

# ENHANCING THE METHODOLOGICAL TRAINING OF FUTURE BIOLOGY TEACHERS THROUGH THE USE OF MODERN DIGITAL TECHNOLOGIES

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**ANNOTATION:** This article explores the role of modern digital technologies in biology education and their significance in enhancing the methodological training of prospective teachers. It provides a theoretical and practical analysis of the integration of virtual laboratories, interactive simulations, mobile applications, and digital assessment tools into the learning process. The study emphasizes the advantages of a technology-based approach in developing students' methodological competencies. The paper also includes practical recommendations for improving the current model of methodological training in biology teacher education.

**KEY WORDS:** biology education, digital technologies, methodological training, virtual laboratory, teacher competence, simulation, digital assessment.

## INTRODUCTION

In the context of modern education, the use of digital technologies enables students and the learning process to become more interactive, visual, and engaging. This is especially significant in the field of biology, where complex biological processes and phenomena can be better visualized, experiments can be simulated, and laboratory work can be carried out safely and accurately using digital tools. Therefore, in the training of future biology teachers, digital technologies are no longer viewed merely as supportive tools, but rather as one of the essential factors contributing to the development of methodological preparedness [1; pp. 22-27].

Biology, by its nature, is characterized by empirical, experimental, and observational content. As such, the educational process in this subject demands the active application of technological approaches such as modeling, experimentation, animation-based analysis, and interactive testing [2; pp. 33-35]. Digital tools - including virtual laboratories, 3D models, simulators, electronic learning resources, and AR/VR technologies - offer significant opportunities to enhance students' understanding of biological concepts. Simultaneously, future teachers increasingly rely on digital tools in their methodological activities such as lesson planning, content explanation, and assessment tasks, integrating them into their teaching practices [3; pp. 18-22].

Methodological preparedness refers to the complex of knowledge, skills, and competencies that enable a teacher not only to have deep subject knowledge but also to teach it effectively using modern instructional strategies. In this regard, digital tools play a crucial role in enhancing pedagogical methods: they help visualize the content of lessons, capture students' attention, and allow differentiated instruction. In particular, showing biological objects and processes in formats that closely resemble real-life conditions significantly improves lesson effectiveness [4; pp. 41-43].

The main objective of this research is to scientifically substantiate the theoretical and practical foundations for enhancing the methodological training of future biology teachers through the use of modern digital technologies. This aim is directly related to the need to integrate the biology teacher training process with contemporary technologies, strengthen interdisciplinary approaches, and develop digital competencies. As part of the research objectives, the first task is to analyze the concept of methodological training and its structural components. Through this, the key elements that constitute a teacher's methodological capacity-such as planning, organization, assessment, and reflection skills-are identified. Additionally, the study examines the types of digital technologies applicable to biology education and explores their methodological potential.

In the third phase, effective methods for using digital tools in the teacher training process are developed. In this context, special attention is given to the role of interactive presentations, virtual laboratories, online testing systems, simulators, and mobile applications. Finally, the research aims to develop practical recommendations that support the formation of methodological competencies based on digital technologies. The scientific novelty of this study lies in the fact that it offers a systematic approach to developing methodological training in biology education through the use of digital technologies - presented for the first time in a comprehensive manner. Practical methodological recommendations for utilizing modern digital tools in the preparation of future teachers have been developed. Furthermore, criteria for assessing digital competencies within the framework of methodological training are proposed, which may serve as a foundation for future research.

Methodological training refers to the process by which future teachers acquire the knowledge, skills, and abilities necessary to effectively deliver educational content to students, organize lesson activities, assess and monitor learning outcomes, and manage the learning process. This training is an integral part of a teacher's professional competence, encompassing not only pedagogical knowledge but also didactic and technological capacities.

Methodological training consists of the following core components: didactic training - the ability to analyze lesson content, design lesson plans, and select appropriate instructional methods; technological training - the ability to apply interactive techniques, digital tools, and modern educational technologies; reflective training - the ability to critically evaluate one's own teaching practices, assess lesson outcomes, and continuously improve methodological approaches; communicative and organizational training - the ability to interact effectively with students, manage the classroom environment, and engage in collaborative work.

In our view, methodological training is not merely about learning how to conduct lessons technically; rather, it is a process of shaping a teacher's methodological thinking and professional culture. Biology, as a natural science discipline, is distinguished by its focus on the content, patterns, and evolutionary development of life processes. It requires the implementation of such cognitive activities as observation, experimentation, analysis, hypothesizing, and interpretation. Therefore, methodological approaches in teaching biology must be aimed at delivering biological phenomena to students in a scientifically grounded, life-relevant, and comprehensible manner.

