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Research paper

Mechanisms for Preparing Future Teachers to Design An Educational Environment in The Conditions of Digitalisation

Olena Kryvylova [1], Raisa Prima [2], Oktaviia Fizeshi [3], Karina Oleksenko [4], Olha Kurylo [1], Roman Oleksenko [5], Natalka Kotelianets [5], Natalia Chernysh [6], Tetiana Khrystova [7], Vladyslav Pyurko [8]

[1] Berdiansk State Pedagogical University, Zaporizhzhia, Ukraine
[2] Lesya Ukrainka Volyn National University, Ukraine
[3] Mukachevo State University, Mukachevo, Ukraine
[4] Communal Institution of Higher Education «Kremenchuk Humanitarian and Technological Academy» of the Poltava Regional Council, Ukraine
[5] Volodymyr Vynnychenko Central Ukrainian State University, Kropyvnytskyi, Ukraine
[6] Hryhorii Skovoroda University in Pereiaslav, Ukraine
[7] Bogdan Khmelnitsky Melitopol State Pedagogical University, Zaporizhzhia, Ukraine
[8] Gymnasium № 22 of the Melitopol City Council of Zaporizhzhya Region, Ukraine
**Corresponding author E-mail: roman.xdsl@ukr.net*

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Abstract

Mechanisms for preparing future teachers to design an educational environment in the context of digitalization include the development of digital competence, mastering digital educational system design technologies, training in interaction with digital tools, and training in creating educational content. The article analyzes the operational-activity component of future primary school teachers' readiness to design the educational environment. The focus is placed on the development of practical skills, the ability to organize the educational process considering the variability of primary education, and the effective use of available resources. Mastery of this component is seen as a key factor in creating a safe, functional, and adaptive learning space that meets the demands of modern primary education. An important role in this process is played by information technologies, which influence psychological mechanisms (cognitive processes, metacognitive skills, emotional and volitional qualities, and reflexivity). The pedagogical research implemented a set of organizational and pedagogical conditions aimed at enhancing this component: fostering positive motivation for project-based activities; updating the practice-oriented content of professional training disciplines; introducing forms and methods of instruction focused on practical modeling of the educational environment; and engaging students in reflective activities throughout the preparation process. The experimental results demonstrated a positive dynamic in the development of the operational-activity component, in particular, an increase in initiative, creativity, and the ability to independently solve multilevel tasks. The reliability of the observed changes was confirmed using statistical methods, including Student's T-test and Pearson's chi-square test. The findings affirm the effectiveness of the proposed conditions in preparing a competent teacher for the New Ukrainian School who can design a child-centered educational environment.

Keywords: *Professional Activity; Psychological Mechanisms; Information Technologies; Digitalisation; Education.*

1. Introduction

The mission of primary school is to support the comprehensive development of the child, considering their age-related and individual psychophysiological characteristics. It involves fostering general cultural, moral, and ethical values, as well as key and subject-specific competencies. It is also important to ensure the acquisition of essential life and social skills that will contribute to successful learning in secondary school and meaningful participation in the life of a democratic society.
According to the professional standard for the occupation "Teacher of a General Secondary Education Institution," one of the key professional functions is participation in the organization of a safe and healthy educational environment. This involves a teacher's developed ability to design learning, upbringing, and development spaces for students. To fulfill this function, a teacher must, firstly, possess knowledge about the specifics of educational space content and the equipment required for effective teaching of school subjects; and secondly, have the skills and competencies to use didactic materials and teaching equipment, considering their relevance, appropriateness,

functionality, aesthetic appeal, and the educational needs of each student. Moreover, it is important that the teacher, together with students, can design such spaces considering their age characteristics, interests, and needs. [1]

The foundation of prospective primary school teachers' ability to design and adapt the learning environment lies in a set of psychological mechanisms. The operational-activity component of readiness is directly linked to several mechanisms: cognitive processes (attention, memory, thinking, imagination) that ensure the processing and transformation of information; metacognitive skills that enable awareness, monitoring, and regulation of one's pedagogical strategies; emotional and volitional qualities that foster self-control, resilience, and responsibility; as well as reflective abilities that provide for critical evaluation and improvement of professional activity.

The study of the psychological foundations of readiness is organically combined with the necessity of experimental verification within the framework of pedagogical research. The monitoring of the professional development of future primary school teachers is based on pedagogical research. Experimental studies play a particularly important role in 2 this process, as they are essential for scientific inquiry. In scientific fields where mathematical tools are actively used, research results can often be theoretically justified, relying on already accumulated empirical data. In contrast, in pedagogy, the experiment often serves as the only means of confirming the validity of proposed hypotheses and theoretical findings. This is due to the lack of a universally recognized system of axioms and a corresponding formalized framework, which makes comprehensive theoretical justification impossible without experimental verification.

