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Methodology for Preparing Future Primary School Teachers to Use Information Technologies and Neuroscience

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Abstract: *The article proposes approaches to addressing the problem of preparing future teachers based on an interdisciplinary paradigm. This paradigm focuses on preparing future primary school teachers to use information technologies in their professional practice and on applying multimedia technologies in the educational process of primary and higher education. This pilot exploratory study aims to formulate research hypotheses and establish a methodological framework for integrating neuropedagogical principles into ICT training systems. The article also provides a rationale for the neuropsychological assessment of the brain organisation of future primary school teachers in the experimental group. The assessment is based on contemporary advances in neurophysiology and neuropsychology, particularly research on the functional hemispheric asymmetry of the brain during the use of information technologies. The article further presents the results of assessing the functional hemispheric asymmetry of future primary school teachers obtained during the experimental study. From the perspective of neuropedagogy, this study proposes a pedagogical system of synthesised learning that incorporates information technologies while taking into account the natural characteristics of thinking. Particular attention is given to the methodological aspects of synthesised learning for future primary school teachers with different patterns of laterality. Such teachers are viewed as the cognitive architects of the digital learning environment. This theoretical model is designed to minimise the risk of teachers' neurocognitive burnout while enhancing information processing among primary school pupils. The findings presented in the article may be used to improve teaching methodology in primary education.*

Keywords: *professional training; multimedia and information technologies; neuropedagogy; functional brain asymmetry (laterality); right-hemispheric and left-hemispheric thinking; pedagogical system.*

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1. Introduction

The relevance of this study arises from the pedagogical and socio-economic significance of training primary school teachers. This is especially important given the expanding role of information and communication technologies, multimedia technologies, and digital learning environments in contemporary education. The ongoing digitalisation of education requires that professional teacher training aligns with the technological level of society. Consequently, updating the scientific framework for the development of future primary school teachers is essential. Information technology education is one of the most critical components of this framework. Such progress is only possible through the systematic implementation of multimedia and information technologies within primary schools and teacher education programmes in pedagogical higher education institutions.

However, it is widely recognised today that primary education faces a shortage of qualified specialists. There is a lack of professionals who can develop electronic textbooks and multimedia educational programmes. Furthermore, many educators cannot effectively apply these tools in the classroom. Graduates from primary teacher training programmes often lack the necessary knowledge and practical skills to design and manage IT-equipped learning environments. There is an urgent need to create and apply multimedia curricula for various subjects, including Mathematics, Ukrainian, Reading, Foreign Languages, Health Education, and Music.

Recent studies on IT and neuroscience have advanced the theoretical and methodological foundations for modelling educational environments. This is evidenced by the works of Filonenko and Tsukanova (2023), as well as Kosholap et al. (2021). Furthermore, the neuropedagogical preparation of students for computer use in primary schools has been addressed by Ching et al. (2020), Coch (2018), and other researchers. The results of these studies suggest that preparing primary education students to use information technologies is highly beneficial for the instructional process.

On the one hand, significant work is being done to implement these technologies in education. Intensive research and experimental studies are exploring the potential of ICT in primary schools. On the other hand, most modern teachers, including those in primary education, remain unprepared for full digitalisation. They often lack sufficient knowledge of the child's brain and its neurobiological characteristics. The brain consists of two large cerebral hemispheres that are closely aligned and connected by the corpus callosum, which serves as a communication channel between them. The interaction between these neural structures follows the laws of unity and the conflict of opposites, stability and preservation, as well as order and disorder. This 'systematic disorder', or the presence of functional asymmetry between the hemispheres, determines the variability of thinking. This factor is crucial when future primary school teachers utilise information technologies in their professional work (Kosholap et al., 2021).

Modern neuroscience shows that cognitive activity depends on the coordinated interaction of large-scale neural networks rather than on isolated brain hemispheres. This interaction supports cognitive flexibility and adaptive thinking when using information technologies. It is therefore important to distinguish established neurophysiological concepts, such as functional hemispheric asymmetry and lateralisation, from the neuromyth that individuals are either "left-brained" or "right-brained". Cognitive and digital activities engage both hemispheres through the corpus callosum. Consequently, a neuropedagogical approach does not classify learners according to hemispheric dominance. Instead, it fosters multisensory learning by engaging multiple cognitive channels (Privitera & Du, 2025).

