INNOVATIVE EDUCATIONAL TECHNOLOGIES IN THE SYSTEM OF ENVIRONMENTAL EDUCATION OF FUTURE TEACHERS

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Abstract: The article examines the improvement of ecological training for pre-service teachers through the integration of innovative educational technologies – project-based learning, digital simulations, gamification, and augmented reality. Based on an analysis of current scientific literature, a methodological model combining competence-based and activity-system approaches is substantiated. It is shown that the effectiveness of technological innovations is determined not by their mere presence but by the quality of their pedagogical integration into a coherent educational process. Specific conclusions are formulated regarding the balance of digital and field-based training formats and directions for further research.

Keywords: ecological training, innovative educational technologies, competence-based approach, digital education, project-based learning, gamification, augmented reality, ecological competence, teacher education, sustainable development.

Introduction. Global environmental challenges – climate change, biodiversity degradation, and increasing anthropogenic pressure on natural ecosystems – bring a fundamental question to the agenda of pedagogical science: how can the system of higher pedagogical education ensure the training of teachers who possess not only subject-specific knowledge in ecology but also a genuine readiness to transmit environmental culture to their future students [1]? This task becomes particularly acute in the context of the digital transformation of educational systems and the transition to the paradigm of sustainable development.

An analysis of the current state of pedagogical education indicates a significant gap between the declared goals of environmental education and the actual educational outcomes. Environmental disciplines are often taught in a knowledge-transmission mode, without immersing students in the practice of ecological thinking and without utilizing the potential of modern technologies. Traditional lecture and seminar formats, despite their methodological validity, do not fully ensure the formation of an active, reflective attitude towards environmental issues [2].

The extent to which this topic has been developed in the scientific literature remains uneven. While the general theoretical aspects of environmental education are quite fully represented in domestic and foreign pedagogy, specific methodological models for integrating innovative technologies into the system of environmental teacher training have been developed much less. This is especially true regarding the capabilities of digital technologies – simulation platforms, augmented reality tools, gamified learning environments – in the context of pedagogical environmental education [3].

The aim of this article is to provide a theoretical justification for a methodological model of environmental education for future teachers, based on the integration of innovative educational technologies with the value foundations of ecological pedagogy. The scientific

significance of the research is determined by the need to bridge the gap between the technological potential of modern education and its pedagogically sound application in the field of environmental teacher training.

Literature Review. The theoretical foundations of environmental education as an independent branch of pedagogy have been forming in domestic science over the past decades. A key contribution to the development of its conceptual foundations was made by the works of I. D. Zverev, who defined environmental education as a continuous process of forming an individual's environmental culture, encompassing cognitive, value, and behavioral aspects [1]. His thesis that environmental education cannot be limited to the assimilation of biological and natural science information – it implies the formation of a special type of worldview attitude towards nature – is fundamentally important. It is this idea that serves as a conceptual guideline when designing any educational models of environmental teacher training, including those based on innovative technologies.

From the perspective of the psychology of human interaction with the natural environment, S. D. Deriabo and V. A. Yasvin made a significant contribution to understanding the value-motivational foundations of environmental education by proposing the concept of subjective attitude towards nature and developing a methodology for diagnosing environmental consciousness [2]. According to their approach, the real environmental culture of a teacher implies not just knowledge of environmental facts, but a stable system of personal meanings connecting a person with the natural world. Significantly, such a system of meanings is not formed in conditions of exclusively classroom-based, let alone exclusively digital, learning: it requires a lively, direct experience of interacting with natural objects.

In the context of the competence-based approach, environmental education is viewed as a process of forming a specific professional competence. N. M. Mamedov identifies a cognitive component (systemic knowledge about ecosystems and mechanisms of anthropogenic impact), a value-motivational component (environmental attitudes and readiness for responsible behavior), and an activity component (practical skills in environmental monitoring and education) in its structure [3]. It is this three-component understanding that sets the logic for designing educational programs focused on real outcomes rather than the formal assimilation of educational content. Applied to innovative technologies, this means the need for their differentiated selection: some tools are effective for developing the cognitive component, others for the activity component, and no single technology ensures an automatic increase in all three components.

In the fundamental work by J. Hattie, which presents a large-scale meta-analysis of factors influencing learning achievement, it is convincingly shown that technologies in themselves do not guarantee an improvement in the quality of education: the decisive factor is the method of their pedagogical integration into the educational process [4]. This thesis is fundamentally important for a correct understanding of the prospects for the digitalization of environmental teacher training. It warns against technological fetishism – a common mistake in designing educational innovations – and shifts the focus from the question "which technology to use?" to the question "how to embed it into a pedagogically sound system?".

Of fundamental importance for understanding the axiological dimension of innovative education is the research devoted to the relationship between the value orientations of a teacher and the nature of their professional decisions in the context of global value

transformations [5]. The value foundations of pedagogical activity determine not only the choice of educational strategies but also the teacher's ability to form stable meaningful connections in students with the subject area they teach. For environmental education, this means that no technological innovation can compensate for the deficit of environmental value orientation in the teacher themselves.

Among modern technologies applicable in environmental education, Project-Based Learning (PBL) occupies a special place. S. Boss and J. Larmer showed that it is the project format that creates optimal conditions for the formation of systemic thinking necessary for understanding environmental interconnections, as it involves working with real, open-ended, multifactorial problems [6]. Students implementing environmental projects in a real natural or social context acquire an experience qualitatively different from that obtained in traditional classroom learning: they face uncertainty, are forced to integrate knowledge from different fields, and bear responsibility for the practical result. All this constitutes a necessary condition for the formation of the activity component of environmental competence.