Several key methodological approaches play an important role in biology education:

visual approach - presenting biological objects and processes through graphics, images, videos, or modeling techniques; experimental approach - enabling students to independently conduct laboratory experiments, record results, and draw conclusions; problem-based approach - fostering inquiry, hypothesis development, and analytical thinking skills through questions and problem-solving tasks; integrative approach - teaching biology in correlation with related disciplines such as chemistry, physics, geography, and computer science; digital approach - organizing instruction through interactive and multimedia tools based on modern information and communication technologies.

These approaches contribute to the integration of theoretical and practical aspects of biology, help students understand the relevance of the subject to real life, and deepen their level of comprehension and engagement.

Modern educational processes demand that a teacher not only possesses subject knowledge, but also masters effective and innovative methods of teaching. For this reason, a teacher's methodological capacity is defined as a combination of knowledge, skills, and professional competencies through which the teacher organizes and manages students' learning activities. This competence enables the teacher to design meaningful instruction, facilitate student engagement, and ensure the effective delivery of educational content.

Table 1

Theoretical Foundations of Methodological Training of Future Biology Teachers

Direction	Description	Significance in Teacher Preparation
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**Concept of Methodological Training** A set of knowledge, skills, and abilities necessary for effective organization of the educational process Ensures the teacher's ability to plan, deliver, and assess lessons effectively

**Key Components** Didactic, technological, reflective, and communicative training Each component contributes to shaping the teacher's methodological competence

**Specific Nature of Biology Based** on processes such as observation, experimentation, analysis, and modeling typical of natural sciences Requires the use of interactive and experiment-based methods and technologies in teaching

**Methodological Approaches** Visual, experimental, problem-based, integrative, and digital approaches Ensures active student participation and reinforces knowledge acquisition

**Modern Requirements** Digital literacy, creativity, reflection, formative assessment, adaptability Helps prepare future teachers in line with 21st-century competencies

**Methodological Capacity** The ability not only to possess subject knowledge but also to teach it using modern methods Has a direct impact on the professional success of the teacher

Today, the following modern requirements are imposed on methodological capacity:

pedagogical adaptability – the ability to work with students of varying levels and to organize lessons under changing conditions;

digital literacy – understanding educational technologies and using them purposefully and effectively; creativity and problem-based thinking – applying methods that encourage students to think independently and strive for innovation;

assessment culture – objectively analyzing learning activities and developing formative and summative assessment tools;

reflection and self-development – continuously analyzing one's professional activity and improving it through critical thinking.

Thus, the methodological training of future biology teachers is not limited to explaining the content of the subject. Rather, it requires mastering the skills necessary to design the educational process in an interactive, technologically enriched, and learner-centered manner. The theoretical foundations of the methodological training of future biology teachers are presented in Table 1 above.

Modern digital technologies are being actively used in biology education not merely as visual aids, but as essential methodological tools for instruction. In particular, tools such as virtual laboratories, biological simulations, mobile applications, and interactive test platforms play a significant role in shaping the professional and methodological preparedness of future biology teachers.

For instance, virtual laboratories enable students to conduct complex experiments in a safe and adaptable environment. These platforms reduce the dependency on physical lab equipment, save time, and enhance the visual and impactful nature of learning [5, pp. 22-24]. Moreover, biological simulators make it possible to visually model complex biological concepts such as intracellular processes, DNA replication, and evolutionary mechanisms [6, pp. 46-48]. Through mobile applications (e.g., "BioClass", "Virtual Biology Lab"), students can independently review learning materials, complete assignments, and assess their understanding through digital tests. These tools reinforce the learner-centered nature of education and make the learning process more flexible and personalized [7, pp. 31-34].

The main functions of digital tools in the educational process are as follows:

visualization - simplifying complex concepts by presenting biological objects and processes in animated and interactive formats; interactivity - enabling students to actively participate in the learning process through question-answer sessions, problem-solving tasks, and direct involvement in laboratory experiments; flexibility - allowing each student to work at their own pace and select learning materials that meet their individual needs; assessment - continuous monitoring of knowledge through online testing systems and electronic portfolios; quality monitoring of education - teachers analyze student activities in real-time and provide support based on individualized approaches [8, pp. 17-20].

Thus, digital technologies enable teachers to organize lessons in an interactive, innovative, and effective manner. Their role is especially invaluable in developing students' biological thinking, experimental reasoning, and analytical approaches.

Digital technologies influence the methodological training of future teachers in three key directions:

development of didactic potential - students learn how to use digital resources and integrate them into lesson plans; formation of technological competencies – skills are developed in selecting, configuring, applying, and evaluating digital applications, platforms, and tools; reflection and innovative thinking - students can assess their own lessons, remain open to innovations, and develop their own methodological approaches. This, in turn, accelerates the professional development process of teachers and prepares them for digital pedagogy.