2. Research Methodology

The study was designed as a pilot exploratory quasi-experimental study. Owing to the practical constraints of academic recruitment, a local sample of 58 participants was recruited. The sample comprised higher education students: 42 women (72.4%) and 16 men (27.6%), aged 18 to 22 years (M = 19.4; SD = 1.1). The participants were enrolled in the first, second, and third years of study (1st year: 34.5%; 2nd year: 44.8%; 3rd year: 20.7%). The control group followed the standard ICT curriculum, whereas the experimental group received instruction based on the proposed neuropedagogical framework.

Assessment was conducted using two primary measures and validated instruments:

Digital pedagogical competence: assessed using an adapted questionnaire based on the DigCompEdu framework (internal consistency: Cronbach's $\alpha = 0.89$; construct validity confirmed through factor analysis).

Media literacy and methodological readiness: assessed using a standardised digital case-study analysis test (content validity index, CVI = 0.91), evaluated by five independent experts.

Assessment timeline:

Pre-test: conducted one week prior to the intervention, at the beginning of the semester, to establish baseline equivalence between the experimental ($n = 29$) and control ($n = 29$) groups.

Post-test: administered immediately after completion of the 8-week training module.

3. Research Questions

The study addresses the following research questions:

- What is the distribution of functional asymmetry profiles among pre-service primary school teachers in the study sample?
- Which theoretical, methodological, cognitive, and instructional principles should guide the development of a system for preparing future teachers to design digital learning environments?

4. Theoretical Foundations of the Study

Within the framework of educational digitalisation, the development and implementation of new teaching tools are a priority. These tools are designed to organise student work within a unified, distributed information-educational environment and to improve the quality of learning. Such tools include Information and Communication Technologies (ICT) and Multimedia Technologies (MMT). These are digital information sources containing graphics, text, speech, music, video, and photographs. They are specifically designed to achieve the goals of modern education. According to Sukhovirskyi (2016), information technologies allow for the storage of vast amounts of data and provide rapid access to necessary information. They also enable the objective assessment of student knowledge and the visual demonstration of complex phenomena. Furthermore, they allow for the use of various graphical representations and the simultaneous presentation of information in multiple formats, such as visual and auditory modes.

Currently, most primary school teachers are only familiar with isolated elements of information-based teaching. Their use of these technologies in the classroom remains fragmented. Consequently, there is a significant challenge regarding the professional and methodological training of primary teachers in higher education institutions. This issue concerns the effective integration of multimedia technologies into the primary school instructional process.

Primary school teachers must not only be aware of information and multimedia technologies but also be able to use them in practice. Furthermore, they should be capable of creating their own multimedia materials while considering the latest findings in neuroscience. This objective can be met if the goals, content, forms, and methods of professional training are oriented towards integrating ICT and MMT through the lens of neuroscience. Despite growing interest in these technologies, the challenge of preparing future primary teachers for their professional use remains an urgent issue (Gutshall, 2020).

In modern pedagogy, several related but distinct concepts describe the professional expertise of primary school teachers in ICT. These include computer literacy, information literacy, ICT literacy, and information culture. Computer literacy refers to the mastery of skills required to use computer equipment. It also involves understanding the basics of informatics and the importance of

ICT in society. The frequent use of this term in academic literature is linked to the introduction of personal computers in educational institutions (Cui & Zhang, 2021).

Information literacy is defined as the knowledge and skills needed to identify, search, and organise information effectively. It also includes interpreting, analysing, and evaluating the accuracy and reliability of data. This encompasses following ethical principles for the use and dissemination of various types of information. Definitions of information competence often deliberately exclude specific technologies to emphasise their fundamental stability. Furthermore, the re-evaluation of educational goals in informatics has led to the inclusion of "information culture" in pedagogical terminology.