In modern conditions, verifying the effectiveness of new approaches to the training of future teachers becomes particularly relevant, considering the concept of the New Ukrainian School [3] and the growing demands for the implementation of teachers' professional functions. [1]

Thus, the main objective of the study is to determine the effectiveness of the organizational and pedagogical conditions that contribute to the formation of the operational-activity component of future primary school teachers' readiness to design an educational environment. To achieve this goal, several research questions were raised: what is the level of development of the operational-activity component of readiness observed at the beginning of the study in the control and experimental groups; whether these groups are homogeneous in terms of the development of this component; how effective the proposed organizational and pedagogical conditions are compared to traditional training approaches; whether there are qualitative and statistically significant changes in the experimental group; and whether the control and experimental groups remain homogeneous at the final stage of the study.

2. Literature Review

The readiness of future primary school teachers to design the learning environment is viewed as a stable internal state that reflects their commitment to effectively creating conditions for the intellectual, social, and moral development of young learners. This state is based on the activation of personal potential, including motivational, operational-activity, cognitive, and emotional-volitional domains, as well as on previously acquired knowledge and experience aimed at achieving desired outcomes and fostering ongoing professional and personal growth. The formation of readiness for professional activity occurs through the acquisition of general and specialized knowledge, the development of necessary skills and abilities, and the enhancement of key professionally significant personal qualities. [4], [5].

Scientists offer diverse interpretations of the essence of the operational-activity component of future primary school teachers' readiness to perform a wide range of professional functions. For instance, L. Korolyova [6] emphasizes the importance of skills such as unconventional comparison of facts, phenomena, views, and concepts; establishing logical connections; observing, selecting, systematizing, and creatively processing information; associating; transforming stereotypical models; identifying contradictions; improvising; formulating hypotheses and assumptions; defining problems; and finding non-standard solutions. According to V. Andriievska [7], a key indicator of the operational-activity component is the development of practical skills necessary for the effective use of productive methodologies that support the development of meta-subject information and communication skills among younger students. A. Kovinko [8] focuses on the skills and abilities that optimize the educational process in primary school within the framework of this component. M. Nesterenko [9] highlights the future teacher's ability to design lessons using modern educational technologies in the context of the variable content of primary education, to reflect on the implementation of their own pedagogical ideas, and to demonstrate motivation for self-development and self-improvement – elements that form the foundation for seeking innovation and developing an individual and creative professional style. T. Atroshchenko [10] examines the system of skills, abilities, and actions that manifest in the ability to understand and evaluate various facts, phenomena, and processes in the context of social behavior and activity within a multiethnic primary school environment. I. Konovalchuk [11] emphasizes the importance of integrating general pedagogical and specialized skills required for effectively organizing interaction among teachers, students, and their parents. I. Upatova [12] defines the content of the operational-activity component through a set of methodological skills: gnostic, projective, organizational-executive, and creative-reflective.

The analysis of the mentioned works makes it possible to distinguish several common and different approaches to understanding the operational-activity component. The common feature is the emphasis on the development of creativity, the ability to design lessons, and the integration of information technologies. The identified approaches differ in the researchers' emphases. For example, I. Upatova focuses mainly on the development of methodological skills of future teachers; L. Korolyova and M. Nesterenko – on cognitive and metacognitive processes that ensure non-standard thinking and the ability to reflect; whereas T. Atroshchenko and I. Konovalchuk emphasize the socio-role and interpersonal aspects of professional interaction. Such differentiation allows us to highlight the multidimensionality of the operational-activity component and to substantiate its integrative nature in our study. Based on these approaches, we define our own understanding of the operational-activity component as an integrative system of skills and mechanisms that combines cognitive and metacognitive processes, methodological and design skills, and socio-communicative competence, thus ensuring the readiness of future teachers to create an adaptive digital educational environment.

In addition, scholars emphasize the importance of cognitive processes, among which sensation, perception, memory, thinking, imagination, and attention are highlighted. A person engages in cognitive activity because they actively set goals and strive to achieve them. Cognition is not a passive process; it is always connected with the transformation of what is known.

Mental processes form the structure of a person's intellect, although the concept of the intellectual sphere of personality is much broader than the cognitive one. Intelligence, as understanding and reason, is a system of mental operations with images, symbols, and signs, united by a certain cognitive style and problem-solving strategy; intellectual ability, skills, and giftedness. Therefore, intellectual activity is primarily associated with reflective and regulatory activity, which involves the ability to effectively solve problems, learn to use acquired experience to solve new problems, and better adapt to new situations. These abilities are largely determined by the functions of thinking, particularly logical thinking, sustained attention, working memory, as well as perception, imagination, intuition, acquisition of new knowledge, and the application of its results.

