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Types of natural science training for biology specialists

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Abstract: The article presents a comprehensive structure for training biologists, covering fundamental theoretical, practical laboratory, field, research, methodological, information and communication, innovative, entrepreneurial, ecological and environmental training. The goals, content, methods and technologies of each type of training are described, which allows to form a comprehensively developed specialist, capable of successfully working in various fields of biology and solving complex problems facing modern society. The proposed structure involves the integration of various types of training throughout the entire training, as well as taking into account the individual needs and interests of students.

Keywords: Training of biologists, training structure, fundamental training, practical training, biological education, teaching methods, educational technologies.

Introduction: In the modern world, where biology and ecology play a key role in addressing global issues, the natural science training of biology specialists becomes particularly significant. In the context of international assessment programs such as PISA (Programme for International Student Assessment), the necessity for high-quality natural science training that can ensure the competitiveness of graduates in the global labor market becomes evident. This training serves as the foundation for developing the professional skills and knowledge necessary for a successful career in science, education, and environmental protection. This article is dedicated to examining the main types of natural science training for biology specialists, analyzing their role in forming competent professionals capable of effectively addressing current challenges in biology and ecology, as well as contributing to the sustainable development of society and the preservation of the environment, considering modern requirements for scientific literacy defined by international standards, including PISA.

Literature review

The problem of natural science training for biology specialists has attracted the close attention of both domestic and foreign researchers. An analysis of the scientific literature allows us to highlight several key areas of research in this field.

Fundamental research in the area of natural science training is represented by the works of scholars such as V.I. Vernadsky, A.A. Pogrebnyak, and S.U. Goncharenko. Their works laid the methodological foundations for understanding the essence of natural science education and its role in forming a scientific worldview [1].

Significant contributions to the development of theoretical aspects have been made by: N.E. Kuznetsova — research on the methodology of natural science education; I.D. Zverev — the theory of interdisciplinary integration in natural science training; O.M. Atutov — concepts of practice-oriented learning [2].

Modern research pays special attention to methodological approaches to natural science training. The works of L.S. Vygotsky, A.N. Leontiev, and other scholars reveal the psychological and pedagogical mechanisms for forming natural science competencies [3].

Key areas of research include: Competency-based approach (works of V.A. Bolotov, V.V. Serikov); Student-centered learning (works of I.S. Yakimanskaya); Systemic-activity approach (research by A.G. Asmolov) [4].

A special place in the literature review is occupied by

studies related to international standards for assessing scientific literacy. The works of foreign scholars such as A. Schleicher and D. McKnight are dedicated to analyzing the PISA program and its impact on the development of natural science education [5].

Domestic researchers G.S. Kovaleva, A.A. Pinsky, and I.D. Frumin consider the adaptation of international approaches to the Russian education system [6].

Practical aspects of natural science training are presented in the works of: M.A. Ponomareva — methodology of field research; V.P. Solomin — integration of theoretical and practical training; E.A. Kriksunov — innovative methods of teaching biology [7].

A significant body of research is devoted to the ecological component of natural science training: N.N. Moiseev — the concept of sustainable development; A.N. Zakhlobny — ecological education; I.T. Suravegina — the formation of ecological culture [8].

Contemporary research (works by S.R. Bogdanov and A.L. Andreev) focuses on [9]:

- Digitalization of natural science education.
- Integration of artificial intelligence into educational processes.
- Development of distance learning formats.

An analysis of the scientific literature shows that the natural science training of biology specialists is a complex, multifaceted system that requires constant development and improvement. Despite the significant volume of research, the following questions remain relevant:

- Full integration of theoretical and practical training.
- Adaptation of international standards to the Russian educational system.
- Development of innovative teaching methods.

Formation of proactive natural science training that meets modern challenges and technological trends [10].

The literature review demonstrates the need for a comprehensive, interdisciplinary approach to the natural science training of biology specialists, taking into account both fundamental scientific principles and modern educational technologies. This means that effective training requires first clearly defining and forming the main types of natural science training that will consider both fundamental scientific principles and modern educational technologies.

METHOD

The formation of these types of training should be based on the analysis of existing approaches, identifying their strengths and weaknesses, as well as taking into account modern trends and challenges in the fields of biology and education. This will allow for the creation of a training system that meets the needs of the modern labor market and provides graduates with the necessary competencies for successful professional activity. Based on the literature review and current trends in education, the following main types of natural science training for biology specialists can be identified and formed (Table 1):