The characteristics of information culture are multifaceted. This complexity makes it difficult to assess the level of its development in pupils. To make education more structured and measurable, the concept of ICT competence was introduced (Shkvyr, 2017).

Consequently, ICT competence is viewed as a specific, measurable level of knowledge and skills. This level is required across all stages of education, from general schools to higher education institutions (Mu, 2023).

Based on these points, a key task of pedagogical higher education is to develop teachers' ICT competence. This serves as a means of fostering their broader information culture (Privitera & Du, 2025).

Building on research into the competence-based approach (Chang et al., 2021), we believe it is necessary to consider the specific duties of a primary school teacher when defining this concept. These duties include propaedeutics, multidisciplinarity, multifunctionality, and the need to account for students' ages. Teachers must also take measures to develop their pupils' own computer and information competences.

We define the professional readiness of a primary school teacher as the ability to conduct professional activities by using specially prepared instructional material. This is achieved using MMT as a universal, modern teaching tool. Information competence in this context refers to a teacher's motivated desire, readiness, and ability to use ICT and MMT. This occurs within multidisciplinary and propaedeutic pedagogical activities designed for primary-aged children. The primary motivation for this readiness is an interest in teaching children through multimedia as a vital instructional tool. The core components of this readiness include professional and methodological knowledge, as well as the skills to apply ICT and MMT effectively as tools in a professional setting (Granado De la Cruz et al., 2025).

We can define a teacher's readiness to use multimedia through three main lenses:

The Psychological Lens: It includes a genuine interest in multimedia and a personal drive to keep improving these skills throughout a professional career.

The Theoretical Lens: It is the mix of professional and technical knowledge needed to understand how multimedia works specifically in a primary school setting.

The Practical Lens: It is the ability to physically organise and run a lesson using digital tools.

To assess how ready students are, we look at several criteria based on the work of Drokina (2014). First, we assess whether the student has a steady interest in ICT and a real desire to use it in class. Second, we look at their theoretical grasp. This also includes basic computer skills, such as setting up hardware or running specific programmes. Finally, we evaluate their practical ability to solve everyday teaching tasks using software, such as educational games, tests, or specialised lesson materials.

According to Tan and Amiel (2022), preparing teachers for this work happens in two main stages:

The Preparatory Stage: The focus at this stage is on fostering an initial interest in ICT. We introduce students to the subject and show them how it fits into their future jobs. The goal is to build a strong foundation of motivation.

The Main Phase: At this stage, general interest is transformed into professional competence. Students learn specific teaching methods and gain hands-on experience using multimedia to solve real classroom challenges.

Our study explores how to improve this training by focusing on practical activities and core competences. This approach ensures that what students learn in university is as close as possible to what they will do in a real classroom.

Ultimately, the goal is to prepare teachers who are fully equipped to integrate technology into teaching. This readiness is more than just technical skill; it is a professional mindset. It involves a deep understanding of multimedia, the ability to teach children effectively, and a solid grasp of neuroscience.

As Ching et al. (2020) suggest, we must understand how a child thinks to develop the right teaching technologies. By taking a “synergistic” approach, we have mapped out how traditional teacher training can evolve into a modern, digital “neuro-educational” space (see Table 1).

To systematise these components and overcome methodological fragmentation, this study proposes conceptual frameworks that align ICT competences with neuropedagogical principles (see Tables 1 and 2).

Table 1. Matrix of convergence: Linking ICT skills with neuropedagogical principles in teacher training.