Intelligence as a person's cognitive activity organically combines both already acquired experience (knowledge, mental skills, and abilities) and the ability for further independent acquisition and creative practical application. Therefore, both categories cannot be considered without considering a person's abilities and certain giftedness, their mental work capacity, ability to solve new problems creatively, insightfulness, ingenuity, curiosity, and linguistic proficiency.

Thus, the cognitive sphere of personality ensures a dynamic reflection of reality and its transformation, the formation of experience, and the regulation of activity. In this sphere, mental processes interact specifically, ensuring a continuous flow of holistic, conscious, reflective, and transformative productive activity.

Metacognitive abilities are understood as personal capacities for the "awareness" of strategies and methods of cognition, which is understood as the ability to mentally perceive and process external information. Various aspects of metacognition are considered in the works [13], [14], [15], [16], [22].

J. Flavell defined the concept of "metacognition" as the sum of a person's knowledge about the features of their own cognitive sphere and ways to control it. The researcher identified the following components of metacognition: metacognitive knowledge, metacognitive experience, and metacognitive goals and strategies. [14]

The first two components are reflective formations that allow the subject to introspect and track the course of their intellectual activity. J. Flavell defines metacognitive knowledge as a domain of "world" knowledge related to cognitive activity (its goals, tasks, actions) and knowledge regarding one's individual characteristics of perception, memory, and problem solving. Metacognitive experience is understood as any conscious experience associated with the intellectual process. Metacognitive goals and strategies are processes aimed at controlling and regulating cognition. This is their difference from cognitive processes, which, according to J. Flavell, should carry out the cognitive process.

A. Brown defines metacognition as knowledge about one's own knowledge. According to the researcher, metacognition includes two major categories: knowledge about cognition, i.e., the set of activities that involve conscious reflection on cognitive actions and abilities; regulation of cognition, i.e., the set of activities that require self-regulation mechanisms. [13]

In their works, D. Ridley, P. Schutz, R. Glanz, C. Weinstein define metacognition as the process of using reflection to consciously study one's own thinking and awareness of thinking strategies. They include: planning, selecting activity strategies, and monitoring cognitive activity. [15]

J. Wilson identifies three components of metacognition: metacognitive awareness – knowledge of personal learning strategies; metacognitive evaluation – judgment of one's cognitive abilities and limitations, their necessity in a particular situation; metacognitive regulation, which manifests in the modification of one's thinking. [22]

R. Sternberg, in the "hierarchical model of intelligence," also highlights certain metacomponents – processes of managing and regulating current information processing, which include: recognition of the existence of a problem; its awareness and selection of possible solutions; strategy choice; selection of mental representation; allocation of available resources; control over the problem-solving process; assessment of result effectiveness. In R. Sternberg's theory, metacomponents are higher components that regulate execution and knowledge acquisition components. [16]

Contemporary research in cognitive psychology and neuroscience emphasizes that the use of informational tools directly affects memory, attention, and cognitive load. Within the framework of cognitive load theory [17], [18], it is highlighted that effective multimedia materials reduce excessive load on working memory while simultaneously enhancing germane load – the processing that promotes learning. Studies by R. Mayer [19] demonstrate that the principles of multimedia learning (the combination of text, visualization, and interactivity) significantly increase engagement and long-term retention.

Moreover, contemporary neuropsychological studies confirm that interactive simulations and educational games activate attention and emotional-motivational systems, thereby stimulating deeper information processing [20], [21]. For example, Kahoot! enhances attention and reduces extraneous cognitive load through game-based motivation; PhET simulates complex phenomena, ensuring deeper processing of learning content; and mind maps facilitate the organization of knowledge in working memory and contribute to the formation of long-term cognitive schemas. [30]

International studies confirm the importance of metacognitive strategies and project-oriented approaches in teacher training. For example, K. Matsumoto-Royo, M. Ramírez-Montoya, and L. Glasserman-Morales [23] showed that authentic, transparent tasks with feedback contribute to the development [24] of metacognition in student teachers. In the study, R. Maor, N. Paz-Baruch, N. Grinshpan, A. Milman, Z. Mevarech, R. Levi, S. Shlomo, M. Zion [25], a close connection between metacognition, creativity, and critical thinking was found in teachers working under the PBL model. W. Payoungkiattikun, A. Intanin, T. Thongsuk, and C. Hemtasin [26] developed a PjBL model for the formation of metacognitive skills in future science teachers.