In the modern education system, effective teaching of biology requires a teacher not only to have a deep understanding of the subject content but also to be well-versed in educational technologies. Developing methodological training based on digital technologies has now become an integral part of a teacher's professional competence. Below, the main directions in this area are analyzed.

Digital integration is the application of digital technologies during the lesson process in close connection with the curriculum, lesson content, and student activities. For future biology teachers, this integration is implemented as follows: simulating experiments and practical tasks through virtual laboratories; enhancing the visual possibilities of explaining topics through interactive presentations and infographics; fostering scientific communication with students via online forums and discussion platforms; designing lessons based on modules, that is, integrating digital content into lesson plans to strengthen the teacher's planning competence. This approach not only improves the teacher's digital literacy but also increases students' interest in learning.

One of the effective ways to strengthen methodological training in biology is organizing practical assignments and project-based lessons using digital tools. This includes:

research and analysis tasks: Students independently conduct research on biological phenomena using open online sources; research projects: for example, to prepare a project on "Changes in plant photosynthesis under artificial light," students use real-time simulators and virtual experiments; digital storytelling: creating video presentations or short animations about biological processes not only cultivates students' interest in the subject but also fosters creative thinking; observation journals based on mobile biology applications: Students enter and monitor their personal data related to plants, animals, or ecological factors.

This approach enhances students' independent thinking, problem-solving skills, and their ability to propose innovative solutions. Assessment based on digital technologies allows the teacher to analyze not only the student's knowledge but also their methodological approach, critical thinking skills, and technological literacy. Digital assessment tools include the following:

interactive testing systems (Quizizz, Kahoot, Google Forms) - enable quick and visual analysis of knowledge; electronic portfolios - allow students to store their work in a digital environment and monitor their progress; digital rubrics - provide the ability to evaluate projects, presentations, or practical tasks based on qualitative criteria; formative assessment tools - enable real-time monitoring during lessons, immediate feedback, and individualized guidance.

Thus, transitioning assessment tools to digital formats enhances transparency, accuracy, and efficiency between the teacher and the student. The results of conducted scientific and practical research indicate that the integration of modern digital technologies in biology significantly improves the methodological training of future teachers. Specifically: the content of methodological training should not be limited to theoretical knowledge but must also include technological, reflective, and digital competencies; digital technologies-such as virtual laboratories, interactive simulations, online tests, and biological mobile applications-help students deepen their understanding of subjects, improve their analytical skills, and enhance mastery;

practical exercises, project work, and a technology-based approach to organizing the educational

process serve as effective tools for shaping the teacher's methodological competence; the use of digital assessment tools has proven to be an important factor ensuring interaction and effectiveness in methodological training.

The following are key recommendations for enhancing pedagogical technologies:

Curriculum modernization: Incorporate modules on digital pedagogy, the STEM approach, and digital methodology into undergraduate and graduate programs in biology education.

Expansion of digital resource bases: Develop Uzbek-language interactive applications, simulation platforms, and educational videos specialized in biology.

Continuous digital professional development for teachers: Organize online courses and webinars through methodological centers to support ongoing digital skill development.

Digitization of assessment processes: Implement systems for collecting and monitoring practical tasks, independent work, and lesson plans in digital formats.

Design of innovative lessons: Develop models of teaching based on digital technologies, including problem-based learning scenarios, quests, and project-based learning in the context of biology.

Prospective Directions for Future Research

Exploring the integration of artificial intelligence (AI) tools into biology education.

Developing new criteria and tools for assessing digital competencies.

Investigating the application of AR/VR technologies in biological experiments.

Experimenting with the creation of individualized learning paths based on mobile applications.

Adapting the didactic foundations of digital pedagogy to align with the national education system.

In our view, the conscious and systematic integration of digital technologies into the process of methodological training serves as a vital pedagogical tool in the professional development of future biology teachers. This process primarily aims to foster students' adaptability to modern educational environments, develop their technological literacy, and enhance their creative thinking skills. Through a systemic approach, digital technologies can be effectively integrated into all stages of teaching - lesson planning, execution, monitoring, and assessment. Consequently, students begin to engage with digital tools not only as passive users but as active agents who incorporate them into the learning process.

As a result, future teachers acquire not only pedagogical expertise but also innovative competencies. Methodologically grounded training that combines scientifically based approaches, modern educational tools, and interactive methods allows for deep engagement with the unique nature of biology - including activities such as experimentation, observation, and modeling. This, in turn, develops students' biological thinking, experimental culture, and skills in scientific-theoretical analysis. Additionally, the integration of digital technologies into methodological training broadens opportunities for implementing student-centered, flexible, and individualized teaching approaches. Ultimately, this process fosters in future educators the capacity to make independent decisions, analyze problems, manage information, and select appropriate modern pedagogical tools.

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