Stage of Future Teacher Training	**Pedagogical and ICT Component (Traditional Basis)**	**Neurocognitive and Neurodidactic Component (Conceptual Foundation)**	**Expected Result / Competence Shift (Neuro-ICT Integration)**
1. Propaedeutic and Motivational (Preparatory Phase)	Developing basic computer literacy and interest in ICT and multimedia technologies; overcoming students' technophobia.	Studying the neurophysiological foundations of perception; analysing the impact of screens and devices on synaptic pruning and cognitive styles in Generation Alpha (Tan & Amiel, 2022)	Neuroethical Readiness: Understanding the balance between digital and physical learning spaces; minimising the risks of fragmented("clip") thinking.
2. Cognitive and Technological (Main Phase)	Acquiring knowledge of specialised software, as well as diagnostic, testing, and gamified multimedia programmes.	Research on the functional interaction of cognitive brain networks; cognitive mapping; dual coding theory (Paivio, 1991)	Differentiated ICT competence: The ability to select digital tools according to learners’ cognitive profiles
3. Operational and Methodological (Practical Phase)	Designing original multimedia lessons; integrating ICT into the curricula of Mathematics, Language, and Natural Sciences.	Managing students' emotional and cognitive load (Cognitive Load Theory)	Cognitive Architecture of the Lesson: Creation of neuro-safe, balanced content that prevents the exhaustion of the child’s cerebral cortex.
4. Reflexive and Managerial (Expert Phase)	Objective assessment of learning outcomes via ICT; monitoring the quality of primary education.	Neuropsychological assessment of thinking dynamics; tracking individual cognitive development trajectories within an ICT-rich environment.	Neuropedagogical Management: The teacher’s ability to act as a cognitive analyst, adjusting ICT workloads

Following the principles of humanising education, we suggest several methods for training future primary teachers. These methods focus on information technology and neuroscience (Tan, 2022):

1. Setting goals and learning tasks. This involves planning goals step-by-step and providing regular feedback. For children who are right-brain dominant, reaching these goals is a key part of their motivation.
2. Changing mental strategies. Teachers should vary their methods and work formats. Long, repetitive lessons do not suit the sensory thinking style of right-brain dominant children.
3. Focusing on thinking rather than just facts. Vygotsky (1978) argued that one step in learning can lead to ten steps in a child’s development. However, ten steps in learning might only lead to one step in development.

4. Learning at one's own pace. Pupils should move through materials independently and track their own progress. Every child needs enough time to succeed. As Sukhomlynsky noted, the inspiration that comes from success creates the interest to learn.
5. Formative assessment. We measure progress by comparing a pupil's current work to their own past achievements, rather than only comparing them to others.
6. Encouraging group work. Children with different thinking styles should work together and share strategies. Left-brain pupils often prefer traditional desk rows. Right-brain pupils usually work better in a semi-circle. Without the right seating, they can lose up to 30% of the information (Ching et al., 2020).
7. Emotional support. Using visual aids, music, and rhythm throughout the lesson helps the brain work more effectively.
8. Promoting student initiative. Encouraging pupils to be active and independent is an effective way to promote lifelong learning.
9. Individual tasks. Lessons should be adapted to meet each student's needs.

We developed a "cognitive-didactic matrix" to show these ideas clearly. This matrix helps to connect different scientific fields. It links humanistic goals with brain science and digital tools (see Table 2).

Table 2. Convergence matrix of humanistic and neuropedagogical approaches in digital teacher training