At the same time, other empirical studies emphasize the direct impact of metacognitive strategies on teachers' professional competence. I. Maryani, M.A. Alhakim, and R. Gestiardi showed that the level of metacognitive abilities of prospective primary school teachers is insufficient in terms of planning.[27]

An important direction is also the study of self-regulated learning, where metacognitive strategies – planning, monitoring, and evaluation – have proven effective in developing language competencies in younger students and are recommended for inclusion in teacher training programs. [28] R. Wass, T. Rogers, K. Brown, K. Smith-Han, J. Tagg, D. Berg, S. Gallagher [29] emphasize that teacher training should include models for developing metacognitive skills that are integrated into learning content, visible, and repeatable. Thus, metacognitive self-awareness contributes to effective planning, implementation, and monitoring of teaching and serves as a factor in teachers' professional growth.

Engaging students in project-oriented tasks and systematic reflection activates several psychological mechanisms that contribute to the formation of their readiness for professional activity: transfer of knowledge to new situations; development of metacognitive skills; intrinsic motivation; professional identification; and social-role learning. Project-oriented tasks require the application of knowledge and skills in modified, professionally approximated conditions, which contribute to the formation of future teachers' ability to model the learning environment and make constructive decisions. Reflection plays an important role in this process, activating self-awareness and self-control, providing critical evaluation of one's pedagogical actions, and improving strategies for educational interaction. The practical significance of project activity lies in its direct connection with real professional roles, which increases motivation, forms readiness for innovative exploration, and supports the development of professional identity. Collective projects, in turn, create conditions for collaboration, alignment of positions, and joint problem-solving in pedagogical tasks, which are crucial for effective learning environment design.

The readiness of future primary school teachers to design the learning environment includes the ability to effectively use a full range of methods necessary for obtaining, processing, and practically applying professional information. Specifically, this involves mastering key didactic concepts and being able to implement various approaches to organizing the educational process. Future educators must understand the specifics of lesson types according to their structure and select them based on defined didactic objectives, while adhering to the

fundamental requirements of a modern lesson. Additionally, they should possess methods and techniques that promote the activation of students' cognitive activity; be able to identify ways to increase the effectiveness of learning activities; organize independent cognitive and research activities for students; analyze lessons in primary school from a didactic perspective; apply various methods and forms of diagnosing learning outcomes; and carry out monitoring and assessment of younger students' academic achievements, among other skills. Special emphasis is placed on the importance of having a developed ability to consistently perform actions aimed at synthesizing pedagogical systems or their individual components, preparing necessary documentation for implementing educational processes, as well as the skills to design, construct, and model various pedagogical situations.

Thus, the operational-activity component of future primary school teachers' readiness to design the learning environment is defined as the ability to organize the educational space considering the diversity of primary education forms and the available resources necessary for the effective support of the educational process.

3. Methodology

3.1 Participants

The experimental research was conducted based on higher education institutions in Ukraine, particularly at Berdyansk State Pedagogical University, Volodymyr Vynnychenko Central Ukrainian State University, Bohdan Khmelnytskyi Melitopol State Pedagogical University, and Mykhailo Dragomanov Ukrainian State University.

For the pedagogical experiment, two groups were formed: a control group (CG) and an experimental group (EG), which included 316 first-level (bachelor's) students majoring in specialty 013 "Primary Education." The control group, consisting of 158 students, studied according to the traditional educational program, while the experimental group, also comprising 158 students, underwent professional training using the developed structural-functional model for forming the readiness of future primary school teachers to design the learning environment.

3.2 Procedure

The ascertaining experiment aimed to determine the initial level of students' professional training and the studied characteristics at the starting stage. In turn, the formative experiment was focused on evaluating the effectiveness of developing the operational-activity component of readiness under the conditions of implementing theoretically grounded organizational and pedagogical conditions.

The first organizational and pedagogical condition involves the formation of positive motivation in future primary school teachers toward designing the learning environment. This facilitates the activation of a set of external and internal motivators that stimulate their activity and give it direction aimed at achieving planned outcomes. The expected result of implementing this condition regarding the operational-activity component of readiness is a focus on creating a learning environment that considers the diversity of forms of primary education and the resource support of the educational process.

The next organizational and pedagogical condition is the modernization of the content of the practice-oriented component of professional and practical training courses, as well as the orientation of the forms of organizing the educational process and teaching methods for future primary school teachers toward developing their readiness to design the learning environment. This promotes a deep understanding of project tasks, the acquisition of knowledge about ways to solve them, and the means to achieve the set goals. As a result of implementing this condition, the operational-activity component of readiness manifests initiative and an active stance in the process of mastering new knowledge and methods for solving problematic issues related to creating the learning environment, taking into account the variability of primary education and resource support of the educational process, as well as the effective application of methods for obtaining and processing professional information.