Digital educational technologies, including simulation environments and augmented reality tools, open fundamentally new opportunities for environmental education. A meta-analysis by Z. Merchant et al., covering a significant body of empirical research, records a positive effect of virtual reality and simulations on motivation, engagement, and understanding of complex systemic processes [7]. Of particular value is the ability to visualize ecosystem interactions that are inaccessible to direct observation – biogeochemical cycles, long-term climate trends, population dynamics. At the same time, the authors point to the importance of the educational environment design: passive "presence" in a virtual space does not yield an educational result without a specially organized learning task.

Regarding gamification, a critical mass of data is accumulating in the scientific discourse indicating its contradictory effects. C. Dichev and D. Dicheva, in a critical review of studies, established that the application of game mechanics in education often shifts students' motivation from substantive goals to achieving external rewards, which can reduce the depth of understanding and the sustainability of learning motivation [8]. The authors emphasize: the evidence base for the long-term effects of gamification remains insufficient, and most positive results are recorded only in the short term. This significantly limits the legitimacy of the unconditional expansion of gamification into such a value-laden field as environmental education.

The analysis of the scientific literature allows us to identify a persistent contradiction between the growing capabilities of innovative technologies and the lack of developed methodological foundations for their pedagogically sound integration into the environmental education of future teachers. Resolving this contradiction requires the development of a theoretically sound model that correlates technological capabilities with the component structure of a teacher's environmental competence.

Methodological Foundations of the Model. The methodological basis of the proposed model is formed by a set of complementary approaches. The systemic-activity approach allows us to consider the environmental education of future teachers as a holistic pedagogical system, all components of which – target, content, technological, and result-oriented – are in relations of functional interdependence [3]. The breakdown of any of these links, including the

replacement of a content-based choice of technologies with a pursuit of novelty, inevitably leads to a decrease in the educational result.

The competence-based approach sets the normative framework, defining the specific educational outcomes whose achievement serves as a criterion for the effectiveness of the applied technologies. At the same time, it is fundamentally important that the three components of environmental competence – cognitive, value-motivational, and activity – require different technological solutions and are not formed by a single universal tool [3].

Proceeding from this logic, the innovative model of environmental education for future teachers is built on four interconnected technological blocks, each of which is primarily aimed at developing a specific component of competence.

Project-based learning is aimed primarily at the activity component. The development and implementation of environmental projects in a real natural or social context form skills in environmental monitoring, planning environmental initiatives, and pedagogical design [6].

Digital simulations are most effective for developing the cognitive component: modeling ecosystem processes ensures an understanding of complex systemic dependencies that are inaccessible in a traditional lecture format [7].

Augmented reality tools support both components – cognitive (visual visualization of biological structures and ecosystem connections) and value-motivational (immersion in the natural context, emotional contact with objects of nature) [7].

Gamification is used in a limited way and exclusively as an auxiliary motivational tool that enhances student engagement, provided that game mechanics do not replace substantive educational goals [8].

Such a differentiated correlation of technologies with competence components allows avoiding both technological fetishism and conservative denial of innovations. The key criterion for selecting a technology is not its novelty, but its justified correspondence to a specific educational outcome [4].

The question of the relationship between digital and field-based formats of environmental education deserves a separate methodological discussion. The value-motivational component of environmental competence, as convincingly shown in the works on ecological pedagogy and psychology, is formed primarily through a lively, direct experience of interacting with natural objects [2]. No digital simulation – no matter how high-quality – can fully reproduce the sensory, emotional, and meaningful experience of fieldwork in a real ecosystem. This means that innovative environmental education is hybrid by its very nature: digital technologies expand and deepen its cognitive and activity dimensions, while field and nature-oriented formats remain indispensable for the formation of environmental values.

The axiological dimension of pedagogical education acquires special significance in this context. The value orientations of a teacher, formed during professional training, predetermine the nature of their future pedagogical activity in the environmental education of students [5]. Technological innovations can contribute to the development of professional pedagogical identity through the experience of successfully solving real environmental problems, but this happens only under the condition of reflective support of the educational process – specially organized discussions, essays, portfolios that allow students to comprehend the personal meaning of the acquired experience.

Conclusion. The conducted theoretical analysis allows us to formulate a number of specific conclusions that are significant both for the theory of teaching methods for environmental disciplines and for the practice of designing pedagogical education programs.

First, the effectiveness of innovative educational technologies in the system of environmental education of future teachers is determined not by the fact of their application, but by the degree of pedagogical validity of their integration into a holistic educational system [4]. Technological choice must be subordinated to the logic of the component structure of environmental competence, and not to a spontaneous orientation towards novelty.

Second, different technologies have unequal potential regarding different components of environmental competence: project-based learning and field practices are most effective for the formation of the activity and value-motivational components [6]; digital simulations and augmented reality – for the cognitive component [7]; gamification as an independent tool demonstrates a limited and unstable educational effect [8].

Third, the value-motivational component of a teacher's environmental competence cannot be effectively formed exclusively by digital means. A genuine environmental culture implies direct experience of interacting with nature, which makes field and nature-oriented formats of work an indispensable element of the educational program [2]. Innovative environmental education is hybrid by its very nature.

Fourth, the axiological dimension of pedagogical education retains its fundamental significance regardless of the degree of digital saturation of the educational process [5]. The value orientations of a future environmental teacher must be formed not as a byproduct of technologically saturated learning, but as an independent pedagogical task solved through reflective formats of work.

Promising areas for further research include: the development of diagnostic tools for measuring value changes in the sphere of environmental consciousness of future teachers; comparative analysis of the effectiveness of various models of environmental education in different national educational contexts; the study of conditions for the successful pedagogical integration of augmented reality technologies into educational systems with limited digital infrastructure; as well as empirical verification of the proposed model in the conditions of real pedagogical education.

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