Methodological aspect	**Neurophysiological and psychological justification**	**Design in the IT environment (Teacher's cognitive architecture)**
1. Goal decomposition	Providing feedback based on the "acceptor of action results" (P. Anokhin, cited in (Sudakov, 1998)), understood as a neural model of the expected outcome of an action, which has conceptual parallels with predictive coding and forward models in contemporary cognitive neuroscience. For students with right-hemisphere dominance, visualisation of the intended outcome may enhance motivational engagement through reward-related neural mechanisms.	Designing adaptive LMS interfaces (e.g., Moodle) with custom progress tracks. Using interactive dashboards for step-by-step self-tracking of goals.
2. Cognitive dynamics	Preventing sensory overload and attentional fatigue	Alternating modalities and timing: Microlearning; switching between audiovisual content and interactive modelling; using digital gamified perception.
3. Primacy of development	Supports learning-related neuroplasticity in the "zone of proximal development". Higher mental functions (abstraction, synthesis) take priority over rote learning.	Using heuristic ICT tools: Mind Mapping, conceptual computer modelling of processes, and AI as a cognitive "sparring partner".
4. Personalised pace	Supporting individual neurobiological rhythms for processing information. Success triggers the mesolimbic pathway, which strengthens neuroplasticity.	Implementing asynchronous learning with adjustable playback speed. Offering flexible time for tests to avoid the stress of strict deadlines.
5.Dynamic verification	Reducing activity in the amygdala (the stress centre), which can block the prefrontal cortex during standard grading. Focuses on individual progress.	Using E-portfolios and criteria-based automated assessment. AI analyses individual growth trajectories without ranking students in a general list.
6. Synchronisation of environment	Optimising information processing through a balanced spatial and visual design of the digital interface	Creating hybrid spaces: using interactive boards (Miro/Padlet) with colour and structural coding for left- and right-brain analysts.
7. Emotional-sensory amplification	Stimulating the limbic system, the brain's main attention filter. Synaesthesia (rhythms, visual codes) lowers cognitive load and aids long-term memory (Ching et al., 2020).	Multisensory design of digital resources: integrating podcasts, infographics, kinesthetic digital trainers, 3D models, and AR/VR technologies.
8.Autonomous learning agency	Reinforcing internal "search activity". Conscious choice activates the frontal cortical areas, which is the basis of Lifelong Learning.	Giving students academic freedom to choose digital tools for their projects (e.g., blogs, videos, podcasts, code, or web pages).
9.Task micro-differentiation	Accounting for individual cognitive profiles, neurodynamic characteristics, and brain laterality.	Using AI and Educational Data Mining to generate tasks: text-based for left-brain learners and visual/project-based for right-brain learners.

The cognitive-instructional matrix (see Table 1) allows the rethinking of primary school teacher training through a systemic and creative approach.

When designing ICT environments, it is vital to consider the contralateral principle of perception and the architecture of interhemispheric interaction. We can synchronise spatial-lateral characteristics through colour-coded interfaces or specific visual layouts in an LMS. These methods may help reduce affective stress and improve information retention by minimising information loss during the perception stage.

Thus, integrating neuropedagogical principles into ICT training transforms the teacher's professional role. They move from being a simple provider of digital content to becoming a "cognitive architect". In this role, they create safe, adaptive, and humanised educational spaces.

In conclusion, these methodological aspects of training in information technology and neuroscience will significantly improve the efficiency of primary education.

5. Conclusion

The methodological aspects of training future primary teachers in information technology and neuroscience will significantly enhance the efficiency of primary education. Based on the theoretical and experimental results of this study, we can draw the following fundamental conclusions:

A new interdisciplinary paradigm for teacher training has been conceptualised and theoretically justified. This paradigm is based on the synergistic convergence of ICT competences and the principles of affective neuropedagogy. In a fully digitalised educational environment, children from "Generation Alpha" perceive information in unique ways.

Therefore, traditional instrumental approaches to ICT may be methodologically limited. To design effective learning environments, the teacher’s role must transform. They must move from being a simple provider of media content to becoming a "cognitive architect" and an analyst of neuro-safe digital spaces.

This system spans from the initial preparatory phase to the final expert stage. The matrix acts as a "translational bridge". It links classical humanistic principles (Vygotsky, Sukhomlynsky) with their neurophysiological foundations. These include Anokhin’s "acceptor of action results", Paivio’s Dual Coding Theory (1991), and Cognitive Load Theory. Furthermore, the matrix connects these theories to specific ICT tools, such as adaptive LMS, immersive AR/VR technologies, cognitive mapping, and AI assistance.

The practical implementation of these methods may contribute to improving teachers’ professional competence and supporting more effective educational practices. Key aspects include goal decomposition, cognitive dynamics, and spatial-lateral synchronisation based on the contralateral principle.

The use of Big Data and Educational Data Mining for micro-differentiation may further help adapt learning activities to individual needs. These approaches may also reduce the risk of neurocognitive burnout among teachers exposed to heavy information loads. At the same time, they may optimise interhemispheric interaction in young pupils, helping to prevent fragmented (“clip”) thinking and improve attention and information retention.

Future research should focus particularly on the neuroethical implications of prolonged exposure to immersive and AI-assisted digital environments. Another important direction is the development of automated systems for real-time monitoring of pupils’ cognitive load during interaction with electronic learning resources, while ensuring appropriate safeguards for privacy and responsible data use.

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