The final important organizational and pedagogical condition is the active involvement of future primary school teachers in reflective activities during the formation of their readiness to design the learning environment. This process is aimed at the regular practice of pedagogical reflection on their own actions. Implementing this condition promotes the continuous improvement of strategies for creating the learning environment, considering the variability of primary education and resource support of the educational process, as well as the adjustment of activity outcomes within the operational-activity component of readiness.

The control experiment was conducted to compare the indicators of the experimental and control groups, which allowed drawing conclusions about the dynamics of the development of future primary school teachers' readiness to design the learning environment across all defined criteria and levels.

The criteria for assessing the level of formation of the operational-activity component consider the variable nature of primary education and the current level of resource provision of the educational environment. The personal criterion involves the presence of a clear internal orientation of the future teacher toward organizing an effective and modern learning space for primary school students. The content-process criterion is characterized by initiative and flexibility in acquiring new knowledge, as well as the ability to find effective ways to solve professional tasks that arise during the design of the learning environment, using various methods of searching, analyzing, and processing professional information. The evaluative-regulatory criterion is manifested in the ability to continuously analyze, update, and improve approaches to creating the learning environment.

Based on the defined criteria and indicators, a characterization of the levels of formation of the operational-activity component of readiness was carried out. A high level is marked by the presence of stable skills to independently organize the learning environment, considering the diversity of primary education and the resource support of the educational process. The sufficient level is characterized by the ability to create a learning environment considering these factors, as well as independently correcting minor errors. The average level is manifested in the partial formation of the relevant skills, which require instructor assistance in eliminating significant errors. The low level is characterized by episodic demonstrations of skills in organizing the learning environment, considering the variability of primary education and the material and technical support of the educational process.

The level of formation of the operational-activity component was assessed not only by comparing the obtained results with established norms or average indicators but also by comparing them with the results of previous measurements to identify the dynamics of development of each structural element of this component. The selection of methods for assessing the level of formation was made considering the methodological foundations of the study. Tests were used, the content of which was directly related to the subject of the research: achievement tests allowed determining the degree of knowledge acquisition, while personality tests helped to identify the psychological characteristics of future teachers. During testing, all necessary procedural requirements were observed: all respondents were given the same tasks,

the process was conducted under standardized conditions, and the results were analyzed according to a clear evaluation system using average statistical indicators.

3.3 Instruments and Data Analysis

The readiness level of the operational-activity component of the readiness of future primary school teachers to design a learning environment was checked using the test for creative thinking (according to S. Mednick) [30], the activity product method, and the diagnostic method of the reflexivity development level.

The verbal creativity test by S. Mednick (or the distant association test) is intended for the verbal creativity diagnosis, which is defined as the recombining of situation elements. Future primary school teachers were offered verbal triads (triplets of words), the elements of which belong to mutually distant associative areas. It was necessary to establish an associative connection between them by finding a fourth word that would unite them so that it would form a phrase with each of them. Methodological tasks were not limited. The methodology was built not on the principle of a test or task, but as an unlimited activity field in the form of the same type of tasks.

Throughout all stages of the experimental study, the method of analyzing activity outcomes was applied, specifically through the completion of tasks of varying complexity related to project activities.

The diagnostic methodology for assessing the level of reflexivity development was focused on evaluating metacognitive functions as well as determining the degree of conscious monitoring of the project activity process.

4. Results

The possibility of continuity of the educational process and the implementation of distance learning during the martial law period in Ukraine is ensured using information technologies, which requires improving the training of future primary school teachers in designing the learning environment.

Future primary school teachers, when designing the learning environment, can use various information technologies, such as Kahoot! and PhET. Kahoot! is an online service for creating interactive tasks in the form of quizzes, surveys, and games, which can be used with different age groups, including primary school students. The teacher can use the platform while explaining new material or for consolidating knowledge, without interrupting the lesson and maintaining students' attention. The service integrates game elements into the educational process, thereby ensuring active interaction and collaborative work among students, promoting the development of their digital competence and critical thinking. The use of Kahoot! is also appropriate for conducting tests and independent work, quick surveys, organizing discussions and group debates, as well as in formative and traditional assessment and reflection.