Table 1
Types of natural science training for biology specialists

Type of training	Goal	Content	Methods	Technologies

Fundamental theoretical training	To ensure a deep understanding of basic biological concepts and laws, as well as to form a scientific worldview.	Study of fundamental disciplines (cytology, genetics, molecular biology, ecology, physiology, anatomy, biochemistry, etc.) with an emphasis on modern scientific achievements (genomics, proteomics, etc.).	Lectures (interactive, with case studies), seminars, discussions, working with scientific literature, using multimedia resources (virtual models, animations).	Online courses (MOOC), virtual laboratories, interactive textbooks with augmented reality, collaborative work platforms, learning management systems (LMS).
Practical laboratory training	To develop skills in working with modern laboratory equipment, conducting experiments, and analyzing data, as well as to form a culture of safety in the laboratory.	Performing laboratory work in basic biological disciplines using modern methods and equipment (PCR, sequencing, cell technologies, etc.).	Laboratory sessions, practical classes, master classes, group work, individual projects.	Virtual simulators of laboratory processes, automated data collection and analysis systems, 3D models of biological objects, laboratory information management systems (LIMS).
Field practice and ecological training	To develop skills for working in natural conditions, studying ecosystems, and assessing the ecological state of the environment, as well as to foster ecological thinking and responsibility.	Conducting field research, collecting samples, observing living organisms, participating in environmental protection activities (forest restoration, water body cleaning).	Field trips, expeditions, ecological projects, work in reserves and national parks, organizing ecological camps.	Use of GPS navigators, drones for monitoring, software for geographic data analysis (GIS), mobile applications for collecting field information.

Research training	To develop research competencies, the ability to formulate scientific questions, develop hypotheses, and conduct scientific research.	Participation in scientific projects, writing course and thesis papers, preparing scientific publications, participating in conferences, internships in scientific laboratories.	Working in scientific laboratories, scientific consulting, seminars on research methodology, master classes on writing scientific articles.	Use of specialized software for statistical data analysis, bioinformatics, access to scientific databases, data exchange platforms.
Methodological and pedagogical training	To develop teaching skills in biology, create educational materials, and use modern educational technologies.	Study of pedagogical theories and methods, development of curricula and lesson plans, conducting trial lessons, using interactive teaching methods.	Lectures, seminars, training sessions, pedagogical practice, master classes from experienced educators.	Use of interactive whiteboards, multimedia presentations, online learning platforms, development of electronic educational resources.
Information and communication training	To develop skills for effective information management, use of modern communication technologies, and presentation of scientific results.	Mastering methods for searching, analyzing, and processing information, using software for creating presentations and scientific publications, participating in online discussions.	Training sessions, seminars, master classes, independent work, project completion.	Use of search engines, databases, software for image and video processing, online communication platforms.
Innovative and entrepreneurial	To develop skills for commercializing scientific developments, creating startups in biotechnology and environmental protection.	Study of the basics of economics and management, intellectual property, marketing and sales, development of business plans.	Lectures, seminars, training sessions, case studies, business games, working with mentors.	Use of software for financial modeling, market analysis, project management.

This table provides a comprehensive overview of various aspects of training for biology specialists,

emphasizing the importance of integrating knowledge and skills for their successful professional activity. Based on the presented table, the following structure for training biology specialists can be proposed, which integrates all key types of training and ensures the comprehensive development of professional competencies (Table 2):

Table 2
Structure of training for biology specialists

Type of Training	Goal	Content	Methods	Technologies
I. Fundamental Theoretical Training (1-2 years)	To lay a solid foundation of knowledge in basic biological disciplines and to form a scientific worldview.	Study of fundamental disciplines: cytology, genetics, molecular biology, ecology, physiology, anatomy, biochemistry, etc. Emphasis on modern scientific achievements: genomics, proteomics, bioinformatics, systems biology.	Interactive lectures using case studies and problem-based learning. Seminars and discussions to develop critical thinking. Working with scientific literature (including English-language sources). Using multimedia resources (virtual models, animations, video lectures).	Online courses (MOOC) for self-study. Virtual laboratories for conducting experiments in a safe environment. Interactive textbooks with augmented reality elements for visualizing complex concepts. Platforms for collaborative project work. Learning management systems (LMS) for organizing the educational process.
II. Practical Laboratory Training (2-4 years)	To develop skills in working with modern laboratory equipment, conducting experiments, and analyzing data, as well as to form a culture of safety in the laboratory.	Performing laboratory work in basic biological disciplines using modern methods and equipment: PCR, sequencing, cell technologies, immunochemical methods, mass spectrometry, etc. Mastering microscopy methods (light, electron, confocal), cell and microorganism cultivation, biochemical analysis, etc.	Laboratory sessions and practical classes under the guidance of experienced instructors. Master classes from leading scientists and specialists. Working in small groups to exchange experiences and develop teamwork skills. Completing individual projects to consolidate acquired knowledge and skills.	Virtual simulators of laboratory processes for practicing equipment handling skills. Automated data collection and analysis systems to enhance experimental efficiency. 3D models of biological objects for visualizing complex structures. Laboratory information management systems (LIMS) for organizing and storing data. Robotic complexes for conducting experiments.

