Health Innovation and Environmental Education*, vol. 2, no. 1, pp. 1–10, 2025, doi: 10.37251/jhiee.v2i1.1723.

[43] H. R. Hagad and H. Riah, “Augmented reality-based interactive learning media: Enhancing understanding of chemical bonding concepts,” *Journal of Chemical Learning Innovation*, vol. 2, no. 1, pp. 52–59, 2025, doi: 10.37251/jocli.v2i1.1919.

[44] K. E. Williams, T. Burr, L. L’Estrange, and K. Walsh, “Early childhood educators’ use of neuroscience: Knowledge, attitudes, self-efficacy and professional learning,” *Trends in Neuroscience and Education*, vol. 38, art. 100247, 2025, doi: 10.1016/j.tine.2025.100247.

[45] M. Caballero and V. J. Llorent, “The effects of a teacher training program on neuroeducation in improving reading, mathematical, social, emotional and moral competencies of secondary school students: A two-year quasi-experimental study,” *Revista de Psicodidáctica*, vol. 27, no. 3, pp. 211–219, 2022, doi: 10.1016/j.psicoe.2022.04.002.

[46] P. B. Mello-Carpes, A. P. da Silva, K. A. da Silva, and J. G. Argenta, “Physiology faculty and student contributions to schoolteacher training in neuroscience: Innovations during the COVID-19 pandemic,” *Advances in Physiology Education*, vol. 46, no. 4, pp. 606–614, 2022, doi: 10.1152/advan.00045.2022.

[47] G. Şişman, D. Demirbulak, and A. Yılmaz Virlan, “The prevalence of neuromyths among K–12 English language teachers,” *European Journal of Education*, vol. 60, no. 2, art. e70070, 2025, doi: 10.1111/ejed.70070.

[48] B. Wang and P. Li, “Digital creativity in STEM education: The impact of digital tools and pedagogical learning models on students’ creative thinking skills development,” *Interactive Learning Environments*, vol. 32, no. 6, pp. 2633–2646, 2024, doi: 10.1080/10494820.2022.2155839.

[49] V.-M. Cojocariu, I. Boghian, and A. Rusu, “A literature review on digital creativity in higher education—Toward a conceptual model,” *Education Sciences*, vol. 14, no. 3, art. 508, 2024, doi: 10.3390/educsci14030508.

[50] S. Rahimi and V. J. Shute, “First inspire, then instruct to improve students’ creativity,” *Computers & Education*, vol. 174, art. 104312, 2021, doi: 10.1016/j.compedu.2021.104312.

[51] Z. Zaremohzzabieh, S. Ahrari, H. Abdullah, R. Abdullah, and W. A. Mohd Zal, “Effects of educational technology intervention on creative thinking in educational settings: A meta-analysis,” *Interactive Technology and Smart Education*, vol. 22, no. 2, pp. 179–198, 2024, doi: 10.1108/itse-11-2023-0224.

[52] Z. Zhan, X. Yao, and T. Li, “Effects of association interventions on students’ creative thinking, aptitude, empathy, and design scheme in a STEAM course: Considering remote and close association,” *International Journal of Technology and Design Education*, vol. 33, no. 4, pp. 1773–1795, 2023, doi: 10.1007/s10798-022-09801-x.

[53] A.-M. Cazan, “An intervention study for the development of self-regulated learning skills,” *Current Psychology*, vol. 41, no. 1, pp. 6406–6423, 2022, doi: 10.1007/s12144-020-01136-x.

[54] S. M. Galal, D. Vyas, M. Ndung’u, G. Wu, and M. Webber, “Assessing learner engagement and the impact on academic performance within a virtual learning environment,” *Pharmacy (Basel)*, vol. 11, no. 1, art. 36, 2023, doi: 10.3390/pharmacy11010036.

[55] J. Privitera, “A scoping review of research on neuroscience training for teachers,” *Trends in Neuroscience and Education*, vol. 24, art. 100157, 2021, doi: 10.1016/j.tine.2021.100157.

[56] M. Sailer, R. Maier, S. Berger, T. Kastorff, and K. Stegmann, “Learning activities in technology-enhanced learning: A systematic review of meta-analyses and second-order meta-analysis in higher education,” *Learning and Individual Differences*, vol. 112, art. 102446, 2024, doi: 10.1016/j.lindif.2024.102446.

[57] E. Gkintoni, H. Antonopoulou, A. Sortwell, and C. Halkiopoulos, “Challenging cognitive load theory: The role of educational neuroscience and artificial intelligence in redefining learning efficacy,” *Brain Sciences*, vol. 15, no. 2, art. 203, 2025, doi: 10.3390/brainsci15020203.

[58] G. Li, H. Luo, D. Chen, P. Wang, X. Yin, and J. Zhang, “Augmented reality in higher education: A systematic review and meta-analysis of the literature from 2000 to 2023,” *Education Sciences*, vol. 15, no. 6, art. 678, 2025, doi: 10.3390/educsci15060678.

[59] S. Kassymbekova, J. Pepania, and M. A. Balushi, “Using a multi-omic approach to investigate a diet intervention in young adults at risk of disease,” *Multidisciplinary Journal of Tourism, Hospitality, Sport and Physical Education*, vol. 2, no. 1, pp. 19–26, 2025, doi: 10.37251/jthpe.v2i1.1782.

[60] M. Amiin, H. A. Faqier, and A. M. Nuevo, “Analysis of the relationship between leg muscle strength and leg power in school students’ athletic performance,” *Multidisciplinary Journal of Tourism, Hospitality, Sport and Physical Education*, vol. 2, no. 1, pp. 56–61, 2025, doi: 10.37251/jthpe.v2i1.1857.