PhET is an educational resource designed for creating and using interactive simulations in the study of mathematics and natural sciences. The development of PhET simulations is carried out taking into account several didactic principles: stimulating scientific inquiry, ensuring interactivity, visualizing thought processes, using different modes of representation (object motion, graphs, diagrams, measuring instruments, numerical data, etc.), relying on real-world phenomena, minimizing instructions to encourage independent exploration, as well as the possibility of flexible application in different learning situations. Thanks to this tool, primary school students can directly observe processes that are mostly only described in traditional learning. PhET is convenient to use both with an interactive whiteboard and on laptops or tablets. The use of simulations increases interest in learning, builds motivation, ensures a deeper understanding of the material, develops independence, and supports continuity of the educational process in blended learning conditions. An important advantage is the ability to work without constant Internet access. Performing creative and research tasks based on PhET simulations stimulates students' individual and independent activities, develops their creative thinking, increases interest in studying subjects, and positively affects the level of knowledge and practical skills. The use of computer modeling allows engaging all students in the class, which increases learning productivity. PhET simulations are effectively applied during the explanation of new material, knowledge assessment, and homework completion. High results are achieved when cognitive tasks integrated with various subjects (STEM education) are developed, which ensures the formation of a holistic view of the world and the development of interdisciplinary connections. Particularly valuable for primary school students are tasks with a practical focus, related to real-life situations. [31]

Thus, modern teaching methods are aimed at developing creative thinking and innovative ideas. They encourage primary school students not just to repeat outdated approaches, but to seek new, unconventional solutions. That is why the modern educational process actively uses electronic devices and gadgets, which help students express their creativity and share innovative ideas.

One of the effective methods suitable for use in primary school lessons is infographics – a way of presenting information using graphic elements. In a broad sense, infographics is considered as a visual representation of data, combining text and images, and facilitating the more accessible presentation of large amounts of information. The main purpose of infographics is to ensure a deeper understanding of educational material, create a more vivid perception, and enhance the emotional impact on the student, promoting active engagement with the topic. For this, maps, diagrams, educational illustrations, as well as video and audio support, which are mostly provided in electronic format, are used. Infographics open wide opportunities for organizing learning activities. Students can be given various tasks: find 3-5 interesting facts in the image; discuss their accuracy and ways of verification with classmates; retell the content of the infographic in their own words; prepare a short oral report for the class, and more. Thus, infographics is an effective tool for processing new material, consolidating knowledge, organizing assessment of learning outcomes, performing problem-solving tasks, and even for emotional relief. Presenting information in a compact and vivid form evokes much greater interest among primary school students than traditional teacher explanations.

Another effective teaching method in primary school is the use of mind maps, which contribute to the development of creative thinking, initiative, persistence, and self-assessment ability in students. Thanks to its flexibility, this tool can be used both in group work for the entire class and for individual activities.

The graphic visualization underlying mind maps helps students move from the general to the specific, activates memory, facilitates understanding of the essence of the problem, and promotes the discovery of new knowledge in the presented information. The use of diagrams, tables, symbols, and other conventional signs facilitates the perception of learning material, ensures its comprehension, and strengthens memorization.

The combination of traditional methods with modern innovative approaches made possible by information technologies has allowed the implementation of mind mapping techniques in teaching. It was developed by the English psychologist and educational consultant Tony Buzan, who defined this method as a universal key to unlocking the potential of the human brain. A mind map reflects so-called radiant

thinking – a special type of associative thinking, where each thought, image, or emotion serves as a nodal element from which connections branch out in various directions, forming an integrated network.

According to the concept of T. Buzan, B. Buzan, [32] mind maps have four main characteristics: a central image representing the subject of study; main topics branching from the central image in the form of branches; smoothly shaped branches labeled with keywords and images, from which secondary ideas branch out; formation of an integrated nodal structure connecting all elements of the map.

Mind maps are an effective tool for visualizing the thought process and structuring knowledge. They organize information in a form that is natural for brain perception, as it reflects the way humans think.

There are many programs and online services for creating and editing mind maps. Among them: Bubbl.us – a web service for maps; Mindomo – a browser-based map creation service without the need to install additional software; Mindmeister, CmapTools – platforms for collaborative work on maps with discussion capabilities. As a result, quality training of future primary school teachers in designing a modern learning environment was ensured. This is manifested in the formed need to possess project activity and the ability to act effectively even under changing conditions; a stable and personally significant interest in creating a learning environment; the desire to independently update knowledge according to the ideas of the New Ukrainian School Concept; development of integrative thinking necessary for successful project work; deep understanding of the specifics of the educational environment and the process of its design. It is also reflected in the ability to create a learning environment, considering the variability of primary education and resource capabilities, in the developed awareness of one's own emotional-volitional resources, the ability to mobilize strength during work, and to make professional decisions responsibly.