III. Field Practice and Ecological Training (2-4 years)	To develop skills for working in natural conditions, studying ecosystems, and assessing the ecological state of the environment, as well as to foster ecological thinking and responsibility.	Conducting field research (botanical, zoological, ecological). Collecting samples and observing living organisms in their natural habitats. Participating in environmental protection activities (forest restoration, water body cleaning, pollution monitoring, etc.).	Field trips and expeditions (including international ones) to study various ecosystems. Ecological projects (in collaboration with environmental organizations) to address specific ecological problems. Working in reserves and national parks to study protected areas. Organizing ecological camps for conducting research and educational activities.	GPS navigators for location determination and orientation in the field. Drones for monitoring ecosystem conditions and identifying pollution. Software for geographic data analysis (GIS) for creating maps and models. Mobile applications for collecting field information and species identification. Sensors for measuring environmental parameters (temperature, humidity, pollution, etc.).
IV. Research Training (3-4 years)	To develop research competencies, the ability to formulate scientific questions, develop hypotheses, plan and conduct scientific research, as well as to present and defend the obtained results.	Participation in scientific projects (within the university or in collaboration with other scientific organizations). Writing course and thesis papers. Preparing scientific publications (including in international journals). Participating in conferences (including international ones). Internships in leading scientific laboratories.	Working in scientific laboratories under the guidance of experienced research supervisors. Scientific consulting for expert assistance. Seminars on research methodology to study the principles of planning and conducting research. Master classes on writing scientific articles and preparing presentations to develop presentation skills. Organizing scientific schools and summer camps for exchanging experiences and knowledge.	Specialized software for statistical data analysis (R, SPSS). Bioinformatics tools (BLAST, ClustalW) for analyzing genetic data. Programs for modeling biological processes (COPASI). Access to scientific databases (PubMed, Web of Science) for information retrieval. Platforms for data exchange and collaborative work (GitHub).

V. Methodological and Pedagogical Training (4 years)	To develop teaching skills in biology at various educational levels, create educational materials, and use modern educational technologies, as well as to enhance pedagogical mastery and a creative approach to teaching.	Study of pedagogical theories and methods (active learning, problem-based learning, project-based learning, flipped classroom, etc.). Developing curricula and lesson plans. Conducting trial lessons (using video analysis and feedback). Using interactive teaching methods (games, discussions, debates, case studies). Creating electronic educational resources (presentations, video lessons, tests, simulations).	Lectures and seminars on pedagogy and teaching methodology in biology. Training sessions to develop pedagogical skills. Pedagogical practice in schools and universities. Master classes from experienced educators. Participation in pedagogical conferences and competitions.	Interactive whiteboards for conducting lessons. Multimedia presentations for visualizing educational material. Online learning platforms (Moodle, Coursera, EdX) for organizing distance learning. Developing electronic educational resources using specialized software (Articulate Storyline, Adobe Captivate). Creating virtual excursions and laboratory work.
VI. Information and Communication Training (throughout the training)	To develop skills for effective information management, use of modern communication technologies, and presentation of scientific results in various formats (oral, written, visual), as well as to foster digital literacy and online communication culture.	Mastering methods for searching, analyzing, and processing information (using databases, search engines, library resources). Using software for creating presentations (PowerPoint, Prezi), scientific publications (LaTeX, Microsoft Word), and websites (HTML, CSS, JavaScript). Participating in online discussions and webinars. Creating and maintaining scientific blogs and social media.	Training sessions and seminars on information technology and communications. Master classes on creating presentations and scientific publications. Independent work on information search and analysis. Completing projects on creating websites and blogs. Working in groups to exchange experiences and knowledge.	Using search engines (Google Scholar, PubMed) for finding scientific information. Accessing databases (Web of Science, Scopus) for searching scientific publications. Software for image and video processing (Adobe Photoshop, Adobe Premiere). Platforms for online communication and collaborative work (Zoom, Microsoft Teams, Slack). Social media (Twitter, Facebook, LinkedIn) for disseminating scientific information.

VII. Innovative and Entrepreneurial Training (throughout the training,	To develop skills for commercializing scientific developments, creating startups in biotechnology and environmental protection, as well as to foster innovative thinking and entrepreneurial activity.	Study of the basics of economics and management, intellectual property, marketing, and sales. Developing business plans. Participating in startup competitions. Internships in innovative companies.	Lectures and seminars on economics and management. Training sessions to develop entrepreneurial skills. Case studies for analyzing real business situations. Business games for modeling business processes. Working with mentors for expert assistance. Participating in acceleration programs for startup development.	Software for financial modeling. Tools for market analysis. Project management systems. Platforms for crowdfunding and finding investors.

This structure implies the integration of various types of training throughout the entire educational process, allowing for the formation of a well-rounded biology specialist capable of successfully working in various fields of biology and addressing complex challenges facing modern society. It is also important to consider the individual needs and interests of students, providing them with opportunities to choose elective courses and specializations, as well as to participate in various extracurricular activities (scientific clubs, conferences, competitions, projects).

CONCLUSION

The presented article details a comprehensive approach to the training of biology specialists, covering a wide range of knowledge and skills necessary for successful work in modern science and practice. It emphasizes the importance of not only fundamental theoretical training but also practical skills, field experience, research work, pedagogical training, information and communication competencies, innovative thinking, and ecological responsibility.

The proposed structure for training biology specialists, which includes eight key areas, allows for the formation of a well-rounded professional capable of solving complex problems in various fields of biology and related disciplines. The integration of different types of training, the use of modern educational technologies and teaching methods, as well as consideration of individual needs and interests of students are important factors for the successful implementation of this model.

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