Data analysis and processing were conducted using a standardized program under uniform conditions, applying a single diagnostic methodology to assess the level of formation of the operational-activity component across all studied groups. This approach ensured the reliability and validity of the obtained experimental results.

The objectivity of the experimental results aimed at testing the effectiveness of the experimental structural-functional model was ensured by the equivalence of the samples. In other words, at the initial stage of the experiment, the control and experimental groups demonstrated an equal level of the studied readiness formation. [33]

To statistically confirm the existing similarities and differences between these groups regarding the level of formation of individual readiness components, the Student's t-test was used. Its application made it possible to reduce the probability of errors during the formative stage of the study. In particular, for the operational-activity component, the coefficient was 0.79.

The research results indicated that at the initial stage, the formation of the operational-activity component of readiness of future primary school teachers for designing the learning environment mostly corresponded to an average level. Specifically, this indicator was 43.04% in the control group and 44.93% in the experimental group. Table 1 presents data on the level of formation of the operational-activity component.

Table 1: Levels of formation of the operational-activity component (%)

Level	At the initial stage of the experiment				At the final stage of the experiment			
	CG = 158		EG = 158		CG = 158		EG = 158	
Low	46	29,11	43	27,22	31	19,62 (-9,49)	23	14,56 (-12,66)
Average	68	43,04	71	44,93	58	36,71 (-6,33)	44	27,85 (-17,08)
Sufficient	30	18,99	31	19,62	52	32,91 (+13,92)	66	41,77 (+22,15)
High	14	8,86	13	8,23	17	10,76 (+1,9)	25	15,82 (+7,59)

CG – a control group.
EG – an experimental group

The results of the analysis of experimental data (Table 1) confirmed that the most significant qualitative shifts occurred at a sufficient level of formation of the operational-activity component. This was associated with an increase in the proportion of students in the corresponding category during the pedagogical experiment by 13.92% in the control group and by 22.15% in the experimental group.

Positive qualitative changes were also observed at the low and medium levels of formation of the operational-activity component, manifested by a decrease in the number of students in the control group by 9.49% and 6.33%, respectively, and in the experimental group by 12.66% and 17.08%. The least pronounced positive dynamics in the level of formation of the operational-activity component were noted in the high-level category, where changes amounted to 1.9% in the control group and 7.59% in the experimental group.

The research results were confirmed using statistical methods, specifically through the application of the Student's t-test and the nonparametric Pearson's chi-square test. The t-test value ($t_{tabl.}$ (1,969) < $t_{calc.}$ (7,43)) indicates a statistically significant difference in the level of formation of the operational-activity component of readiness for designing the learning environment between the experimental and control groups with a 95% confidence interval. Similarly, Pearson's chi-square result ($x^2_{exp.}$ (8,2) > $x^2_{crit.}$ (7,8)) at a significance level of 0.05 confirms the influence of the organizational and pedagogical experimental conditions on the formation of the specified component.

5. Discussion

Positive dynamics in the development of the operational-activity component of future primary school teachers' readiness to design the educational environment is observed in their orientation towards creating an educational environment that takes into account the variability of primary education and the resource provision of the educational process; initiative and dynamism in acquiring new knowledge and methods for solving problematic issues related to the creation of the educational environment (handling all necessary methodologies for obtaining and processing professional information), considering the variability of primary education and the resource provision of the educational process; and continuous improvement of the strategy for creating the educational environment in accordance with the variability of primary education and the resource provision of the educational process, as well as the correction of activity results.

Positive changes in the formation of the operational-activity component are ensured through the implementation of a system of project-based tasks, consisting of three groups: educational, quasi-professional, and educational-professional tasks. The primary type of activity is transformational, which involves creating projects of varying complexity levels and degrees of engagement by future specialists. Mini-projects focus on solving professional tasks based on the situational activity of higher education students. This includes educational activities in the form of lectures and seminars, where information is transmitted and assimilated. Projects based on suprasituational activity involve students independently setting their activity goals, actively applying knowledge from various subjects in practice, and interacting with one another. This quasi-professional activity is carried out through business games, working with problem situations, training, and similar formats that simulate integral elements of the educational process, considering their subject-technological and social-role content.

Projects grounded in creative activity involve higher education students solving professional and educational tasks and problems, as well as engaging in interpersonal interactions with participants in the educational process. This type of activity includes scientific research work, internships, and the preparation of term papers and theses.

Transitioning from one form of activity to another, future primary school teachers practically apply educational and scientific information, which enables them to gain real professional experience in designing the learning environment and facilitates their natural integration into the teaching profession. They improve their skills in conducting various types of instructional and educational sessions, which contribute to the development of essential professional and personal qualities, as well as the motivation for continuous professional growth. Additionally, future educators become familiar with the advanced practices of teachers, psychologists, and lecturers, fostering a need for regularly updating their knowledge and creatively implementing it in their practical work as primary school teachers.

The presented results are consistent not only with previous pedagogical studies but also with the principles of cognitive learning theory. The applied informational tools confirmed the key assumptions of cognitive load theory [17], [18] and multimedia learning theory [19]: Kahoot! enhances attention through game-based motivation while simultaneously reducing extraneous cognitive load; PhET simulations support deeper information processing (germane load) and the formation of long-term knowledge; and mind maps structure learning material in working memory, thereby supporting the development of cognitive schemas and facilitating memorization.

The obtained results confirmed that project-oriented tasks and reflective activities ensure a positive dynamic in the development of the operational-activity component of future primary school teachers' readiness for designing the learning environment. This effect is explained by the activation of several psychological mechanisms. These mechanisms determine the ability of future teachers not only to master individual methods but also to comprehensively design the learning environment, considering its resource, social, and pedagogical dimensions. [34]

Despite the positive results, the study has certain limitations. First, it focuses mainly on pedagogical and psychological aspects, without sufficient involvement of data from related sciences (cognitive psychology, neuropsychology, neuroscience [35]). Second, the analysis covers only the training of primary school teachers in the Ukrainian educational context, whereas comparative studies with other educational systems could expand the scientific and practical significance of the results.

Therefore, several important directions can be considered promising for further research. First, neuropsychological analysis, which will make it possible to determine how performing project tasks and reflection affect the functioning of key cognitive functions – attention, memory, and creative thinking. Equally significant are interdisciplinary studies integrating findings from cognitive science, learning psychology, and pedagogy, as this approach will allow a deeper explanation of the mechanisms of readiness formation for professional activity. Another important direction is a comparative analysis of the implementation of similar educational strategies in different countries and education systems, which will contribute to identifying universal and specific models. Special attention should also be paid to studying the impact of digital technologies, in particular STEM tools, simulations, and educational games, on the development of the operational-activity component and the formation of reflectivity.

6. Conclusion

Key mechanisms for preparing future teachers to design an educational environment in the context of digitalization include specialized training courses, practical classes, the use of educational technologies and platforms, as well as the development of skills in working with digital tools to create and implement educational projects.

Thus, the positive trend in the level of formation of the operational-activity component according to the personal, content-process, and evaluative-regulatory criteria indicates the effectiveness of the established organizational and pedagogical conditions. By the end of the experiment, the proportion of future primary school teachers in the experimental group demonstrating a high level of formation of the operational-activity component of readiness for designing the learning environment increased by 7.59%. At the same time, the number of higher education students with a low level of formation of this component decreased by 12.66%.

The reliability and validity of the obtained results were confirmed using statistical methods, in particular through the verification of the homogeneity of the control and experimental groups at the initial stage and their heterogeneity at the end of the study using the Student's t-test, as well as the assessment of the influence of experimental factors using Pearson's criterion x^2.

7. Practical Recommendations

7.1 Main Training Areas

1. Development of digital competence: future teachers should master both technical skills in using ICT and pedagogical competencies necessary for the effective use of digital tools in the educational process.
2. Design of the Digital Educational Environment (DEE): it is necessary to train teachers in the skills of planning and creating the DEE, including the selection and integration of technological tools, the formation of content, and the organization of the educational process.
3. Teaching methods and technologies: training includes the development of various digital pedagogical technologies, such as multimedia, trainers, simulators, and distance learning, to create an active and free educational environment.
4. Working with educational content: teachers should learn how to create and select digital educational content, as well as effectively use it within the framework of the DEE they have developed.

7.2 Practical Mechanisms

1. Inclusion of courses on digitalization in pedagogical programs: development of academic disciplines aimed at the formation of knowledge and skills in the field of digital technologies and the DEE.
2. Practice-oriented learning: conducting practical classes and internships where future teachers can directly work with digital tools and platforms.
3. Using educational platforms and technologies: using existing digital platforms to organize training and simulate real conditions of work in the digital environment.
4. Developing teamwork skills: training teachers to jointly create digital educational projects and interact within the digital environment.

7.3 Important Conditions for Success

1. Conformity of the educational process to modern realities: training should be based on the principles according to which the learning process comes first, and technology comes second.
2. Developing the professionalism of teachers: It is necessary to ensure a high level of professionalism of teachers in the field of digital technologies.
3. Appropriate material and technical conditions: the availability of an appropriate material and technical base, including ICT equipment, is a prerequisite for the successful formation of the digital educational system.

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